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Insect Pollinators & Role of Bee Pollination in Crop Production (Quality and Quantity)

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Pollination is a multi-million-year-old co-evolutionary process involving flowering plants and pollinators. It is one of the most important mechanisms in preservation and promotion of biodiversity as well as life on Earth. Pollinator diversity is essential for maintaining overall biological diversity in many habitats including agro-ecosystems. Pollination plays a vital role in maintaining the natural balance of ecosystems and is the cornerstone of crop production, providing a link between agriculture and the cycle of life. Consequently, pollination has a role in the economic sector owing to the improvement of quality and quantity.

Pollination is defined as the process by which pollen moves from the male anthers to the female stigmata, either within the same flower (self-pollination) or between plants (cross-pollination). Pollinators are the key players of the crop yield process since plants completely rely on vectors to transfer their pollen in cross-pollination. For instance, incorporating both wild and managed bee species in a region could enhance cross-pollination Possible other vectors include water and wind, and animal pollinators involve bats, birds, butterflies, hoverflies, wasps, thrips, Diptera, and other animals.

Animal pollinators contribute to the production of 87 global crops, including maize *(zea mays)* cocoa (*Theobroma cacao*), kiwi *(Actinidia deliciosa* var. deliciosa), passion fruit (*Passiflora edulis*), and watermelon (*Citrullus lanatus*) from 200 countries. Thirty percent of these crops participate in global economic food production.

Pollination by insects is a key element in the production of a large number of agricultural products worldwide, including aromatic and medicinal plants such as black cumin (*Nigella sativa* linn), cumin (*Cuminum cyminum* linn), anise (*Pimpinella anisum* linn), sunflower (*Helianthus* spp.), and coriander (*Coriandrum sativum* linn). Each season, honey bees, local bees, and flies pollinate 48 crops of the world's most valuable commodities, contributing significantly to the global economy. The economic value of the 6 most commonly cultivated pollinator dependent crop species grown in India was US $ 3720 million. The total EVIP (Economic Valuation of Insect Pollination) of these 6 crops was calculated as US $ 726 million.

The Western honey bee (*Apis mellifera* L.) is the main species responsible for bee pollination worldwide and meets, for instance, 34% of pollination service demands in the United Kingdom. Although several other bee species also contribute to pollination, researchers have focused on only a limited number of these to date, particularly the bumble bee (*Bombus* spp.). In comparison to wild bees alone, Greenleaf and Kremen observed that interactions between wild bees and honey bees doubled pollination rates and enhanced the prevalence of hybrid sunflowers by five-fold.

This review aims to highlight the role of the bee in plant pollination and its impact on the economy. The factors influencing bee visitation of flowers and plants, in addition to a comparison of bees and other insect pollinators, are reported.

The number of visits and the aggregate effects of various bee species influence not only the quantity of crops produced but also their quality, which is important mainly from an economic perspective. Plant pollination by more than one bee species, including honey bees, carpenter bees, stingless bees, bumble bees, long-tongued bee, feral bees, social bees, and solitary bees, results in a better pollination/vegetation process.

Role of Bee Pollination

Honey Bees: Western honey bees have been widely used as pollinators since the application of pollination services began, and are the primary managed species worldwide for both honey production and crop pollination Indeed, the Western honey bee ranks as the single most popular species of pollinator for crops globally and is the most effective crop visitor worldwide, contributing approximately 13% of floral visits to 5% of plant species across all plant networks. However, there are at least eight other honey bee species in the genus *Apis*, such as *A. florea* Fabr., *A. cerana* Fabr., *A. andreniformis*, and *A. dorsata* Fabr.

Honey bees are considered significant pollinators due to their effectiveness and wide availability. The mutualistic relationship between plants and honey bees results from the exchange of nectar and pollen. Bees play a vital role in the pollination of plants, and plants secrete a rich liquid sugar similar to nectar from their glands to attract pollinators to their flowers so that the pollen can adhere to bee-collected pollen grains. Researchers have found that honey bees (*A. mellifera* L.) appear to prefer crops rich with nectar and pollen in order to store large quantities of food, thus sustaining the colony growth and improving foraging performance.

