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Deciphering pollination implications of *Apis cerana, Apis mellifera* L. on yield of mango (*Mangifera indica*) in urban landscape

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Abstract
Honeybees play a significant role in the plant–pollinator interactions of many flowering plants. The ecological consequences in urban landscape have not been well studied. The efficacy of pollination by two honey bee species, *Apis cerana* and *Apis mellifera*, in mango flowers in the field condition was examined in the present study. The number of honeybees of these two species and other pollinators foraging on the open branches were also observed regularly during three different timings (i.e., 9.00 am, 12.00 pm, and 3.00 pm) in a day. *Apis cerana* population showed that it was directly proportional to the emergence of flowers and similar 33 phenomenon was observed at the shedding of flowers. Significantly higher fruit yield (78%) in open-pollinated branches than closed-branches (22%) was recorded. Moreover, fruit size and quality were better in open-pollinated branches than closed-branches (covered with muslin cloth). We concluded that *A. cerana* was more active than *A. mellifera* during flowering and shedding in mango. This study will help to manipulate the timings of insecticide spray because the populations of honey bees and other pollinators will not be affected if spray done in the late evening (18.00 pm to 19.00 pm).

Keywords: *Apis cerana*, *Apis mellifera*, mango, insect pollinators

1. Introduction
Intense landscaping often alters the plant composition in urban areas, knowing the plant species that pollinators are visiting in urban areas is necessary for understanding how landscaping impacts biodiversity and associated ecosystem services. Bees are significant floral visitors among other pollinators for the pollination of many plants. The most important is the use of pesticides, which can cause the death of entire colonies. To evaluate the consequences of environmental change on plant-pollinator interactions, it is necessary to understand several aspects involved in the distribution of species, such as the way they respond to patterns of landscape structure and management, besides the foraging and nesting behavior, among others. Pollinators accomplish prime ecosystem facilities for global food security and ecosystem stability. The world population will increase to 9-10 billion in 2050 and hence the consumption of food will be accelerated (Ehrlich *et al*., 2015) [1]. The enhancement of food production is the main important task that will be achieved by global pollinator protection in their native place. The entomological fauna especially pollinators declining due to human activity reduces bee diversity and creates a shift in natural seasonal changes that influences the number and type of bees present, affecting pollination services (Van *et al*., 2015) Bees living in urban landscape possess relatively less variation in behaviors and physical characteristics (For example, food preferences), meaning they might not be able to render the range and quality of pollination services that bee communities in undisturbed habitats can provide. The loss of diversity and changes to seasonal turnover of bee species may threaten plant pollination in the community and potentially even crops that rely on wild bee species for pollination. Total agricultural income of the dependent crops and the economic share of pollinators is about 30%. The earlier reports have shown that pollinators enhanced the quantity and quality of fruit, which increase the economic value of crop production. Among 124 main crops used directly or indirectly by human beings in the world, about 87 cultivated crops rely on pollinators for pollination. Due to delightful taste, nutritional and medicinal value, the popularity of the mango has continued to grow and today, the mango currently holds the honor of being named the most widely consumed fruit in the world.

