



RESEARCH COMMUNICATION

Diversity and abundance of insect visitors on Apple ber (*Ziziphus mauritiana* Lam.)

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Abstract

Pollinator presence significantly impacts the quality and yield of crops like ber that rely heavily on insects for their pollination. This study assessed pollinator diversity and abundance on apple ber (*Ziziphus mauritiana* Lam.) in Hisar, Haryana, India, over 2 consecutive years (2022–2023). A total of 25 insect species belonging to 5 orders: Hymenoptera, Diptera, Lepidoptera, Coleoptera and Hemiptera were recorded visiting apple ber. Insect visitors were collected using a cone-shaped hand net and their relative abundance was determined by recording the number of individuals observed on a single, randomly selected branch over a 5 min period. Hymenoptera emerged as the most dominant order, contributing approximately 75–77 % of the total insect visitors. Bees (including family Apidae), wasps (Vespidae) and flies (families Calliphoridae, Musidae and Syrphidae) are recognised pollinators. The most abundant species was *Apis florea*, followed by *A. mellifera* and *A. dorsata*. The study provides a comprehensive account of apple ber pollinators under semi-arid conditions, highlighting the critical importance of conserving native pollinator diversity for sustainable fruit production and enhanced crop yields.

Keywords: abundance; apple ber; diversity; insect visitors; pollinators

Introduction

Ber (*Ziziphus mauritiana* Lam.) is an important fruit with a long history of cultivation in India. It is a tetraploid ($2n=48$) species and regarded as the 'King of arid fruits' and 'Poor man's apple' (1). It grows both wild and cultivated across the warm arid and semi-arid regions up to an altitude of 1500 m above mean sea level. The total production of ber in India is 526.32 thousand metric tonnes whereas Haryana stands at 7th position with a production of 28.86 thousand metric tonnes and contributes around 5.48 % to the total production in India (2). *Ziziphus mauritiana* is a versatile fruit shrub, its fruits are often consumed fresh, are exceptionally nutrient-dense and abundant in variable content of vitamins A, B and C as well as minerals like calcium, phosphorus and iron. The fruit has a higher vitamin C content (85–95 mg per 100 g) however, more vitamin C has been discovered in the fruit flesh close to the seed than in the fruit skin. Fruits length (2.5–6.25 cm) varies with cultivar and has a varying shape like oval, oblong, or round.

Pollinators are crucial for the successful reproduction of ber trees, due to their cross-pollinating nature (3). *Ziziphus* trees exhibit both male and hermaphrodite flowers, demonstrating protandry, where male parts develop before the female parts. To attract pollinators such as flies and bees, visual cues play an important role. The nectar disc when exposed to open sunlight gives an impression of exposed sugar drop, which serve to attract a diverse group of pollinators, creating a polyphilic system (4, 5). To ensure pollination, flowers have evolved features according to sensory abilities, mobility and morphology of pollinators. The flowers of *Z. mauritiana* are

primarily adapted for insect's pollination in field condition. The characteristics of flower of ber species are frequently associated with entomophilous syndrome. Flowers are usually small, orange or yellow and contain large amount of dilute and unscented nectar (6).

Diverse insect visitors have been observed on ber flowers because of its thick and heavy nature pollen (3). Insects which visit ber flowers belong to various groups including bees, wasps, ants and butterflies (7, 8). During flowering of *Z. mauritiana*, 86 insect species were identified which consisted of 32 species of wasps, 30 flies, 18 butterfly and 6 bee species. Wasps were the most significant pollinators, contributing 37.20 %, followed by flies (34.88 %), butterflies (20.93 %) and bees (6.97 %) (4). Flies and wasps are the primary pollinators of *Z. mauritiana* (9). Pollination by flies, often alongside Hymenopteran insects is a common characteristic among entomophilous plants (10, 11). Among all insect visitors, *Apis* spp. were observed foraging on ber plant for nectar and pollen while dipteran and lepidopteran insects are foraged only for nectar (12).

Cultivation of the *Z. mauritiana* variety 'Apple ber' has recently gained popularity and it has a lot of advantages over traditional ber farming with high economic return and a longer shelf life of fruits (13). Apple ber fruits are sweet, crispy, juicy and delicious, like apple. Pollinators play a crucial role in improving fruit quality and increasing fruit set in this crop. While studies in India have explored honeybee pollination in traditional ber varieties, comprehensive research on pollination in apple ber variety is lacking (14). Considering the aforementioned information, this study aimed to identify the key pollinators of apple ber.

Materials and Methods

Site description

The present experiment was conducted in the apple ber orchard situated at the Horticulture experimental area, Chaudhary Charan Singh Haryana Agricultural University (CCSHAU), Hisar, Haryana, India during 2022 and 2023. The location is situated at 215.2 m above sea level, with coordinates of 29°10' N latitude and 75°46' E longitude. The experiment was laid out in a randomized block design (RBD) with 3 replications to minimise experimental error. All cultural practices including training, pruning, weeding, hoeing and irrigation were followed in accordance with the recommended package of practices (15).

