

Diversity of Insect Pollinators and Their Foraging Behavior on Pomelo (*Citrus maxima*) Flowers in North 24 Parganas, West Bengal, India

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Abstract

Field observations were undertaken between February and March 2025 to examine the diversity of insect pollinators and their foraging behaviour on pomelo (*Citrus maxima*) flowers in North 24 Parganas, West Bengal, India. Observations were carried out on eight medium-sized trees (approximately 10 ft in height) across four study location. In the time of flowering season nearly 120 open flowers from each tree were observed carefully. Altogether, 12 insect species belonging to four different insect orders were written down. Honeybees visited the flowers more frequently than other insects and showed more effective pollination activity during the whole day. Their activity varied according to changes in temperature and humidity. A comparatively higher number of insect forages were found under favourable weather conditions. The findings of the field study suggest that insect pollinators are highly important for successful pollination and better fruit production of pomelo in the study area.

Keywords: Fruit Production; Honeybee; Insect Pollinators; Pollination Activity; Pomelo (*Citrus maxima*)

Introduction

Pomelo is a vast citrus fruit that grows broadly in state of West Bengal. It is known as valuable fruit as well as it has medicinal benefits and has cultural importance among the people in West Bengal specially. Profitably Fruit production in citrus plants largely depends on insect-mediated pollination, which enhances fruit set and improves entire yield (Klein *et al.*, 2007; Corbet, 2000). Citrus fruit attract a wide range of insect visitors including Bees, flies, butterflies, and other nectar feeding species, which engage pollen transfer and fertilization (Rader *et al.*, 2016). Among various pollinators such as bees are considered the most efficient due to their floral constancy, foraging activity and effective pollen dispersal. Their role in increase agricultural production and maintain ecosystem services has been widely accepted (Khalifa *et al.*, 2021).

Recent studies have also declared that animal-mediated pollination significantly increases citrus fruit production and improves nutritional values as well as quality (Monasterolo *et al.*, 2024). Non-bee pollinators like butterflies and other flies also participate to pollination by contributing supplementary services. These insects play complementary roles and help maintain stable pollination under various environmental (Garibaldi *et al.*, 2013). Pollinator behaviour and activity are naturally influenced by environmental factors such as temperature, humidity as well as light intensity (Willmer, 2011).

Beside their ecological and economic importance, message regarding pollinator diversity and foraging behaviour in pomelo cultivation, particularly in the lower Gangetic plains of southern part of West Bengal, remains limited. Therefore, the recent findings aimed to document the diversity of insect pollinators and evaluate their foraging behaviour on pomelo (*Citrus maxima*) flowers in North 24 Parganas, West Bengal, India.

Methodology

Study Area

The field investigation was conducted during February to March 2025, coinciding with the peak flowering season in period of *Citrus maxima*, in the North 24 Parganas district of West Bengal, India. The area is located in the lower Gangetic plains and is characterized by a tropical humid atmosphere.

Field observation was carried out at four selected sites under Habra II Community Development Block: Ashoknagar (22.824° N, 88.642° E), Nurpur (22.903° N, 88.579° E), Sendanga (22.889° N, 88.606° E), and Dighirhat (22.887° N, 88.610° E).

These areas represent mostly semi-urban and rural landscapes abundant by agricultural fields, crop fields homestead gardens, and scattered vegetation, which provide suitable habitats for diverse pollinator gatherings. These areas are presented in Figure 1.