Many countries have used honey bees and achieved great results in terms of the quality and quantity of crops. In the USA, the pollination activity of honey bees is well recognized for three species of crops: cucumber (*Cucumis sativus* Linn), for which there has been a 10% increase in yield and the number of colonies has increased from 40,000 to 45,000; cranberry (*Vaccinium oxycoccos* Linn), which experienced an increase in yield from 3.7 million in 1989 to 5.4 million in 1998, and pear (*Pyrus communis* Linn), which exhibited a 7% increase in fruit size and a net income increase of $400 per hectare. In INDIA, the use of honey bees as pollinators improved the fruit quality of guava (*Psidium guajava* Linn), as well as the fruit length and girth of coconut (*Cocos nucifera* Linn) and citrus (*Citrus* spp.) compared with the controls. In Egypt, honey bees have significantly improved the seed set percentage and seed yield in onion (*Allium cepa* Linn) crops compared with other insects. Furthermore, in Burkina Faso, the production of sesame (*Sesamum indicum* Linn) seeds tripled after using honey bees as pollinators.

The pollination of oilseed rape (*Brassica napus* Linn), buckwheat (Fagopyrum esculentum Moench), and strawberry (*Fragaria* × *ananassa* (Duchesne ex Weston) Duchesne ex Rozier) have clearly been dominated by honey bees, which have improved their quality and yield. Similarly, black cumin flowers are attractive to a range of pollinators, such as Hemiptera (true bugs), Coleoptera (beetles), Diptera (flies), and Hymenoptera (bees). However, honey bees are the most abundant pollinators affecting its productivity and quality, with their pollination activity increasing the number of seeds and affecting the total yield, which has led to the recommendation that beekeepers place bee colonies near black cumin fields for better pollination.

The yield of anise also significantly relies on pollinator activity. One study showed that honey bees exhibited a daily peak in anise pollination activity between 12 noon and 2 p.m., and increased the yield above levels seen with insect exclusion, though levels were

below those obtained with open pollination. Honey bees and six species of Andrenidae are the main pollinators of coriander, with 63% of honey bee visits and 100% of the visits by three species of Andrenidae resulting in pollinating activity.

For the apple (*Malus domestica* Borkh), increased flower visitation rates by high-quality honey bee colonies increased fruit set by 15%, as well as the fruit sugar content and seed set compared with visits by conventional colonies, resulting in the farmer's profits increasing by 70%. Pollination by high-quality colonies also increased fruit weight by approximately 20%. In the fruit of cape gooseberry (*Physalis peruviana* Linn), western honey bees' pollination improved the equatorial diameter by a mean of 13.3%, fruit mass by 30.3%, seed variety by 7%, and seed mass by 8.4% compared with self-pollination, while the use of honey bees for almond pollination increased fruit set by 60% compared with bee-remote trees, which translated into a 20% increase in yield. Observations of blueberry (*Vaccinium corymbosum* Linn) pollination in the presence of wild bees (Bombus spp., Halictids bees, Andrenids bees, and *Xylocopa virginica*) and controlled honey bees in small isolated and large fields in Michigan, USA, showed that wild bees were the primary pollinators in the small fields, accounting for 58% of flower visits, whereas honey bees were the main pollinators in the large fields, accounting for 97% of visits. Furthermore, it was found that flowers in the large fields were visited by four times as many bees as flowers in the small fields. The weight of the fruit was affected by the level of bee pollination and the abundance of bees, and the weight of berries was twice as high in the large fields compared with the small fields.

Bumble Bees: Bumble bees (Apidae: Bombini) are vital pollinators for agricultural and wild plants worldwide, and their pollination supports food security.

