International Journal of Zoology Studies
www.zoologyjournals.com
ISSN: 2455-7269
Received: 02-12-2025, Accepted: 01-01-2026, Published: 15-01-2026
Volume 11, Issue 1, 2026, Page No. 11-15

Species composition and diversity of insect pollinators visiting Radish (*Raphanus Sativus* L.) in semi-arid climate of Gangapur City, Rajasthan, India

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Abstract
Insect pollinator's variety and quantity are essential for both environmental stability and agricultural output. The variety, species composition, and relative abundance of insect pollinators in Gangapur, Rajasthan, were investigated in the present study on radish (*Raphanus sativus* L.). A total of fifteen species of insect pollinators from seven families and three orders, Hymenoptera, Lepidoptera, and Diptera, were identified. The total relative abundance of pollinators was 66.1 insects/m², dominated by Hymenoptera, particularly the Apidae family. *Apis dorsata* (9.0 insects/m²) was the most abundant species, followed by *Apis mellifera* (8.2) and *Apis florea* (7.0). Among lepidopterans, *Danaus chrysippus* (4.8) was the most prevalent. Syrphid flies, including *Sphaerophoria macrogaster* (3.1) and *Episyrphus balteatus* (2.0), were the main dipteran pollinators. According to the Shannon–Wiener diversity index (H′ = 2.5920), diversity analysis showed a significant degree of species diversity. A well-distributed pollinator population with little dominance is suggested by the low Simpson's dominance index (D = 0.08215) and high Simpson's index of diversity (1 − D = 0.91749). A high level of evenness in the distribution of individuals among species was further demonstrated by Pielou's evenness index (E = 0.9571). The presence of lepidopteran and dipteran pollinators highlights the need for functional diversity, while Apis species play a crucial role in pollination. Conservation and habitat management are very important to sustain pollination services in our ecosystem and to support diverse insect pollinator communities.

Keywords: Apis species, diversity, hymenoptera, insect pollinators, lepidoptera, insect pollinator, radish, *raphanus sativus*, simpson index

Introduction

Plant pollinator interactions are important for maintaining ecosystem stability. These interactions connect different levels of the food web and support the long term relationship between flowering plants and insect pollinators. Both plants and pollinators benefit from this association and gradually adapt to each other over time. Such interactions help maintain ecological balance and support biodiversity conservation (Divija *et al.,* 2022) [4]. Biodiversity means the variety of life found in an ecosystem including genes, species, and habitats. It is important for sustainable development. Ecosystems with more biodiversity are usually more stable and productive. Insects show very high diversity and play an important role in keeping ecosystems healthy, especially through pollination (Kachhawa *et al*., 2021) [8]. Among insects, bees are considered highly efficient pollinators for many plant species and play a key role in increasing fruit and seed production in different agricultural crops (Younas *et al*., 2023) [25]. Radish (*Raphanus sativus* L.) is a common root vegetable from the Brassicaceae family and is widely grown across India. India is the world's second-largest vegetable producer after China and produces about 13% of the global vegetable output showing the importance of vegetable cultivation in the country (Sharma *et al*., 2023) [17]. Radish is a fast-growing crop with a short growing period. It is mainly grown for its edible tuberous roots which can be eaten raw or cooked. Radish seeds also produce a non-drying fatty oil that is used for food, soap making, and lighting purposes (Sharma *et al*., 2023) [18]. The nutritional and medicinal value of radish is well known. The majority of commercially grown radish cultivars however, have a sporophytic self-incompatibility system, which means that they are primarily cross-pollinated and totally reliant on insect pollinators for successful seed development (Asritha *et al*., 2024; Mahesh *et al*., 2022) [2,12]. The main pollinators of radish plants and many other horticultural crops are honey bees, bumblebees, and solitary bees. Even when radish plants are pollinated naturally they usually produce only 2 to 20 grams of seed, and the seed yields often remain low. This shows that it is important to understand the diversity of pollinators and their activity patterns to improve seed production (Siregar *et al*., 2016) [21]. The foraging behavior of insect pollinators changes depending on the time of day and environmental conditions. Many studies have shown that pollinators are most active around midday and in the afternoon. Their activity is usually lowest in the early morning. According to Divekar *et al*., (2024) [3] the main pollinators of radish flowers show their highest foraging activity at about 14:00, their next highest activity at 12:00, and the lowest activity at 08:00. The foraging rate which is the number of flowers visited per minute by a pollinator increases as the temperature rises from morning to midday. It decreases when the relative humidity is high (Kachhawa *et al*., 2022) [7].