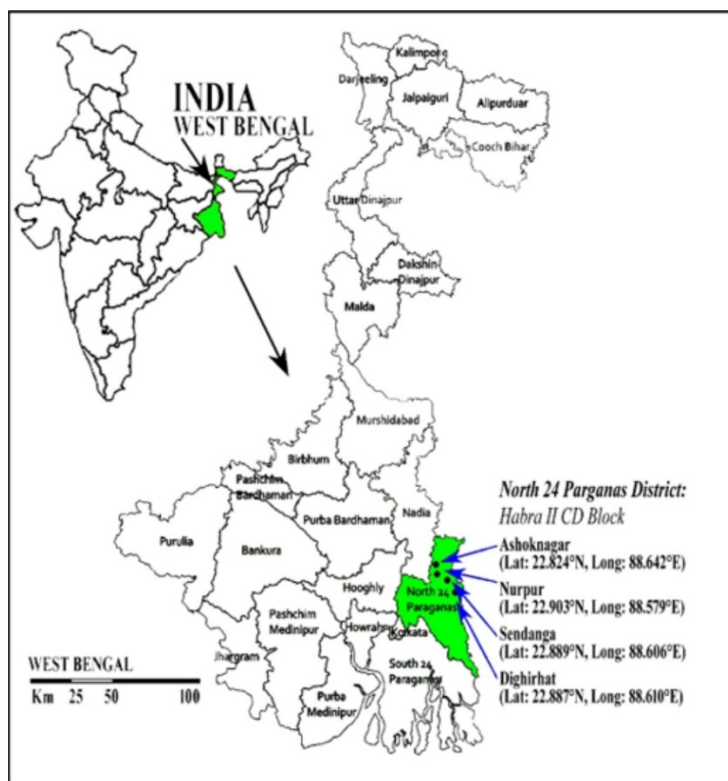


Figure 1: Map Showing the Selected Study Location of Pomelo Trees in N 24 PGS. District, West Bengal, India

Sampling Design and Observation

The whole observations were made across four locations-Ashoknagar, Nurpur, Sendanga, and Dighirhat. Two medium-sized *Citrus maxima* trees of similar growth condition were selected from each site, resulting in a total of eight trees. To stable consistency, observations were conducted on one tree at a time. During the peak flowering phase, approximately 120 flowers in fully open condition were recorded per tree. Regular observations were made to record insect visitation and foraging behavior.

Data Collection and Analysis

Insect visitors were recorded through direct visual observation. The insects were identified based on taxonomic identity, scientific name, common name. Foraging time and relative efficiency were also

recorded. Findings collected from all the trees were pooled to obtain mean values. Observations showed consistent pattern across different sites, indicating similarity in pollinator diversity and activity.

Insect visiting activity and resource gathering behavior were recorded following standard field observation methods commonly used in pollination ecology studies (Monasterolo *et al.*, 2024).

Results

Twelve insect species belonging to four various orders were recorded visiting pomelo (*Citrus maxima*) flowers during the study period. Table 1. Shows the diversity of insect pollinators and their foraging habit on pomelo flowers.

Table 1: Diversity of Insect Pollinators and Their Foraging Behavior on Pomelo Flowers

Sl. No.	Pollinator Type	Order	Scientific Name	Common Name	Foraging Time	Efficiency
1	Insect	Diptera	<i>Stomorphina</i> sp.	Snout fly	Day (Morning-Afternoon)	Low
2	Insect	Diptera	<i>Musca</i> sp.	Housefly	Day	Low
3	Insect	Hymenoptera	<i>Apis cerana indica</i>	Indian Honey Bee	Morning-Noon	High
4	Insect	Hymenoptera	<i>Apis mellifera</i>	European Honey Bee	Morning-Noon	High
5	Insect	Hymenoptera	<i>Euodynerus</i> sp.	Mason wasp	Day	Moderate
6	Insect	Hymenoptera	<i>Paratrechina</i> sp.	Crazy ant	Day	Low
7	Insect	Lepidoptera	<i>Ypthima</i> sp.	Ring butterfly	Sunny Day	Moderate
8	Insect	Lepidoptera	<i>Elymnias</i> sp.	Chocolate pansy	Sunny Day	Moderate
9	Insect	Lepidoptera	<i>Cephrenes</i> sp.	Orange palm dart	Day	Moderate
10	Insect	Lepidoptera	<i>Oriens</i> sp.	Smaller dartlet	Day	Moderate
11	Insect	Lepidoptera	<i>Borbo</i> sp.	Rice swift	Day	Moderate
12	Insect	Neuroptera	<i>Chrysopa</i> sp.	Green lacewing	Day	Low

Among all the groups, the order Lepidoptera showed the highest species diversity followed by Hymenoptera, Diptera and Neuroptera. The order-wise distribution of pollinators is presented in Figure 2. Hymenopteran insects, especially *Apis cerana indica* and *Apis mellifera*, show the maximum foraging efficiency and were mainly active during morning to noon period. Dipteran insects exhibit relatively lower efficiency.