It's no wonder, then, that the mango is often referred to as the "king of fruits." Mangos are filled with vitamins, minerals, fiber and antioxidants. Each serving of mango is also relatively low in calories, making it an incredibly healthy and nutrient-dense food. Mango (*Mangifera indica*) flowers are pollinated by various insects such as wasps, ants, flies, butterflies, beetles, and bees as well as by wind. Pollinator contribution to mango fruit set was estimated at 53% of total fruit set production. The important role of insect pollinators in mango production has been recognized in many mango producing countries in the world. Sung *et al.,* (2006) [2] reported that honey bees (*Apis* spp.) and flies were responsible for successful pollination hence good mango production in Taiwan. In India, Sharma *et al*., (1998 reared *Lucilia* sp. (*Calliphoridae*) and *Sarcophaga* sp. (*Sarcophagidae*) flies in their attempt to increase the abundance of pollinators in a mango orchard. Up to the present time, modern agriculture shows heavy reliance on domesticated pollinators for crop production. For that matter, more focus is given to managements of pollinators particularly honey bee (*Apis mellifera*) populations within agricultural environments. In an attempt to improve mango production in Urban Landscape, this study was aimed to assess the contribution of wild pollinators under extensive conditions contaminated with pesticide spray and other toxic chemical for successful fertilization of mango flowers by quantifying the yield. The present investigation reports *A. cerana*is more active than *A. mellifera* during flowering and shedding. This study would help to manipulate the timings of insecticide spray in mango orchard because the populations of honey bees and other pollinators will not be affected if spraying is done in the late evening. In addition, we estimated the efficiencies of various pollinator species through their visitation rate on the mango flowers and compared the efficacy of two honeybee species viz. *A. cerana*Feb. and *A. mellifera L.* and other pollinators in mango farm, and to find their effect on the quantity and quality of mango fruit. The pollination potential of two honey bee species, *Apis cerana* and *Apis mellifera,* in mango (*Mangifera indica*) in the urban landscape (Bengaluru) was examined in the present study. One hive of each honey bee species was kept in orchard and their effect on the yield of mango fruit setting was measured. The number of honey bees of these two species and other pollinators foraging on the open branches were also observed regularly during three different timings (i.e., 9.00 am, 12.00 pm, and 3.00 pm) a day. *Apis cerana* population showed that it was directly proportional to the emergence of flowers and similar phenomenon was observed at the shedding of flowers. Significantly higher fruit yield (79%) in open-pollinated branches than closed-branches (17%) was recorded. Moreover, fruit size and quality were better in open-pollinated branches than closed-branches (covered with muslin cloth).

2. Materials and Methods

This study was undertaken at University of Agriculture Science GKVK Campus Bengaluru. The area of farm was ten acres consisting of 120 Mango trees distributed in 12 rows. The distance between each row was kept at ~5 × 5 m. Bees' hive (number of honey bees in one hive was 1000) of both species *A. mellifera and A. cerana*were kept at the center of the orchard. The hive made up of wood with the front side open, held one meter above the ground by using wooden table stand. Three straight sticks each 70 cm in length and two iron wire rings each 35cm in diameter were folded around the sticks. Cages were installed on the experimental/fruit tree branch in such a way so that cloth should not touch the flower buds and the air can easily go inside and outside of bags but restricted the access of pollinators.

2.1 Data Recording

Data was recorded three times (9.00 am, 12.00 pm, and 3.00 pm) in a day from blooming to fertilization. The cages were removed from the branches after the fertilization. There was no role of honeybees or other pollinators in caged branches. The number of bees foraging the open branches were observed thrice regularly. Data about numbers of flowers, pollinators and fruits was subjected to statistical analysis using analysis of variance (ANOVA). Means were compared by using least significance difference test at p = 0.05, data was analyzed using SPSS statistical program.

3. Results and Discussions

The wild pollinators are declining, and their loss will imperil our food supply, warns a recent United Nations report, based on the global assessment of pollinators by an international team of more than 75 scientists from different parts of the world, including India. The large scientific panel was brought together by the Intergovernmental Platform on Biodiversity and Ecosystems Services (IPBES). In India, the important pollinators of food crops are various species of honeybee, *Apis*, such as *A. Dorsata*, *A. Cerana*, *A. Florae*, *A. Andreniformes* and *A. Laboriosa.* The European honeybee, A. Mellifera, also pollinates many crops and fruits such as apples and Mango. Many of these pollinators are declining. Ashoka Trust for Research in Ecology and the Environment (ATREE) have been monitoring the abundance of colonies of the giant Asian bee, *Apis Dorsata*, in Biligiri Rangana Hills near Mysore. The number of bee colonies has shrunk significantly over the last decade. Many other researchers have also reported a decline in the number of honeybee colonies in India. The decreases in fruit yield have been attributed to reduction in the number of bees, but the exact causes of low yields are not known. From the present study all total of 11 species viz.; *Apis cerana, A. mellifera, A. florea, Vespa magnifica, Musca domestica, Episyrphous balteatus, Chrysomya megacephala, Coccinella septempunctata, Papilio demoleus, Pieris rapae and Oecophylla smargdina* were recorded. Out of these *Apis cerana* was recorded to be maximum (42.66%) followed by *Apis mellifera* (9%). Major pollinators included *Apis cerana* and *A. mellifera* and an *allodapine bee* (*Braunsapishewitti)* of the Apidae and sweat bees (*Halictus sp. and Lasioglossum sp.)* of the Halictidae among the *Hymenoptera* and *Chrysomya megacephala, Chrysomya pinguis* and *Musca domestica* of the Diptera, which were considered to be the dominant species due to their frequent appearance. Other foragers which were found but in lesser number were *Coccinella septempunctata* (5.00%), *Oecophylla smargdina* (03.33%), Pieris rapae (2.66%) and Papilio demoleus (1.33%) (Table 1). The visits of bee population were recorded at 5% emergence of flowers during morning to early evening and there was non-significant difference between different timings in *A. cerana*, and same trend was found in *A. mellifera* and other pollinators. Bees visits increased with the percentage of flowers emergence as 5 to