The strong adaptation to different climates and habitats of bumble bees explains their ability to continue foraging even in high and low temperatures. Bumble bees have contributed to the crop pollination via increasing the yield and enhancing the quality of fruits. Indeed, fruit growers gain many benefits from pollination by bumble bees, which are good pollinators of several crops, such as kiwifruit (*Actinidia Deliciosa*), sweet pepper (*Capsicum annum* Linn), and red clover (*Trifolium pretense* Linn).

Bumble bees are important pollinators of a diverse range of crops, including buzz-pollinated crops, such as blueberry and tomato, as well as both large-flower and small-flower crops, giving them the potential to be sufficient pollinators in open fields and greenhouses. It has also been shown that buzz pollination by *Bombus haemorrhoidalis* Smith in India leads to bigger, longer, heavier, and healthier fruits, especially in kiwi fruit.

Pollination by bumble bees enhances the quality and quantity of tomato fruit, including the number of fruits per cluster, the number of fruits per plant, fruit length, fruit freshness, fruit breadth, and fruit yield. In addition, pollination of sweet pepper by bumble bees results in a larger number of pollen grains and a higher level of seed set on the fruit than self-pollination, such that flowers visited by bumble bees produce larger and heavier fruit than non-visited flowers. Finally, bumble bees have provided maximum pollination services to hybrid leek (*Allium porrum* Linn), resulting in a 25% increase in plant quality, which has influenced the plant quality and crop price value by an estimated USD 18,007 and USD 17,174 hectare, respectively. In some cases, wild pollinators give better pollination than honey bees, as seen in apple crops pollinated by bumble bees, because all wild bee species are able to hold and deposit more apple pollen than honey bees.

Stingless Bees: Stingless bees (Apidae: Meliponini) are common floral visitors in tropical and subtropical areas around the world. They exhibit greater dietary diversity and intensity in their foraging behavior than honey bees and so are likely to influence the future development of pollination solutions that are best suited to the needs of particular crops and habitats.

Stingless bees are a large, diverse group of eusocial bees, making them good candidate pollinators. They vary widely in their body size, being described as small- to medium-sized, and have vestigial stings. Some species tend to be large and smooth, with long hairs that help to bring pollen and other products to the colony. The physiology of stingless bees is suited to flower pollination because they have suitable structures for collecting pollen, nectar, and an absence of stinging behavior, making them easier to handle than the majority of honey bees. Some stingless bees, such as those in the genus Melipona, exhibit vibration behavior to extract the pollen, which is needed in crops with poricidal anthers, such as tomato and pepper.

The neotropical stingless bee *Melipona quadrifasciata* Lepeletier is used to pollinate greenhouse tomatoes, and has improved the production of fruit with lower levels of mechanical injury. Stingless bees also play a prominent role in the pollination of greenhouse cucumber crops, improving both the fruit weight and yield. The pollination of cucumbers by the stingless bee *Heterotrigona itama* and manual cross-pollination improved crop quantity and fruit quality, allowing heavier, longer, and wider fruit to be produced. Similarly, the pollination of rockmelon (*Cucumis melo* var. reticulatus) by stingless bees and manual cross-pollination had a positive effect on fruit set and the number of seeds per fruit compared with self-pollination, and the pollination of strawberries in greenhouses by stingless bees increased the quality and commercial value of the fruit compared with a control group. Furthermore, the pollination of eggplant (*Solanum melongena* Linn) by *Melipona fasciculata* Smith in greenhouses increased fruit set by 29.5% and increased fruit quality (measured as fruit weight) compared with self-pollination.

Carpenter Bees: Large carpenter bees are a group of bees that occur in tropical and subtropical areas and belong to the genus Xylocopa in the tribe Xylocopini (Apidae: Xylocopinae). Compared with other non-*Apis* bees, carpenter bees have numerous advantages in crop pollination, as they feed on a broad range of plant species during their long activity seasons. They also have the ability to buzz-pollinate flowers, making them even more diverse crop pollinators. However, there is a great need for a sufficient breeding program to be developed that involves the selection of genotypes, controlled mating, and nest foundation.