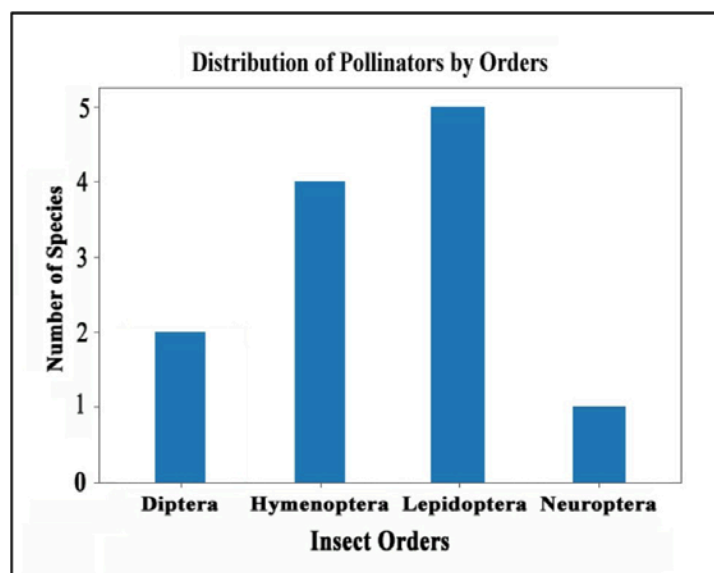


Figure 2: Order-wise Distribution of Insect Pollinators Species Recorded on Flowers of *Citrus maxima* During the Study Period

Based on foraging efficiency, pollinators were categorized into moderate (50%), low (33%) and high (17%) efficiency groups (Figure 3).

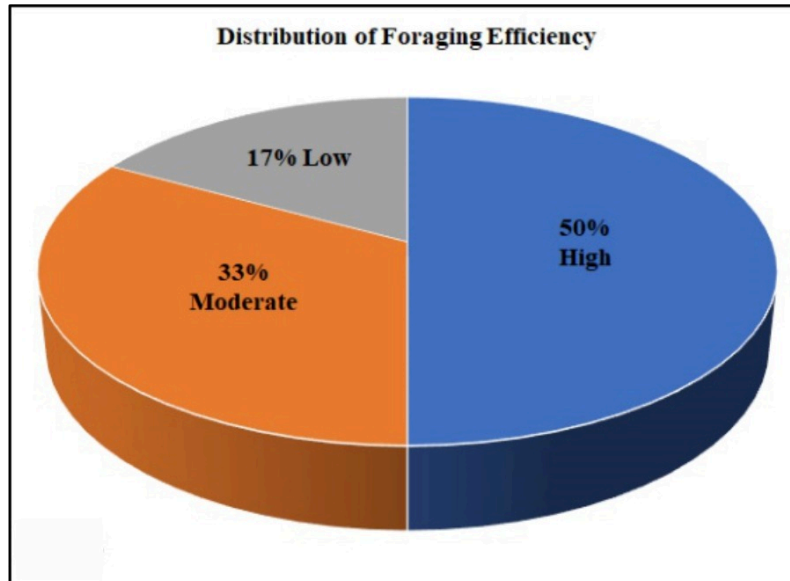


Figure 3: Percentage Distribution of Insect Pollinators Based on Their Relative Foraging Efficiency on Flowers of *Citrus maxima*

Pollinator activity varied during different times of the day. In morning time, the maximum activity observed and gradually declines towards noon, afternoon, and evening (Figure 4)

