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Studies on species composition, diversity of insect visitors of *Luffa cylindrica* (Roem.) L. in the Gangapur City, Rajasthan, India

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Abstract
Insect pollinators play a crucial role in the reproductive success of entomophilous crops like *Luffa cylindrica* (sponge gourd), a nutritionally and economically significant cucurbit cultivated across tropical and subtropical regions. This study aimed to assess the composition, abundance, and diversity of insect pollinators visiting *L. cylindrica* flowers in a semi-arid agroecosystem in Udai Kalan, Gangapur City, Rajasthan. A total of 14 insect species were recorded across three orders: Hymenoptera, Diptera, and Lepidoptera. Hymenoptera emerged as the most dominant order, with the family *Apidae*, particularly *Apis dorsata*, *Apis florea*, and *Xylocopa fenestrata*, contributing the highest pollinator activity. Secondary pollinators, including *Campsomeriella spp.*, *Musca domestica*, and several butterfly species, were also observed, indicating a supportive role in pollination. Diversity indices revealed a well-structured pollinator community with a Simpson's Index of 0.9117, Shannon–Wiener Index of 2.5338, and Pielou's Evenness Index of 0.9616, suggesting high species richness and an even distribution. Floral traits and climatic factors, especially morning temperatures and humidity, influenced visitation patterns. The findings confirm the dependence of *L. cylindrica* on a diverse assemblage of insect pollinators for successful fruit set. This study emphasizes the importance of conserving native pollinator communities through sustainable agricultural practices. It also provides baseline data essential for future research and strategies aimed at enhancing pollination services in cucurbit cultivation.

Keywords: *Apidae, Calliphoridae, Cucurbitaceae,* Pollination

Introduction

Insects represent the most diverse group of organisms on Earth, with an estimated 5.5 million species, of which only about one million have been formally described (Stork, 2018) [10]. They are integral to ecosystems, performing vital roles such as pollination, nutrient cycling, decomposition, and natural pest control (Berenbaum, 2000; Losey and Vaughan, 2006) [1]. Among these roles, pollination is particularly critical, with insects facilitating the reproduction of approximately 87.5% of all flowering plants (Ollerton *et al*., 2011) [8]. Bees, butterflies, beetles, flies, and moths serve as key pollinators, with bees, particularly *Apis mellifera* and wild bee species, considered the most efficient due to their foraging behavior and floral fidelity (Garibaldi *et al*., 2013) [3]. Despite their ecological and agricultural importance, insect populations are in global decline due to habitat loss, pesticide use, climate change, pollution, and disease (Hallmann *et al*., 2017; Potts *et al*., 2016) [4, 9]. This decline threatens biodiversity and food security, highlighting the urgency for conservation strategies such as pollinator-friendly habitats and reduced pesticide use.

The pollination biology of *Luffa cylindrica* (Roem.) L., commonly known as sponge gourd, reflects the importance of insects, especially bees. This economically and nutritionally valuable crop is grown widely in tropical and subtropical regions and is rich in dietary fibre, vitamins A and C, minerals, and antioxidants. It relies on biotic, entomophilous pollination due to its large, yellow, unisexual flowers that attract various insect species. These include *Apis cerana*, *Apis dorsata*, *Xylocopa* spp., butterflies, flies, and beetles, with bees being the most efficient pollinators due to their frequent foraging and effective pollen transfer.

Insect visitation patterns are influenced by floral traits such as colour, fragrance, flower position, and nectar and pollen rewards—nectar being a high-energy carbohydrate source, and pollen a protein-rich food (Kachhawa *et al*., 2020) [5]. Pollinator activity typically peaks during early morning when flowers are fully open and nectar availability is highest. Studies show that insect-mediated pollination significantly increases fruit set, yield, and seed quality in *Luffa cylindrica*, with bee-pollinated plants outperforming those relying on self- or manual pollination (Divekar, 2024) [2]. Conservation efforts promoting sustainable farming and preserving insect diversity are therefore essential for maintaining productivity.