Carpenter bees are known for their ability to make their nests in tunnels in hard wood, logs, stumps, or the dead branches of trees. In India, carpenter bees are active throughout the year and forage on a variety of flowers during the day and sometimes even work through moonlit nights. It has been noticed that flowers visited by carpenter bees produce nectar that is odoriferous, so it is possible that these bees use this odor as a cue to visit the correct flowers.

The use of carpenter bees for pollination services is necessary to guarantee adequate pollination for several crops, including passion fruit (*Passiflora edulis* f. flavicarpa), cucurbits, and other vegetables and fruits, as observed in the India Philippines, Brazil, USA, and Malaysia. Yellow passion fruit is satisfactorily pollinated when the flowers are only visited by native bees, especially carpenter bees. Furthermore, when native carpenter bees (*Xylocopa (Lestis*)) was used as an alternative to bumble bees for tomato pollination in a greenhouse, the females visited and buzz-pollinated the flowers and the resulting fruit were heavier and contained more seeds than those that were not pollinated by these bees. The carpenter bee *Xylocopa pubescens* Spinola is also used to pollinate greenhouse-grown honeydew melons (*Cucumis melo* Inodorus Group), as it was noticed that while this species had shorter visit durations per flower than the honey bee, pollination by both bees resulted in a similar fruit mass and seed numbers, and *X. pubescens* pollination increased fruit set three-fold compared with honey bee pollination.

Solitary Bees: Solitary bees comprise the majority of bee species in the world. Solitary bee species account for 85% of all bee species. The majority of solitary bees are polylectic (i.e., collect pollen from numerous plant species), while a smaller number are oligolectic (use a

narrow range of plants) and very few are monolithic (use only a single plant species). In recent decades, there has been a decline in monolithic and oligolectic species in Britain. Solitary bees play a major role in pollination, and it has been demonstrated that wild bees contribute USD 3251/hectare for their pollination services worldwide, seven out of ten of which are solitary. Solitary bees are more effective pollinators than honey bees for some crops that depend on pollinators for their reproduction, such as apple. Indeed, in the United Kingdom, the economic gains of using solitary bees for apple production were estimated to be € 51.4 million compared to honey bees of € 21.4 million.

Conclusion

Bee pollination provides a wide variety of benefits to humanity, contributing to food processing, raw materials, medicines, fibers, social, cultural values, and the maintenance of biodiversity and environmental protections. Bees' pollination has direct effects on the profitability and productivity of a substantial amount of global crop varieties, including most vegetables, seeds, and nuts, and some high-value agricultural products, such as coffee, cocoa, and rapeseed. Currently, 5–8% of all global crop production would be lost without the pollination services provided by bees, necessitating changes in the human diet and the expansion of agricultural lands to resolve shortfalls in crop production. Bees are faced with many challenges that can distort their lives, including shifts in land use, climate change, pesticides, genetics and cultivation management. Concerns regarding the decline of domestic and wild bees have intensified the need to encourage the usage of the wild pollinators on agricultural lands. As wild bee trips have increased with the development of high-diversity bee habitats in the surrounding landscape, the restoration of high-diversity bee habitats is necessary to increase free pollination levels. A secure atmosphere for bees should be provided to produce healthy crops. The use of insecticides and pesticides is damaging to human health because both crops and bee products become contaminated with agrochemicals that humans must eventually ingest. Although the roles played by non-bee pollinators cannot be ignored, bee pollination remains a precious asset that should be protected. Bee pollination must be enhanced not only to improve environmental balance but also to maintain food security worldwide. The role played by bees is important for worldwide crops and certain medicinal plants, with significant effects on quantity and quality. Researchers should focus their attention on studying the impacts that bees have on crop quality, which should provide more detailed data regarding how bees can alter the chemistry of certain crops.

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