Diversity of insect visitors

A variety of insect visitors from apple ber flowers were collected using a cone-shaped hand net. Floral visitors were collected by sweep sampling at hourly intervals from 0600–1800 hr during the flowering period (starting after 10 % flowering and continuing until 90 % flowering) of apple ber. Caught insects were transferred to the killing bottle. They were further mounted and spread as per standard protocol for “collection and preservation of insects”. These specimens were preserved as dry specimens in the insect collection box (16). Collected insects were compared to reference collection kept at the Department of Entomology, CCSHAU, Hisar (Haryana). Remaining specimens were identified from the Department of Entomology, Maharana Pratap University of Agriculture and Technology, Udaipur. Diversity of pollinators was estimated by separating them based on their order and family, counting each and utilising appropriate tools.

Relative abundance of insect visitors

Relative abundance of floral visitors/pollinators visiting flowers/inflorescence was recorded on a single branch of apple ber for 5 min. These observations were recorded when the crop was at 30–80 % of flowering at 2 hr intervals from 0600–1800 hr (7 intervals) using a hand tally counter during different day hours for 10 calm, clear and sunny days.

Data analysis

This study presents quantitative data on species diversity and abundance of common pollinators visiting apple ber fields during the flowering season in the Hisar, Haryana. We characterised the pollinator community and assessed their abundance by dividing the number of individuals of each species by the total number of insect visitors recorded during the observation period and expressing the value as a percentage (17). Data recorded for temporal abundance was statistically analysed by using OPSTAT system software (18). Significance of differences in insect species was evaluated by "F" test and critical difference (CD) was computed at 5 % level of significance.

Results

Diversity of insect visitors

Apple ber was confirmed as a predominately entomophilous fruit crop with a total number of 25 insect species belonging to 17 families and 5 orders recorded visiting apple ber flowers during the study period (Table 1). The most prominent order of visitors was Hymenoptera, which accounted for 10 species from 4 families (Apidae, Vespidae, Sphecidae and Formicidae). Within Hymenoptera, the family Apidae was most diverse with 5 species being *Apis florea* F., *Apis mellifera* L., *Apis dorsata* F., *Apis cerana* F. and *Xylocopa* sp.

Following Hymenopterans, the order Diptera was second most prominent with 7 different species representing 5 families namely Syrphidae (*Eristalinus taeniops*, *Helophilus* sp. and *Syrphus opinator*), Stratiomyidae (*Hedriodiscus vertebratus*), Calliphoridae (*Lucilla sericata*) Ulidiidae (*Physiphora* sp.) and Muscidae (*Musca domestica*). Lepidoptera was the next major order, represented by 3 species belonging to the families Pieridae, Nymphalidae and Lycaenidae. The presence of butterflies, like *Eurema hecabe* and *Danaus chrysippus*, indicates that while they may not be the primary pollinators, but they contribute to the overall pollinator diversity.

Table 1. Diversity of insect visitors on apple ber bloom during 2022 and 2023

Sr. No.	Common name	Scientific name	Family	Order
1	Little honey bee	<i>Apis florea</i> F.***	Apidae	Hymenoptera
2	European honey bee	<i>A. mellifera</i> L.***	Apidae	Hymenoptera
3	Giant honey bee	<i>A. dorsata</i> F.***	Apidae	Hymenoptera
4	Indian honey bee	<i>A. cerana</i> F.**	Apidae	Hymenoptera
5	Oriental hornet	<i>Vespa orientalis</i> L.***	Vespidae	Hymenoptera
6	Common paper wasp	<i>Polistes olivaceus</i> De Geer**	Vespidae	Hymenoptera
7	Arizona paper wasp	<i>Polistes</i> sp.*	Vespidae	Hymenoptera
8	Yellow mud dauber	<i>Sceliphron</i> sp.***	Sphecidae	Hymenoptera
9	Little black ant	<i>Monomorium</i> sp.*	Formicidae	Hymenoptera
10	Carpenter bee	<i>Xylocopa</i> sp.**	Apidae	Hymenoptera
11	Hover fly	<i>Eristalinus taeniops</i> ***	Syrphidae	Diptera
12	Sun fly	<i>Helophilus</i> sp.*	Syrphidae	Diptera
13	Picture winged fly	<i>Physiphora</i> sp.*	Ulidiidae	Diptera
14	House fly	<i>Musca domestica</i> L.**	Musidae	Diptera
15	Black margined flower fly	<i>Syrphus opinator</i> **	Syrphidae	Diptera
16	Green bottle fly	<i>Lucilla sericata</i> Meigen**	Calliphoridae	Diptera
17	Soldier fly	<i>Hedriodiscus vertebratus</i> Say*	Stratiomyidae	Diptera
18	Common grass yellow	<i>Eurema hecabe</i> (L.)*	Pieridae	Lepidoptera
19	Plain tiger butterfly	<i>Danaus chrysippus</i> (L.)*	Nymphalidae	Lepidoptera
20	Blue Pierrots	<i>Tarucus</i> sp.*	Lycaenidae	Lepidoptera
21	Lady bird beetle	<i>Coccinella septempunctata</i> L.*	Coccinellidae	Coleoptera
22	Grey ash weevil	<i>Myllocerus</i> sp.*	Curculionidae	Coleoptera
23	Chaffer beetle	<i>Oxyctonia versicolor</i> (F.)*	Scarabaeidae	Coleoptera
24	Blister beetle	<i>Mylabris pustulata</i> Olivier*	Meloidae	Coleoptera
25	Praying mantis	<i>Mantis religiosa</i> (L.)*	Mantidae	Mantodea