Additionally, insights from related crops like *Tagetes erecta* (Mexican marigold) show that species such as *Apis dorsata* possess high pollination indices, further underscoring the value of native bee species in enhancing pollination services (Kachhawa *et al*., 2020) [5].

Material and methods

a. Study area

The study was conducted in Udai Kalan, Gangapur City, Rajasthan, characterized by a semi-arid climate. Vegetation includes xerophytes and crops. Foraging activity increased with temperature and declined with humidity. Observations showed peak flower visitation from morning to noon, influenced by climatic conditions.

b. Floral biology of sponge gourd

Staminate and pistillate flowers of sponge gourd were examined under a stereo microscope. Observations included floral whorls, ovary position, ovule number, and stamen structure. The analysis revealed key floral adaptations that facilitate cross-pollination through insect-mediated mechanisms.

c. In the Field

Bee species composition and their diurnal and seasonal activity on vegetable crops will be observed twice weekly using Olympus binoculars. Bee behaviour and pollination will be video recorded using a Canon EOS1200D. Bee visitation time will be recorded from 6:00 to 18:00 using a mobile stopwatch.

d. In the Laboratory

1. Spreading of Specimens

Collected specimens will be sorted taxonomically, pinned through the thorax, and stretched to expose key structures. After drying, they will be preserved in airtight entomological boxes for further examination and identification.

2. Identification of Bee Pollinators

Specimens will be examined under a stereo-zoom microscope using taxonomic keys, Camera Lucida, and micrometres. In ambiguous cases, electron microscopy will aid identification. Characters like genitalia and hidden sterna will be emphasized. Pollen load analysis will assess pollination efficiency, and data from field observations will be compiled and analyzed.

e. Diversity analysis

1. **Simpson index (D):** This index was used to estimate the probability of capturing various insect species during field sampling. It represents the sum of the square of the relative proportion of insect pollinator abundance in the ecosystem. When subtracted from 1, it is a calculation of the Simpson diversity index which is also known as the PIE (Probability of Interspecific Encounter). Simpson index was estimated by using the following formulas.

Simpson Index (D) = $\Sigma Pi si'$=1.2

Simpson Index of Diversity= 1-D

n= Number of insects species, Pi'= (n/N), ln= natural log

N=Total number of insects in sample, S= Total number of species in the sample

2. **Shannon index (H):** It is a measure of the diversity of the environment that contains the abundance and richness of species in a particular habitat that estimate the uncertainty in a set of data.

Shannon Index (H) $=-\Sigma \boldsymbol{PilnPisi}=\mathbf{1}$

n = Number of insect's species

N =Total number of insects in sample

Pi = (n/N), ln= natural log

3. **Pielou's evenness index (J):** It is defined as the index showing closeness of abundance of different species in an ecosystem. Its value is range from 0 to 1.

Pielou's evenness index (J) = H / ln S

Here, H = Shannon index, lnS = natural log of Species richness.

Table 1: Pollinator Diversity of Insects on *Luffa cylindrica* (Roem.) L.

S.N.	Insect pollinator	Family	Order	Relative abundance (Insects/ m^2)
1.	*Apis dorsata*	*Apidae*	Hymenoptera	8.6
2.	*Apis cerana*	*Apidae*	Hymenoptera	4.0
3.	*Apis Florea*	*Apidae*	Hymenoptera	5.2
4.	*Xylocopa fenestrate*	*Apidae*	Hymenoptera	4.3
5.	*Xylocopa aestuans*	*Apidae*	Hymenoptera	3.7
6.	*Amegilla zonata*	*Apidae*	Hymenoptera	2.3
7.	*Campsomeriella collaris*	Scoliidae	Hymenoptera	4.9
8.	*Campsomeriella annulata*	Scoliidae	Hymenoptera	3.4
9.	*Scoliidae spp.*	Scoliidae	Hymenoptera	2.5
10.	*Musca domestica*	Muscidae	Diptera	2.8
11.	*Lucilia sericata*	*Calliphoridae*	Diptera	1.37
12.	*Pyrisitia nise*	Pieridae	Lepidoptera	2.4
13.	*Danaus chrysippus*	Nymphalidae	Lepidoptera	1.9
14	*Thyrsus spp.*	Nymphalidae	Hymenoptera	3.1