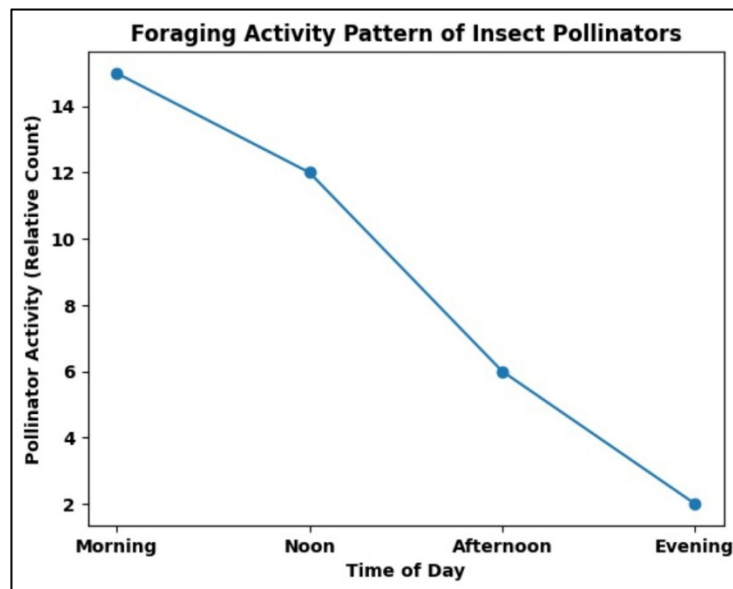


Figure 4: Regular Foraging Pattern of Insect Observed at Different Time Gaps on Pomelo (*Citrus maxima*) Flowers

Environmental factors influence pollinator behavior. The activity of pollinator was highest under moderate temperature and relatively higher humidity conditions. Reduced activity was recorded during high temperature and low humidity (Figure 5).

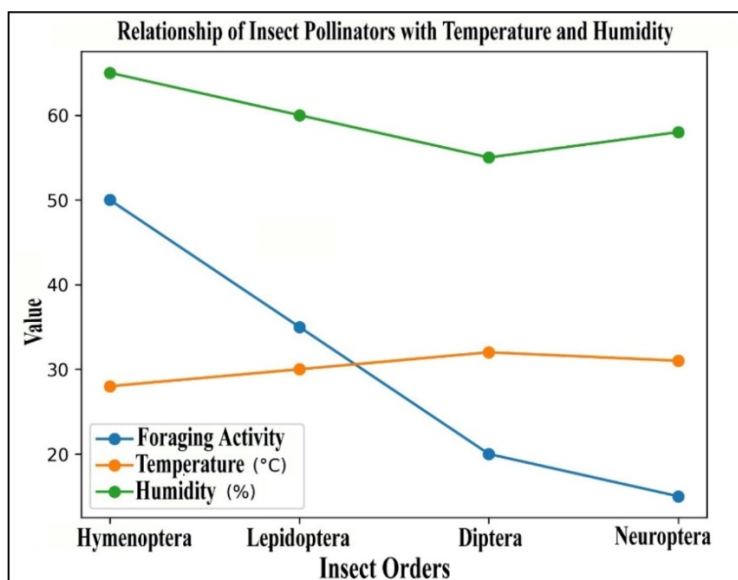


Figure 5: Influence of Environmental Factors (Temperature and Relative Humidity) on Foraging Activity of Insect Species on Pomelo (*Citrus maxima*) Flowers