6%, and there was significant difference in population of *A. cerana*in the morning to early evening than other flies and the largest population (0.60±0.38) was found at 3:00pm ($p<0.05$, F=45, DF=77, n=5). Data of mean temperature and humidity was recorded from morning to evening, and the mean temperature and humidity was measured as 22.00±2.00℃ and 65.00±2% during pollination, respectively. We also found a significant difference in population when flower emergence was 10 to 14% from morning to early evening. Other pollinators were found to be the largest (2.40±0.78) at 3:00 pm, For other pollinators, the greatest population (3.40±1.11) was found at 12:00pm ($p<0.05$, F=45, DF=77, n=5) and *A. cerana* (1.60±0.41) and *A. mellifera* (0.23±0.09) populations were also mainly observed at 3:00pm. Open-pollinated mango achieved the largest yield as compared to caged-pollinated or un-pollinated trees (Figure 1). Our results are fully in agreement with the previous studies, who also found high yield in open pollinated trees than closed trees (Melntire *et al*., 2014). In native areas, there are varieties of plants and trees, and they have various pollinators that visit during flowering season. Actually, plants have a generalized community so have similar pollinators and keep mutualistic behavior. Due to indiscriminate use of insecticides, natural fauna of pollinators has been disturbed and nowadays growth regulator is being used for increasing the yields, which are very expensive. Due to over use and without proper timing of chemical sprays, bee keeping in orchard is very difficult for pollination. Moreover, we observed different patterns from morning to early evening when flower emergence was 16 to 30%. Data was recorded when flowers emergence was 57 to 60% from morning to early evening, and *Apis cerana* population was largest (2.60±0.01) at 12.00 pm ($p<0.05$, F=45, DF=77, n=5) and other pollinators populations were higher 1.40±0.52 than *A. mellifera* at 15:00 pm, while *A. mellifera* (0.42±0.03) were found to be the largest at 09:00am. Data of pollinators was recorded when emergence of flowers was between 80 to 90%, and there were significant differences in the insect populations. *A. cerana* population was the greatest (2.60±0.85) at 12:00 pm ($p<0.05$, F=45, DF=77, n=5), while *A. mellifera* population was the highest at 9:00 am (i.e. 0.35±0.07) and other pollinators were observed mostly at 3:00 pm (i.e. 1.60±0.46). The data of pollinators was also recorded at 100% flowering, and other pollinators were much higher 1.8±0.32 at 3.00 pm ($p<0.05$, F=45, DF=77, n=5) than bees, while *A. cerana*and *A. mellifera* populations were found to be largest (0.21±0.05) at 12.00 pm (Figure 2). When the shedding of flowers reached at 20%, other pollinators increased to the largest number (1.40±0.79) at 3.00 pm, ($p<0.05$, F=45, DF=77, n=5). Data of pollinators was recorded with the increase in percent of flowers shedding (between 20 to 50%), and other pollinators were higher 1.00±0.43 ($p<0.05$, F=45, DF=77, n=5) than *A. cerana* (0.40±0.26) and *Apis mellifera* (0.03±0.01) in the morning at 9.00am. Similar trends were observed at 60 to 70% flowers shedding for other pollinators, while *A. cerana* population increased at 12.00pm (i.e. 0.20±0.20). The pollinators were also observed with the increase in percent of flowers shedding (90 to 95%), and other pollinators were the largest (1.00±0.37) at 15.00 pm ($p<0.05$, F=45, DF=77, n=5), while *A. cerana* was observed only at 12.00 pm i.e. 0.20±0.01. At 98 to 100%, other pollinators were found to be the largest (0.40±0.24) at 3.00 pm ($p<0.05$, F=45, DF=77, n=5), while *A. mellifera* was only observed at 9.00 am (Figure 2). Here, *A. cerana* population was found to be the highest as compared to other pollinators. Our studies showed that caged-pollinated branches have low quality fruits. These results are consistent with the previous investigations, who also found less quantity of mango fruits in un-pollinated fruits. Interestingly, the average fruit set of the open branches gained a large fruit size, and increased the quality and number of fruits. The effect of *A. cerana* and *A. mellifera* pollination in respect to yield per plant and yield per hectare were found to be significant increase in the fruit set of the crop and the average fruit per plant which reveals that *A. cerana*and *A. mellifera* were the most dominant as well as much more efficient pollinator of mango compared to other insects (Table 2).