Results

A total of 14 insect pollinator species belonging to five families across three insect orders, Hymenoptera, Diptera, and Lepidoptera, were recorded visiting *Luffa cylindrica* flowers (Table 1). The data reveal that Hymenoptera was the most dominant order, both in species richness and relative abundance, confirming its primary role in pollination. Within Hymenoptera, the *Apidae* family was the most prevalent, represented by six species. Among them, *Apis dorsata* exhibited the highest relative abundance (8.6 insects/m²), followed by *Apis florea* (5.2), *Xylocopa fenestrata* (4.3), *Apis cerana* (4.0), *Xylocopa aestuans* (3.7), and *Amegilla zonata* (2.3). These bees, particularly *Apis* and *Xylocopa* species, were observed making frequent and efficient visits to both staminate and pistillate flowers, indicating their critical role in the pollination process. The Scoliidae family, also under Hymenoptera, was represented by *Campsomeriella collaris* (4.9), *Campsomeriella annulata* (3.4), and unidentified *Scoliidae* spp. (2.5). Although not traditionally known as primary pollinators, their consistent flower visits suggest a supporting role in pollination, particularly under conditions where bee populations fluctuate. The Diptera order included *Musca domestica* (2.8) and *Lucilia sericata* (1.37), both known for their generalist feeding habits. While they are not efficient pollinators compared to bees, their moderate abundance and presence on flowers indicate potential as opportunistic or secondary pollinators. Lepidoptera was represented by three butterfly species: *Pyrisitia nise* (2.4), *Danaus chrysippus* (1.9), and *Thyrsus* spp. (3.1). Though butterflies typically have lower pollination efficiency due to their feeding style and low pollen loads, their repeated visitation contributes to the overall pollination network and may enhance genetic diversity through long-distance pollen transfer. Overall, the dominance of *Apis dorsata* and the diversity of other pollinators emphasize the significance of conserving a wide range of insect pollinators. The presence of both primary and secondary pollinators suggests a resilient pollination system, essential for optimal fruit set in *Luffa cylindrica*. These findings also highlight the importance of maintaining habitat diversity to support pollinator populations across seasons.

The diversity analysis of insect pollinators visiting *Luffa cylindrica* revealed a total of 14 species, with a cumulative relative abundance of 50.47 individuals per square meter (Table 2). The Simpson's Index of Diversity was calculated as 0.9117, indicating a high level of species diversity and a low probability of dominance by any single species. The Shannon–Wiener Index (H′) value of 2.5338 further supports the presence of a diverse pollinator community, reflecting both species richness and a balanced distribution. Additionally, the Pielou's Evenness Index was found to be 0.9616, suggesting a nearly uniform distribution of individuals among the recorded species. These results demonstrate that the pollinator assemblage on *Luffa cylindrica* is both diverse and evenly structured, with significant contributions from species such as *Apis dorsata*, *Apis florea*, *Xylocopa fenestrata*, and *Campsomeriella collaris*. The high diversity and evenness imply a stable and resilient pollination system, which is critical for maintaining effective pollination and consistent fruit set in this economically important crop. The relative abundance of insect pollinators belonging to six different families was assessed during the study period. Among these, members of the family *Apidae* were the most dominant, accounting for the highest proportion of individuals observed (Fig. 2). Scoliidae and Muscidae were also well represented, contributing moderately to the overall pollinator community. In contrast, *Calliphoridae*, Pieridae, and Nymphalidae exhibited comparatively lower abundance. This pattern indicates a clear dominance of *Apidae* in the pollinator assemblage, suggesting their key role in the pollination of the studied crop. The observed variation in family-level abundance reflects differences in foraging behavior, floral preferences, and activity periods among the insect taxa.