***Most frequent visitors; **Frequent visitors; *Less frequent visitors.

Other insect visitors included Coleopterans such as *Coccinella septempunctata* L. (Coccinellidae), *Mylocherus* sp. (Curculionidae), *Oxyctonia versicolor* F. (Scarabaeidae) and *Mylabris pustulata* Olivier (Meloidae), along with one species from Mantodea (*Mantis religiosa*). These insects are less common as pollinators but can play a role in the pollination process or may be present as opportunistic visitors or predators.

The study also revealed a notable year-to-year variation in insect diversity. During 2022, a total of 25 insect species were recorded, whereas only 20 species were observed in 2023. Five species recorded in 2022 were absent in 2023, including 4 coleopteran species such as *Coccinella septempunctata* L. (Coccinellidae), *Mylocherus* sp. (Curculionidae), *Oxyctonia versicolor* F. (Scarabaeidae) and *Mylabris pustulata* Olivier (Meloidae) and 1 mantodean species, *Mantis religiosa* (Mantidae).

Relative abundance of insect visitors

Out of the total 25 insect visitor species recorded on apple ber bloom, the mean relative abundance of only prominent insect visitors is presented in Table 2. The results clearly indicate the supremacy of hymenopterans as insect visitors of apple ber accounted for 75.20 % in 2022 and 77.72 % in 2023 of all visitors. Among the hymenopterans, Apidae was the most abundant family (56.15 % and 55.73 %) followed by Vespidae (12.57 % and 13.99 %) and Sphecidae (7.21 % and 8.05 %) during 2022 and 2023 respectively.

Among the honeybees, *A. florea* was the most abundant insect visitor with a mean relative abundance of 21.49 and 22.72 % during flowering period in the first and second year respectively. It was followed by *Apis mellifera*, which was the second most frequent visitors, accounting for 15.54 % and 17.00 % of total floral visitors. In contrast, the Asian honeybee (*Apis cerana*) was the least abundant honeybee visitor, representing only 5.30 % and 4.35 % of visitors during the respective years (Fig. 1 and 2).

The order Diptera was found to be the second most abundant group of visitors on apple ber bloom. Among dipterans, green bottle fly, *Lucilla sericata* (8.62 and 7.29 %) was the most frequent visitors followed by *Eristalinus taeniops* (5.95 and 6.92 %), *Musca domestica* (5.58 and 3.46 %) and *Syrphus opinator* (3.94 and 4.52 %) in 2022 and 2023 respectively.

Temporal abundance of insect visitors of apple ber bloom during different days and periods of observation

Temporal abundance of insect visitors was studied over 10 clear, calm and sunny days during the flowering season of 2022 and 2023. Significant variation was observed in the mean abundance of different insect visitors. The findings highlight the importance of various insects as pollinators and their activity patterns, which are crucial for effective pollination management. *Apis florea* was the most common visitor, with an average population of 2.88 and 3.02 individuals per branch/5 min in 2022 and 2023 respectively. It was followed by *A. mellifera* (2.09 and 2.26) and *A. dorsata* (1.40 and 1.55) during 2022 and 2023 respectively. The lowest mean population (0.46 per branch/5 min) was recorded for *Xylocopa* sp.

The mean abundance of prominent insect visitors varied across different observations days (Fig. 3 and 4). In 2022, the highest abundance (1.17 per branch/5min each) was observed on September 27 and October 5, while the lowest (1.06) was on September 26. In 2023, the peak abundance was recorded on September 28 (1.23 per branch/5min), with the lowest on September 18 (1.07 per branch/5min). Among the insect visitors, *A. florea* were the most active species, showed its highest population on October 3, 2022 (3.01 per branch/5min) and its lowest on September 26 (2.77 per branch/5min).