Table 1: Diversity of insect foragers of mango flowers

S. No	Common name	Scientific name	Order	Family	% relative abundance
1	Indian bee	*Apis cerana F.*	*Hymenoptera*	*Apidae*	41.66
2	Western bee	*Apis mellifera L.*	*Hymenoptera*	*Apidae*	10.00
3	Little bee	*Apis florea F.*	*Hymenoptera*	*Apidae*	8.00
4	Wasp	*Vespa magnifica* (*Smith*)	*Hymenoptera*	*Vespidae*	9.00
5	Ant	*Oecophylla smaragdina F.*	*Hymenoptera*	*Formicidae*	3.33
6	Syrphid fly	*Episyrphous balteatus*	*Diptera*	*Syrphidae*	8.00
7	House fly	*Musca domestica L.*	*Diptera*	*Muscidae*	6.00
8	Blowfly	*Chrysomya megacephala F.*	*Diptera*	*Calliphoridae*	6.66
9	Ladybird beetle	*Coccinella septempunctata L.*	*Coleoptera*	*Coccinelidae*	5.00
10	Cabbage butterfly	*Pieris rapae L.*	*Lepidoptera*	*Pyrallidae*	2.66
11	Lemon butterfly	*Papilio demoleus L.*	*Lepidoptera*	*Papilionidae*	1.33

Table 2: Effect of *Apis cerana* and *Apis mellifera* pollination on yield of mango

Treatments	Yield/ plant (kg)	(±SE) Yield/ha (q)	(%) Yield increase over OP
Other Pollination (OP)	23.06 ± 0.48	68.53± 0.21	-
Bee pollution	33.38 ± 0.67	84.75± 0.77	23.66