Table 2: Diversity analysis of insect pollinators on *Luffa cylindrica* (Roem.) L.

Species Richness (S):	**14**		
Sum of relative abundance (N):	50.47	$\sum Pi^2$ =0.088326	$\sum$PilnPi =-2.53376
Simpson Index (D): $\sum Pi^2$	$\sum Pi^2$ = 0.088326		
Simpson Index of Diversity: (1-D):	1-0.088326 = 0.911674		
Shannon Index (E): -$\sum$Pi*ln*Pi	-(-2.53376) = 2.53376		
Pielou's Eveness Index: E/ *ln* S	2.5376/ 2.6390 = 0.9616		

Fig 1: Pollinator Diversity of Insects on *Luffa cylindrical (Roem.) L.*

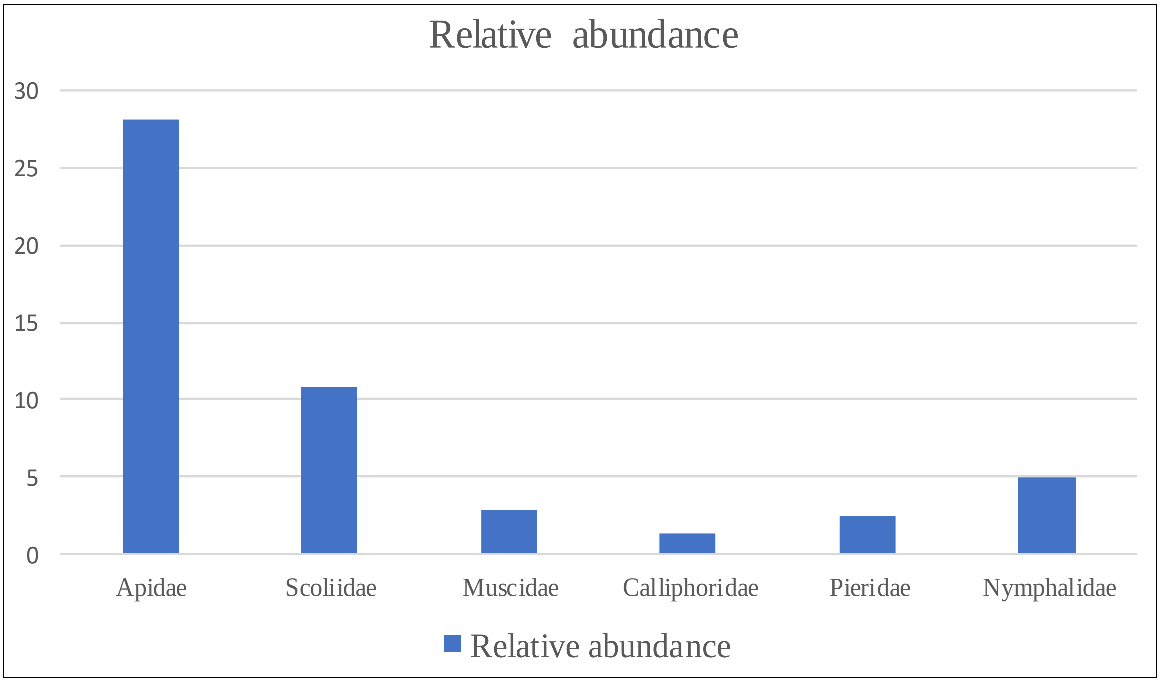

Fig 2: Relative abundance of insect pollinators on *Luffa cylindrical (Roem.) L.*