Material And Methods

a. Study site

The present study was conducted in Gangapur City, Rajasthan, India. The city is located at approximately 26.47° north latitude and 76.71° east longitude and is part of the Sawai Madhopur district. The region has semi-arid climate with high temperatures and low to moderate annual rainfall. The study area also shows clear variation in temperature between day and night. The natural vegetation mainly consists of crops and xerophytic plant species. Observations on insect pollinators were conducted under natural field conditions.

b. Floral Biology of Radish

Radish (*Raphanus sativus* L.), belonging to family Brassicaceae is a cross-pollinated and entomophilous crop governed by a sporophytic self-incompatibility system (Jakhar *et al.,* 2015) [6]. The flowers of Radish plant have cruciferous floral architecture and are present on a racemose inflorescence. This plant has four cruciform petals and a tetradynamous androecium with four long and two short stamens. The flowers are complete and hermaphrodite in nature. The gynoecium is bicarpellary and syncarpous with a superior bilocular ovary and a capitate stigma. The structure of the flower and the features of pollinators together influence the foraging behaviour of insect pollinators.

c. Field Observations

Field observations were done to record the types of insect pollinators and their daily and seasonal activity on radish (*Raphanus sativus* L.) flowers. Observations were made twice a week during the flowering season from 2024 to 2025. Insect activity was watched directly using Olympus binoculars to avoid disturbing their natural foraging. A Canon EOS 1200D digital camera was used to record videos of pollinator activity, including flower visits, time spent on flowers, and movement between flowers. A mobile stopwatch was used to measure how long each insect stayed on a single flower. Pollinator visits were recorded from 6:00 to 18:00 hours. Regular observations during this time helped in understanding how pollinator activity changed throughout the day.

d. Insect Pollinator Collection, Preservation, and Identification

All collected insect specimens were first sorted into major taxonomic groups. The specimens were gently stretched to clearly observe important morphological characters such as wings legs and abdominal segments. Each specimen was pinned through the thorax to preserve body structures and allow proper examination. Identification was carried out using a stereo zoom microscope fitted with ocular micrometres and a camera lucida. For species level identification standard taxonomic keys were used when there is difficulty in understanding the morphology of an insect pollinator. When identification was uncertain the specimens were compared with reference collections in museums and relevant published literature.

e. Diversity Analysis

- **Shannon–Wiener Diversity Index (H′):** It measures uncertainty or randomness of a distribution, considering both richness and evenness (Shannon and Wiener, 1949) [16]. $H' = -\sum(p_i \ln p_i)$
- **Simpson's Diversity Index (1 – D):** This index represents the probability that two individuals randomly selected from a sample belong to different species. It measures species dominance and diversity (Simpson, 1949) [20].

$$D = \sum\left(\frac{n}{N}\right)^2, \qquad \text{Simpson's Diversity} = 1 - D$$

- **Evenness (E):** Species evenness was calculated using Pielou's Evenness Index to determine the uniformity of species distribution (Pielou, 1966) [13].

$$E = \frac{H'}{\ln S}$$

Definitions of terms used in all formulas

- p_i= proportion of individuals belonging to the i-th species (number of individuals of species i divided by total individuals in the sample)
- n= number of individuals of a particular species
- N= total number of individuals of all species in the sample
- S= total number of species in the sample
- H'= Shannon–Wiener diversity index value
- E= species evenness index
- D= dominance index or Simpson's dominance index (depending on context)