Insect activity was recorded at 2 hr interval from 0600–1800 hr (Fig. 5 and 6). The highest abundance of insect visitors was recorded at 1400 hr followed by 1000 hr and 1200 hr, while the lowest activity occurred at 0600 hr. The population of *A. florea* foragers was lowest in the early morning (0600 hr) (0.25 and 0.39 per branch/5 min), gradually increasing and attaining its peak at 1400 hr (4.50 and 4.64), then declining towards the evening at 1800 hr (2.51 and 2.65 per branch/5 min). *A. cerana* and *A. mellifera* followed a similar pattern, with their peak activity also occurring at 1400 hr. Other insects, such as *Vespa orientalis* and *Polistes olivaceus*, also showed peak activity at 1400 hr. Dipteran species like *Eristalinus taeniops*, *Lucilla sericata* and *Musca domestica* were rarely seen in the early morning but reached their maximum population at 1400 hr.

Table 2. Mean abundance of insect visitors on apple ber bloom during 2022 and 23

Orders/floral visitors	2022		2023	
	Mean population (per branch/5 min)	Mean proportion (%)	Mean population (per branch/5 min)	Mean proportion (%)
Hymenoptera				
<i>Apis florea</i>	2.88*	21.49	3.02*	22.72
<i>Apis mellifera</i>	2.09	15.54	2.26	17.00
<i>Apis dorsata</i>	1.40	10.40	1.55	11.66
<i>Apis cerana</i>	0.71	5.30	0.57	4.35
<i>Xylocopa</i> sp.	0.46	3.42	-	-
<i>Sceliphron</i> sp.	0.97	7.21	1.07	8.05
<i>Vespa orientalis</i>	0.66	4.91	0.79	5.94
<i>Polistes olivaceus</i>	1.03	7.66	1.07	8.05
Total Hymenoptera	10.21	75.20	10.33	77.72
Diptera				
<i>Lucilla sericata</i>	1.16	8.62	0.97	7.29
<i>Musca domestica</i>	0.75	5.58	0.46	3.46
<i>Eristalinus taeniops</i>	0.80	5.95	0.92	6.92
<i>Syrphus opinator</i>	0.53	3.94	0.61	4.58
Total Diptera	3.24	24.09	2.96	22.28
Mean total population	13.45	100	13.29	100

*Observations are mean of 30 replications (10 days x 3 replications).

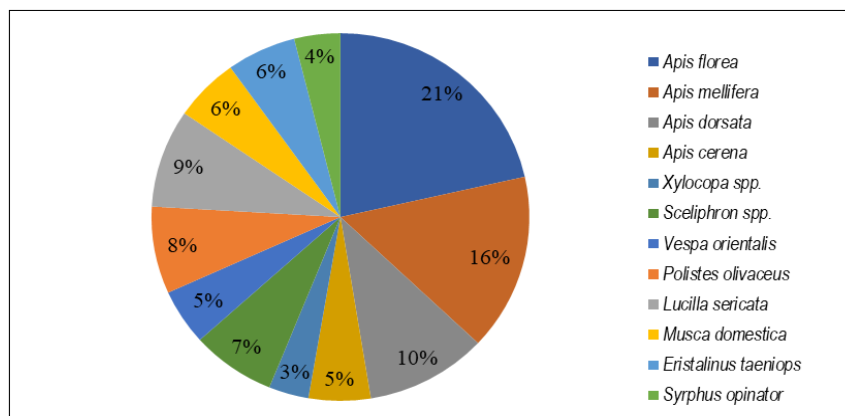


Fig. 1. Abundance of insect visitors on apple ber bloom during 2022.

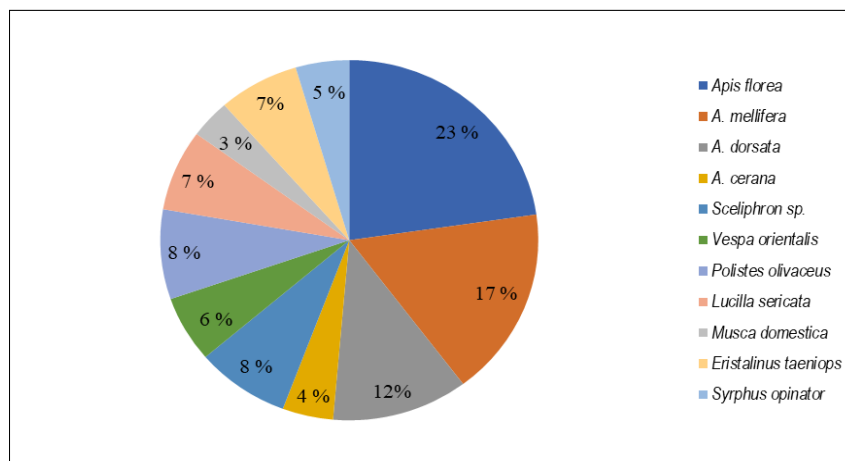


Fig. 2. Abundance of insect visitors on apple ber bloom during 2023.