Mean of 4 observations

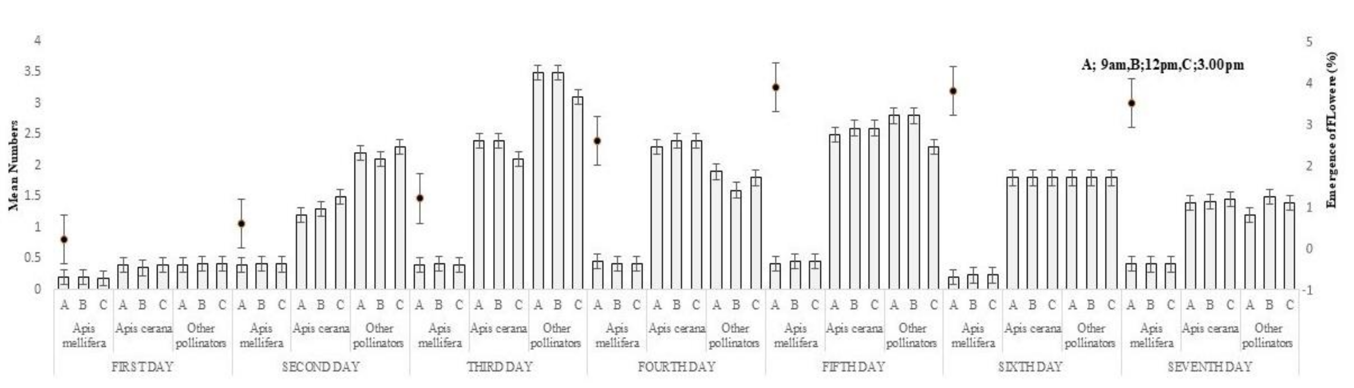

Fig 1: The number of pollinators in three different timings on Mango during flowers emergence

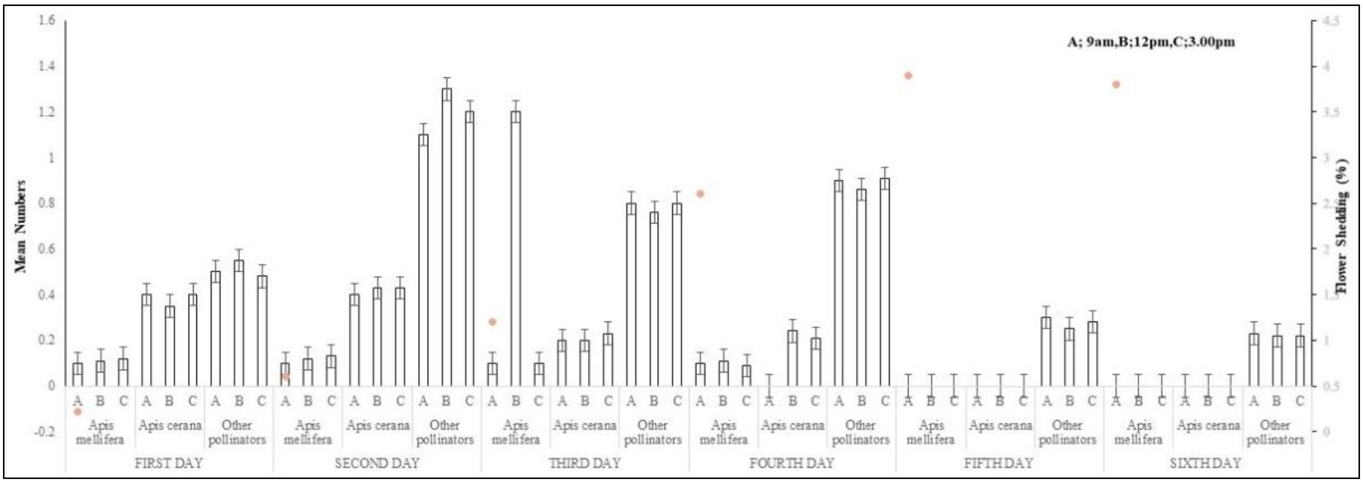

Fig 2: The number of pollinators visited mango during three different timings at shedding of flowers

4. Conclusions

Understanding the diversity of pollinators, the evolution of the pollination systems in which they play a role, and ecology of the networks in which they are embedded (and how all of this can be conserved as a vital aspect of the biodiversity of the planet) requires more observational and experimental data, monitoring, and detailed surveys to build a robust picture of pollinator diversity and decline. Honey bees are important tools of pollination in mango and we can save honey bee population in our orchards by manipulating the timings of insecticides spray. Our study suggests that farmers should use insecticides in the late evening (6.00 pm to 8.00 pm) in mango orchard. In this way, they can protect native pollinators' fauna in their orchards/farms, and may increase fruit quality and quantity that are environmentally safe and cheaper source for increasing yield as compared to other methods. Farmers can help by planting fallow fields and road edges with flowering plants to support wild pollinators throughout the growing season, and by reducing pesticide use, especially during crop bloom when more bees are in their fields. The average person can help, too. By filling their gardens with diverse, native plant species and limiting pesticides, anyone can create more pollinator-friendly spaces and help keep their local pollinator community diverse, healthy and beautiful.

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