Result

The present study recorded a total of fifteen insect pollinator species belonging to seven families and three orders, namely Hymenoptera, Lepidoptera and Diptera, from Gangapur city, Rajasthan, on Radish *(Raphanus sativus L.)* (Fig. 2). The species composition along with their relative abundance is presented in Table 1. The overall relative abundance of pollinators recorded during the study period was 66.1 insects/m². Among the recorded orders, Hymenoptera emerged as the dominant group in terms of both species richness and abundance, followed by Lepidoptera and Diptera (Fig. 1). The family Apidae constituted the most dominant group among hymenopteran pollinators. *Apis dorsata* was observed to be the most abundant species with a relative abundance of 9.0 insects/m², followed by *Apis mellifera* (8.2 insects/m²) and *Apis florea* (7.0 insects/m²). *Apis cerana* showed comparatively lower abundance (4.0 insects/m²). Other apid bees, such as *Tetragonula spp*. and *Xylocopa spp.* were recorded in moderate numbers with relative abundances of 5.0 and 3.5 insects/m², respectively. Among the non-apid bees, *Lasioglossum spp.* showed higher abundance (4.5 insects/m²) than *Megachile spp.* (3.0 insects/m²), while *Nomia spp.* was recorded in very low numbers and represented the least abundant pollinator species in the study area. Lepidopteran pollinators were represented by three species belonging to the families Nymphalidae and Pieridae. *Danaus chrysippus* was the most abundant butterfly species (4.8 insects/m²), followed by *Euploea core* (3.8 insects/m²) and *Eurema blanda* (3.5 insects/m²). Dipteran pollinators were mainly represented by syrphid flies. *Sphaerophoria macrogaster* and *Episyrphus balteatus* were recorded with relative abundances of 3.1 and 2.0 insects/m², respectively, while *Vespula vulgaris* showed a moderate abundance of 3.9 insects/m². The diversity indices calculated for the recorded pollinator species are presented in Table 2. A total species richness of 15 pollinator species was recorded, with a cumulative relative abundance of 66.1. With an estimated Simpson's dominance index of 0.08215, the pollinator community has low dominance and a comparatively balanced input of species. Accordingly, the Simpson's index of diversity was high (0.91749), indicating a high likelihood that two individuals chosen at random are members of different species. The studied area appears to have a high degree of species diversity, as shown by the Shannon–Wiener diversity index of 2.5920. Additionally, Pielou's evenness index was found to be 0.9571, which indicates that there is little variation in species abundance and a high degree of evenness in the distribution of individuals among the observed pollinator species.

Table 1: Species Composition and Relative Abundance of Insect Pollinators on Radish *(Raphanus sativus L.)*

S.N.	Insect pollinator	Family	Order	Relative abundance (Insects/ m^2)
1	*Apis dorsata*	Apidae	Hymenoptera	9.0
2	*Apis mellifera*	Apidae	Hymenoptera	8.2
3	*Apis florea*	Apidae	Hymenoptera	7.0
4	*Apis cerana*	Apidae	Hymenoptera	4.0
5	*Tetragonula spp.*	Apidae	Hymenoptera	5.0
6	*Xylocopa spp.*	Apidae	Hymenoptera	3.5
7	*Megachile spp.*	Megachilidae	Hymenoptera	3.0
8	*Lasioglossum spp.*	Halictidae	Hymenoptera	4.5
9	*Nomia spp.*	Halictidae	Hymenoptera	0.8
10	*Danaus chrysippus*	Nymphalidae	Lepidoptera	4.8
11	*Euploea core*	Nymphalidae	Lepidoptera	3.8
12	*Eurema blanda*	Pieridae	Lepidoptera	3.5
13	*Sphaerophoria macrogaster*	Syrphidae	Diptera	3.1
14	*Episyrphus balteatus*	Syrphidae	Diptera	2.0
15	*Vespula vulgaris*	Vespidae	Hymenoptera	3.9