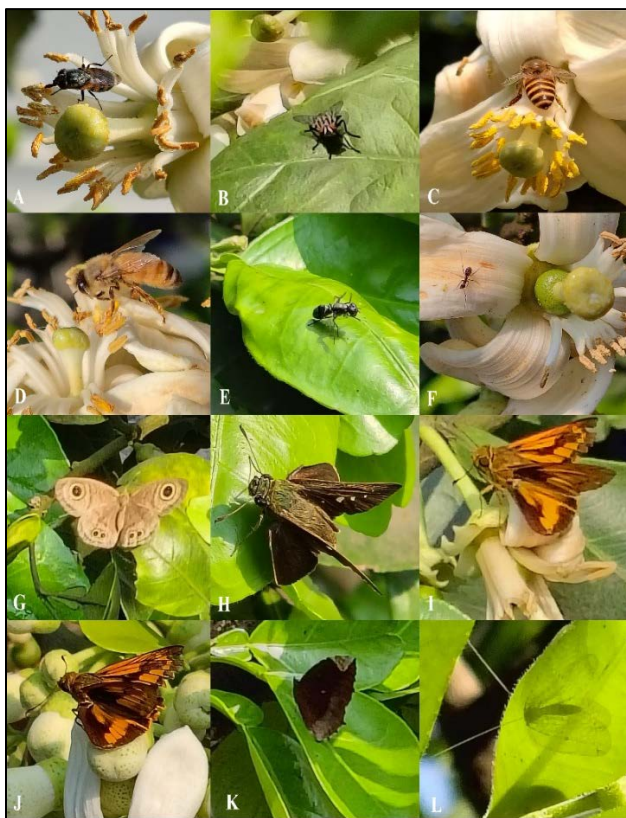


Figure 6: Photographic Representation of Insect Pollinators Visiting Pomelo (*Citrus maxima*) Flowers Recorded During the Study Period: A. *Stomorphina* sp. B. *Musca* sp. C. *Apis cerana indica* D. *Apis mellifera* E. *Euodynerus* sp. F. *Paratrechina* sp. G. *Ypthima* sp. H. *Elymnias* sp. I. *Cephrenes* sp. J. *Oriens* sp. K. *Borbo* sp. L. *Chrysopa* sp.

Discussion

Findings from the present field observations indicate that flowers of *Citrus maxima* support a diverse assemblage of insect pollinator community in N 24 PGS. district. A total of 12 species belonging to four insect orders were recorded. Although Lepidoptera showed the highest species richness, hymenopteran insects, particularly *Apis cerana indica* and *Apis mellifera* were indicated as most efficient pollinators. Frequent visits by the insects and much more transfer of pollen played a major activity in successful pollination (Villa-Galaviz *et al.*, 2023).

The results of present study agree with previous findings that explore the importance of apes in flower pollination and improved fruit production (Potts *et al.*, 2010; Garibaldi *et al.*, 2013). Lepidopterans showed moderate pollination efficiency and were mostly active in diurnal conditions. In comparison, Dipteran and neuropteran insects were less effective, although they also assist in complementary pollination (Nurdiansyah *et al.*, 2004).

The presence of a variety of pollinators reflects functional diversity and promotes balanced pollination systems. Environmental factors like temperature and humidity greatly affect the behavior and foraging efficiency of pollinators. The findings of the study may help improve pollinator-friendly practices in citrus farming and promote sustainable fruit production (Pradhan *et al.*, 2025).

The present findings emphasize the ecological value of maintaining diverse pollinator communities in citrus cultivation area. While honeybees have shown the most efficient foraging activity, the contribution of non-paid pollinators deserves attention. Butterflies, flies, ants, and other flower-visiting insects may provide pollination assistance and support maintaining reliable pollination in response to environmental changes. Recent studies have shown that diverse pollinator communities enhance pollination efficiency, fruit production, and environmental resilience (Monasterolo *et al.*, 2024; Fijen *et al.*, 2025).

The present study showed that environmental conditions also affected the activity of pollinators. The Higher number of pollinator visits observed during the morning hours may be associated with favorable temperature and humidity conditions that support vigorous foraging activity. Same thing happened in recent pollination studies, where environmental factors significantly affected the movement, visitation frequency, and efficiency of pollinating insects (Kratz *et al.*, 2025; Balfour & Ratnieks, 2025).

The observation of different insect species on pomelo flowers suggests that active pollination depends on the diverse contribution of various pollinators rather than one species. Such factors can contribute to sustainable fruit production by ensuring effective and viable pollen transfer across varying environmental conditions. Recent research suggests that protecting pollinator diversity plays a key role in improving fruit yield, pollination efficiency, and long-term agricultural sustainability (Cholis *et al.*, 2020).

Conclusion

The present study highlights the importance of insect pollinators in pomelo cultivation in North 24 Parganas, West Bengal. Twelve insect species from four different insect orders were agree with visiting pomelo flowers during the flowering season.

Among the observed pollinators, apes were found to be the most active and efficient flower visitors. Pollinator activity was greater during morning hours and varied with environmental conditions such as temperature and humidity.

The study indicates that conserving a variety of pollinators is essential for better fruit production in pomelo. The findings may also serve as useful reference material for future research related to pollinator ecology and citrus cultivation.

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