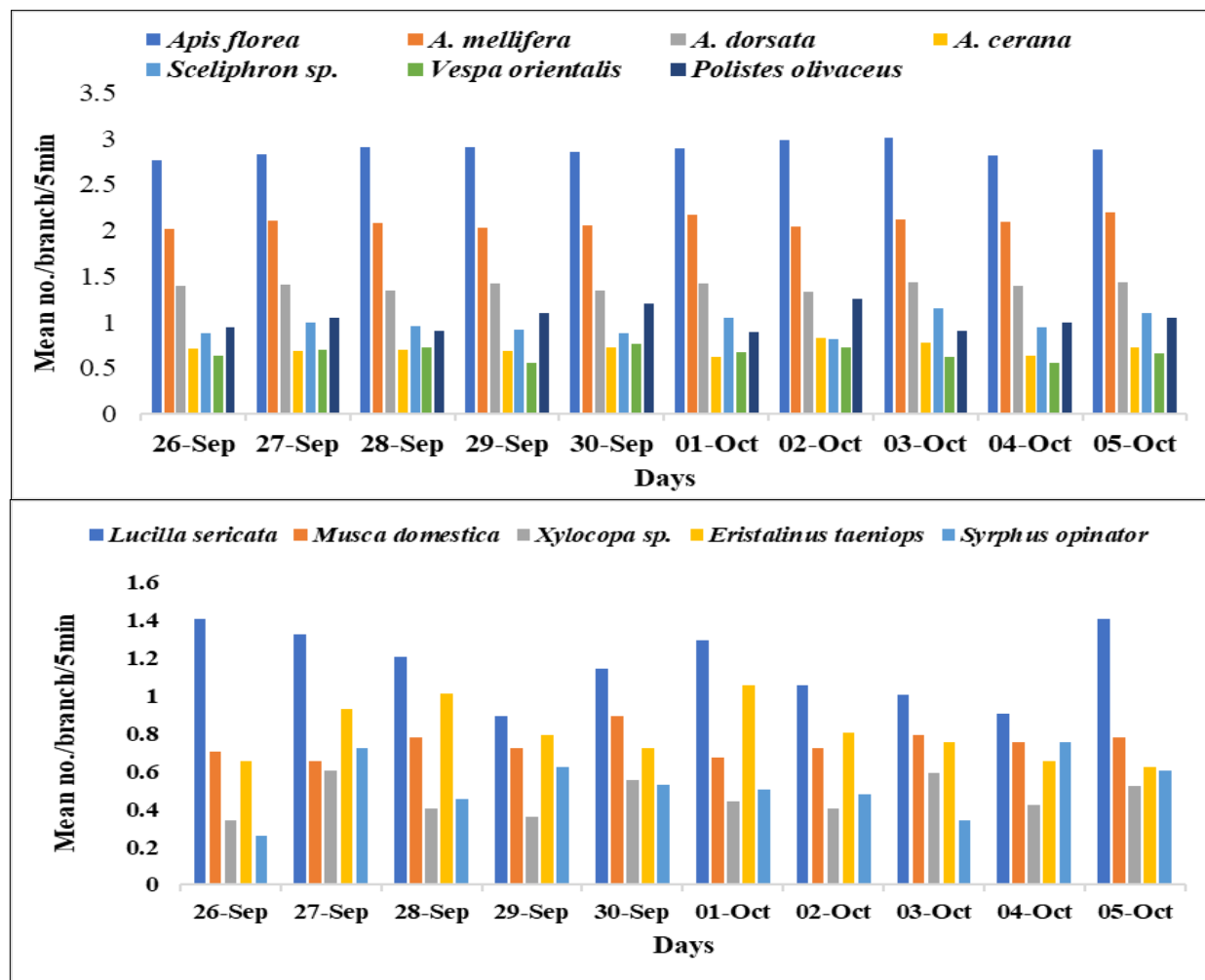


Fig. 3. Mean abundance of insect visitors on apple ber bloom on different days during 2022.