Table 2: Diversity Analysis of Insect Pollinators on Radish *(Raphanus sativus L.)*

Species Richness (S):	**= 15**
Sum of relative abundance (N):	= 66.1
Simpson Index (D): $\sum Pi^2$	= 0.08215
Simpson Index of Diversity: (1-D):	= 0.91749
Shannon–Wiener diversity index (H′): $-\sum Pi \ln Pi$	= -(-2.5920) = 2.5920
Pielou's Evenness Index: E/ *ln* S	= 2.5920 / 2.7080 = 0.9571

Discussion

This study shows that Hymenoptera was the most common group of insect pollinators. A total of fifteen pollinator species belonging to seven families and three orders were recorded. Hymenoptera showed the highest number of species and individuals which agrees with earlier studies by Klein *et al*., 2007 [9]. Bees were the main pollinators in the study area. Species such as *Apis dorsata Apis mellifera* and *Apis florea* were observed most frequently. Similar dominance of these species has been reported by Sihag (2001) [19] and Abrol (2012) [1] in tropical and semi-arid regions of India. The high number of *Apis dorsata* may be due to its wide foraging range and ability to survive in open habitats. Other bees such as *Tetragonula, Xylocopa, Lasioglossum* and *Nomia* were present in low numbers but still contributed to pollination as also reported by Heard (1999) [5] and Somanathan *et al*., 2008 [22]. Butterflies showed moderate diversity with *Danaus chrysippus* being the most common species. Their role as supporting pollinators has been described by Kunte (2000) [11] and Tiple *et al.,* 2006 [23]. The diversity indices showed high species diversity low dominance and high evenness which indicates a stable and balanced pollinator community similar to observations by Winfree *et al*., 2011 [24].

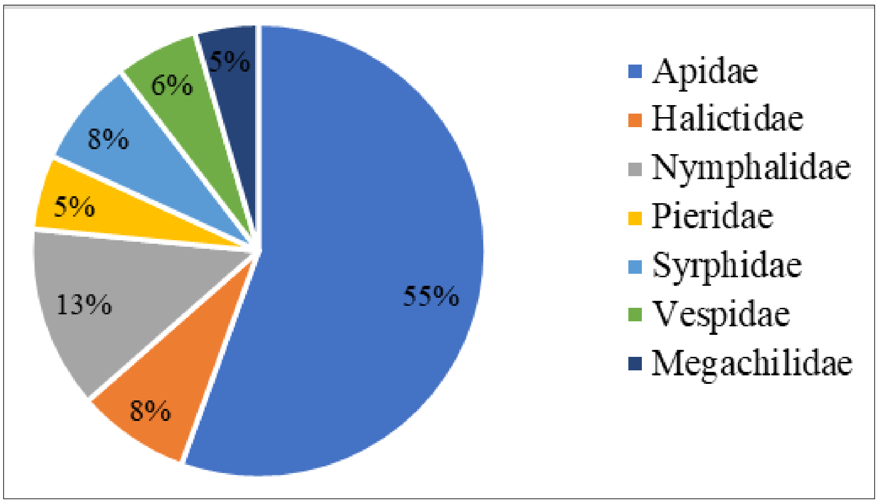

Fig 1: Family-Wise Percentage Composition of Insect Pollinators on Radish *(Raphanus sativus L.)*

Fig 2: Diversity of insect pollinators observed visiting flowers of Radish *(Raphanus sativus L.)*

Conclusion

The study showed that Hymenoptera mainly the family Apidae and species of *Apis* were the most important insect pollinators in terms of species number and abundance. This observations confirmed their major role in maintaining pollination in the study area. The diversity indices indicated good species diversity and even distribution among pollinators which suggests a fairly stable ecosystem even though a few species were more common. The presence of dipteran and lepidopteran pollinators along with bees shows the importance of maintaining functional diversity in the ecosystem. Such type of diversity helps the ecosystem remain stable and supports continuous pollination even under changing environmental conditions.

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