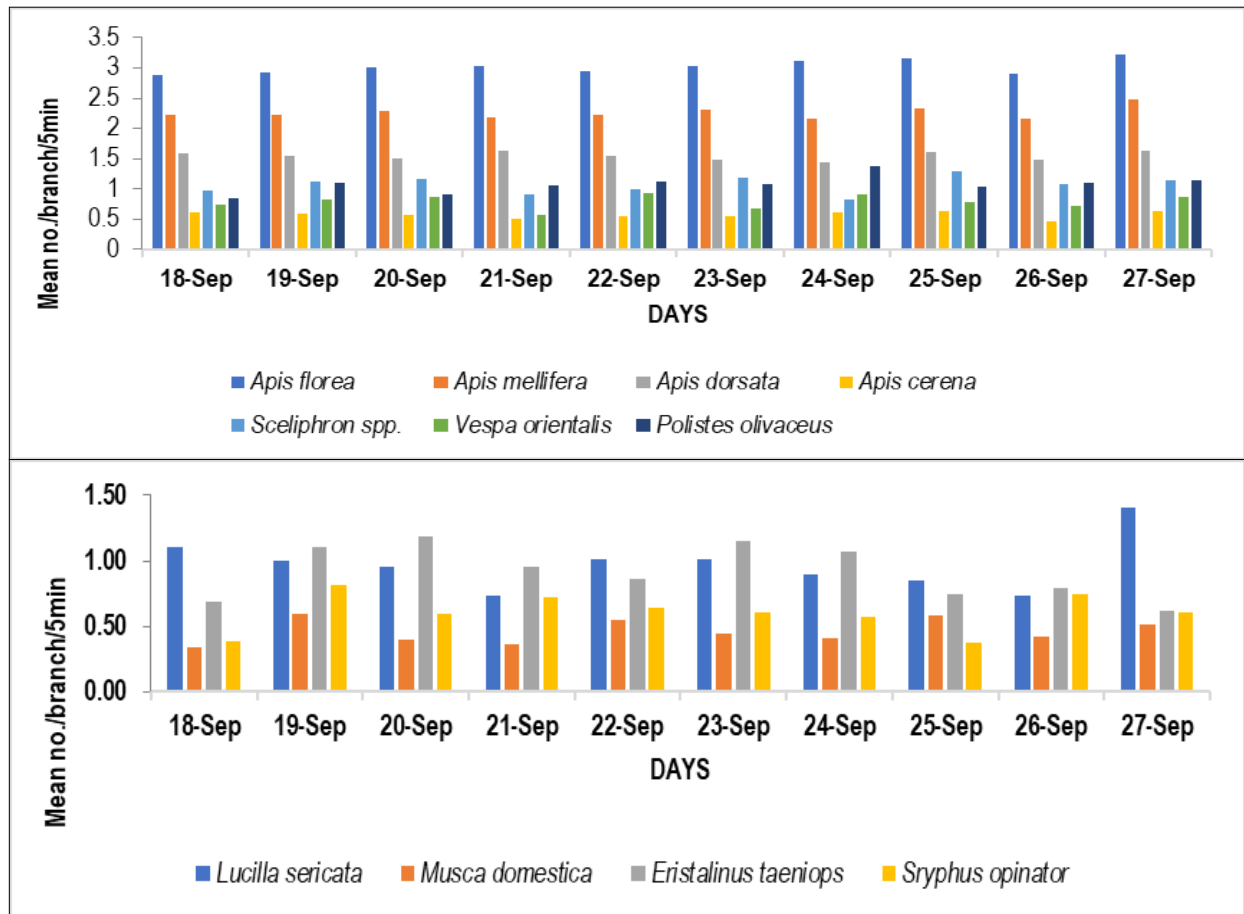


Fig. 4. Mean abundance of insect visitors on apple ber bloom on different days during 2023.

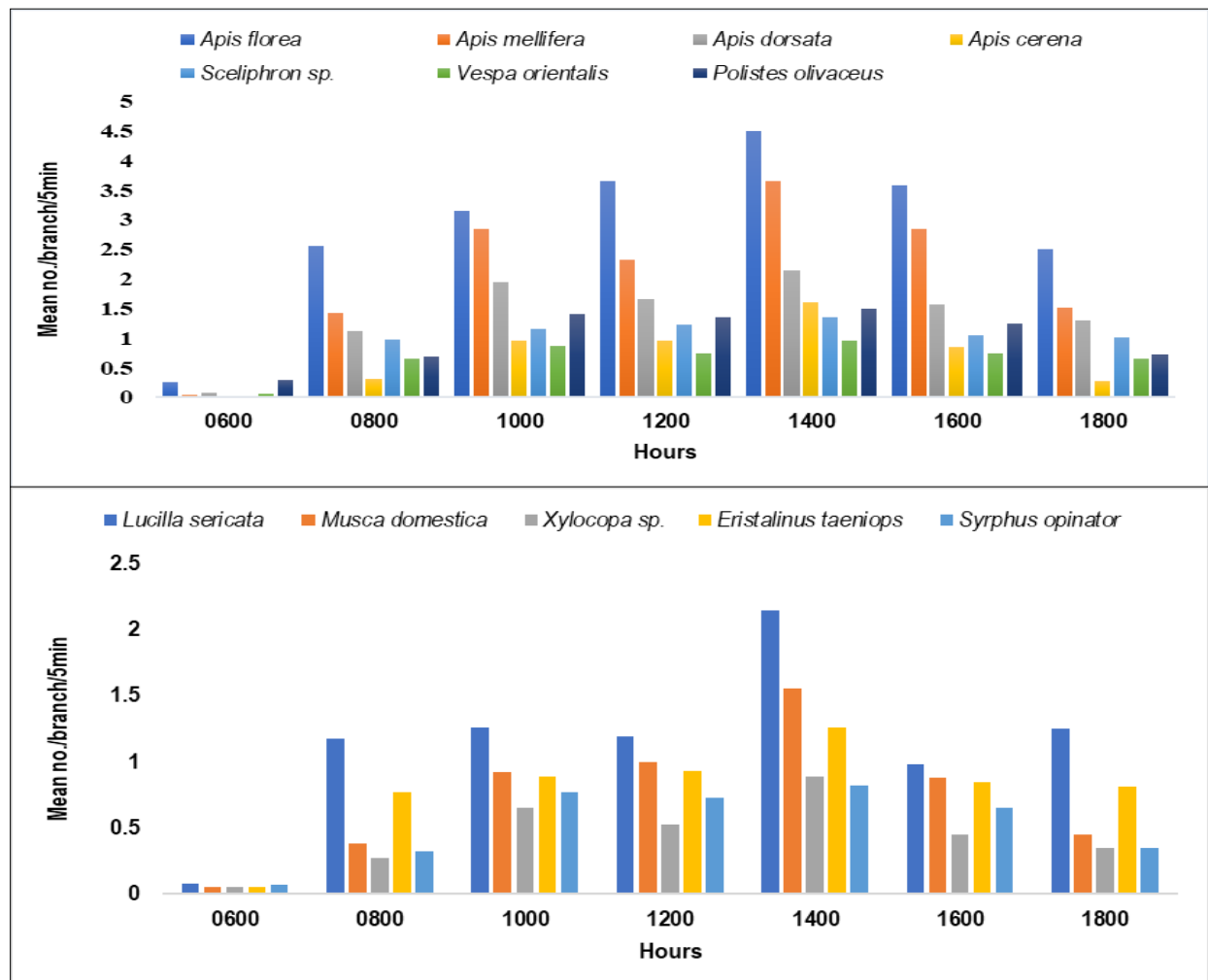


Fig. 5. Temporal abundance of insect visitors on apple ber bloom during 2022.

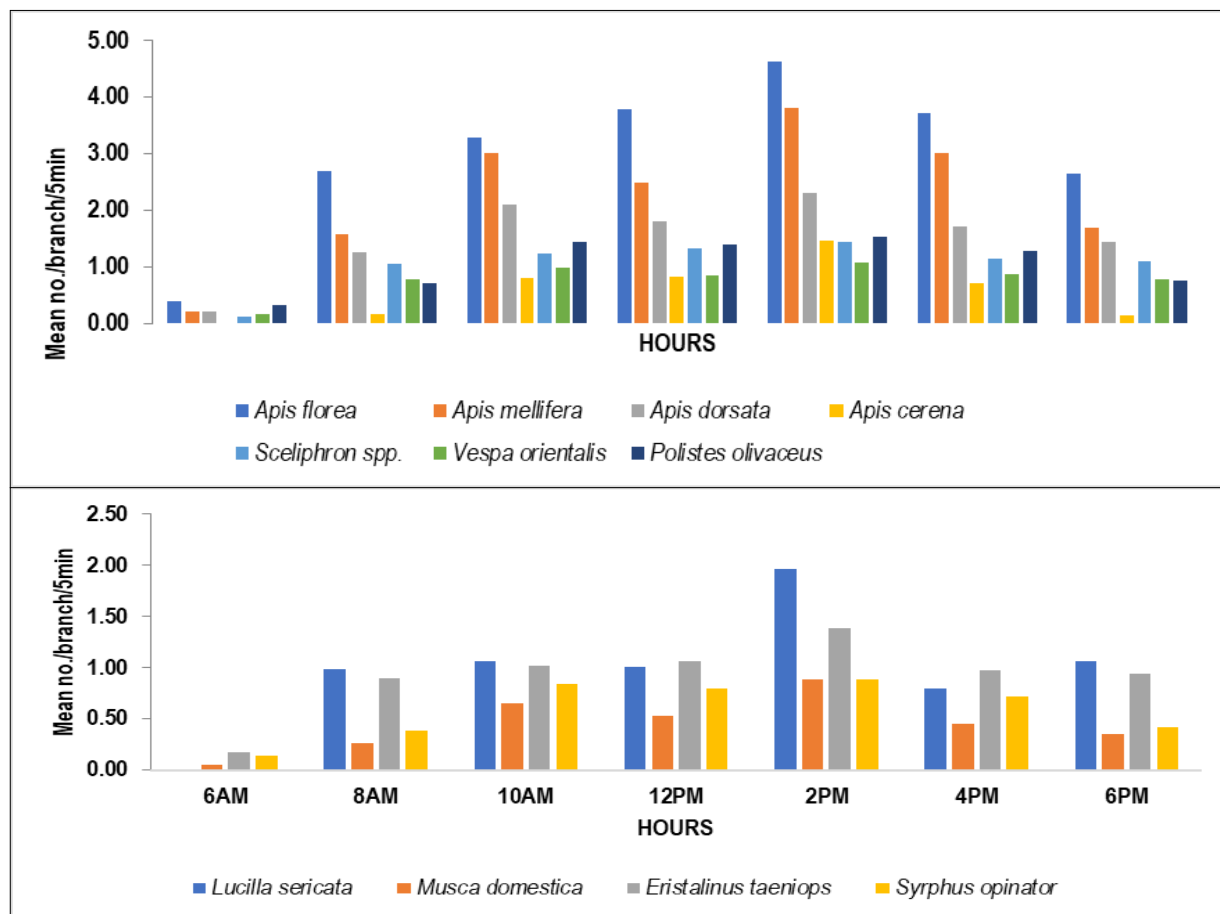


Fig. 6. Temporal abundance of insect visitors on apple ber bloom during 2023.

Discussion

The dominance of Hymenoptera, particularly honeybees, observed in the present study is characteristic feature of entomophilous crops and is consistent with earlier findings on *Ziziphus* species. The predominance of the family Apidae, especially *Apis florea*, *A. mellifera* and *A. dorsata*, confirms the crucial role of honeybees in apple ber pollination. These species are known for their foraging efficiency, floral constancy and effective pollen transfer, making them key contributors to successful fruit set (19). The coexistence of multiple *Apis* species reflects a favourable agro-climatic environment in the Hisar region, capable for supporting both wild and managed bee populations (20, 21). Similar dominance pattern on *Ziziphus* blooms has also been previously reported across different geographical regions (8, 22).

Dipteran visitors constituted the second most abundant group of floral visitors. Although flies are generally considered as secondary pollinators, their consistent presence suggests a supplementary role in pollination, particularly during periods of reduced bee activity (22, 23). The presence of Lepidopterans further enhanced pollinator diversity, even though their contribution to effective pollination may be limited due to lower visitation frequency and reduced pollen transfer efficiency, as reported earlier (22, 24). Nonetheless, such groups enhance pollination stability by increasing functional redundancy within the pollinator community.

The absence of 5 insect species in 2023 highlights year to year variability in pollinator diversity, which may be influenced by climatic conditions, availability of floral resources or fluctuations in local insect populations. The total number of insect species recorded in the present study exceeds earlier reports of 15 species

(25), indicating a relatively rich pollinator community in the study area, although it remains lower than the 86 species documented (4). Such variation emphasises the strong influence of geographical location, habitat heterogeneity and sampling intensity on pollinator diversity assessments.

The consistent predominance of *A. florea* in both relative and temporal abundance suggests its high adaptability and preference for apple ber flowers under semi-arid conditions. Its dominance may be attributed to its small body size, efficient foraging behaviour and preference for small, nectar-rich flowers like those of ber (26). The comparatively higher abundance of *A. mellifera* and *A. dorsata* further emphasises the collective role of honeybees in ensuring effective pollination of apple ber. Variations in dominant bee species reported by different authors may be attributed to differences in region, floral density and competing crops (24, 27).

Temporal fluctuations in insect abundance across observation days indicate that pollinator activity is not uniform throughout the flowering period. Peaks in abundance during specific days in both years likely coincided with optimal flowering intensity and favourable weather conditions that enhance nectar secretion and pollen availability. Conversely, reduced activity on certain days may be associated with unfavourable microclimatic conditions or diminished floral rewards (28). Such variability underscores the importance of maintaining a diverse pollinator community to buffer against short-term declines in individual species activity.

Diurnal patterns of insect visitation revealed increasing activity from morning to afternoon, with peak abundance around 1400 hr, followed by a gradual decline towards evening. Reduced

activity during early morning hours can be attributed to lower temperatures and light intensity, which limit insect flight and foraging efficiency (29). The pronounced afternoon peak, particularly among honeybees and flies, corresponds with optimal temperature, light conditions and increased nectar concentration, making flowers more attractive to foragers. Similar diurnal trends have been documented in other fruit crops, reinforcing the role of environmental factors in shaping pollinator behaviour (30). Practically, these findings have direct practical implications for orchard management. Agricultural operations such as pesticide application, irrigation and pruning should be avoided during peak pollinator activity and scheduled during early morning or late evening to minimise negative impacts on beneficial insects.

Overall, the findings highlight the ecological and agronomic importance of conserving diverse pollinator communities, especially native honeybees to ensure stable and sustainable apple ber production under semi-arid conditions.

Conclusion

Apple ber was confirmed to be a truly entomophilous crop, attracting a total of 25 insect species belonging to 5 orders, highlighting its strong dependence on insect pollination. The order Hymenoptera emerged as the most prominent group, with the Apidae family being the most prominent. Among the hymenopterans, *Apis florea* was the most dominant and frequent visitor, closely followed by *A. mellifera* and *A. dorsata*. The second most important order was Diptera, which emphasised the diversity of floral visitors. Significant year-to-year variation in species diversity and a clear temporal abundance peak around 1400 hr were observed, suggesting strong influences from microclimate and local ecological factors. Overall, the findings demonstrate the critical role of honeybees in apple ber pollination and the need for localised pollinator management strategies to optimise fruit set and yield.

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Authors' contributions

VY conducted the experiment and data collection. MKJ designed the study, manuscript editing and coordination. SY and HK assisted in the study and provided technical support. PY and VY contributed to data analysis and drafted the manuscript. SSS and MKJ contributed to the conceptualisation and supervision of the research. M and P review the final manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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