Discussion

The present study highlights the diversity, abundance, and ecological roles of insect pollinators visiting *Luffa cylindrica* flowers in a semi-arid agricultural landscape. A total of 14 pollinator species from three insect orders—Hymenoptera, Diptera, and Lepidoptera—were recorded, with Hymenoptera being the most dominant both in species richness and relative abundance. Within this order, the family *Apidae* exhibited clear dominance, particularly *Apis dorsata*, *Apis florea*, and *Xylocopa fenestrata*, confirming their primary role in pollination of *L. cylindrica*. These findings are consistent with previous reports emphasizing the efficiency of bees due to their foraging fidelity, high floral visitation rates, and effective pollen transfer mechanisms (Garibaldi *et al*., 2013) [3]. The high Simpson's Index of Diversity (0.9117) and Shannon–Wiener Index (2.5338) reflect a well-structured and resilient pollinator community. Furthermore, Pielou's Evenness Index (0.9616) suggests that no single species monopolized floral resources, indicating a balanced distribution of pollinator activity. Such diversity and evenness are beneficial for ecological stability, as they reduce the vulnerability of the pollination system to the decline or loss of any single species (Potts *et al*., 2016) [9]. Interestingly, the presence of non-bee pollinators such as *Campsomeriella spp.* (Scoliidae), *Musca domestica* (Muscidae), and butterfly species (*Danaus chrysippus*, *Pyrisitia nise*, *Thyrsus* spp.) suggests that a broader range of insect taxa contribute to pollination. While these species may not match the efficiency of bees, their consistent visitation indicates a supporting role, particularly under conditions where primary pollinator populations fluctuate due to climatic or anthropogenic factors. Similar patterns have been reported in other crops, where flies and butterflies act as secondary pollinators, enhancing genetic diversity through long-distance pollen dispersal. The floral morphology of *L. cylindrica*—including large, bright yellow, unisexual flowers with accessible nectar and pollen rewards—strongly attracts a range of diurnal pollinators. Peak activity was observed during the early morning hours, aligning with the time of maximal floral resource availability and favorable climatic conditions. These findings underscore the influence of floral traits and microclimate on pollinator behavior (Kachhawa *et al*. 2020) [5]. From an applied perspective, the dominance of native bee species such as *Apis dorsata* and *Xylocopa spp.* highlights the need for conserving natural habitats and nesting sites in and around agricultural fields. Practices such as reducing pesticide use, maintaining flowering hedgerows, and promoting polyculture can enhance pollinator presence and activity. These strategies are crucial not only for sustaining crop yields in *L. cylindrica*, but also for supporting broader agroecosystem resilience.

In conclusion, this study reaffirms the vital role of insect pollinators—especially wild bees—in the reproductive success of *Luffa cylindrica*. The high diversity and evenness of the pollinator community suggest a robust pollination system capable of sustaining fruit set even under variable environmental conditions. Conservation and management of pollinator diversity should therefore be prioritized to ensure the continued productivity and ecological balance of cropping systems that rely on biotic pollination.

Conclusion

This study documented the composition and abundance of insect pollinators associated with *Luffa cylindrica* in a semi-arid region of Rajasthan. A total of 14 insect species from three orders Hymenoptera, Diptera, and Lepidoptera were recorded visiting the flowers. Among these, Hymenoptera was the most dominant order in both species' richness and relative abundance. The *Apidae* family, particularly *Apis dorsata*, *Apis florea*, and *Xylocopa fenestrata*, accounted for the majority of pollinator activity, suggesting their central role in the pollination process. Diversity indices indicated a highly diverse and evenly distributed pollinator community, with no single species dominating the assemblage. These findings provide a detailed overview of the pollinator fauna contributing to the reproductive success of *L. cylindrica* under field conditions.

Significance

This study highlights the ecological relevance of diverse insect pollinator communities in supporting the reproductive success of *Luffa cylindrica*, an economically important cucurbit crop. The dominance of native bee species, particularly *Apis dorsata* and *Xylocopa spp.*, reinforces their critical role in ensuring effective pollination through frequent and targeted floral visits. The high species diversity and evenness observed in the pollinator assemblage indicate a resilient pollination system, capable of maintaining function despite fluctuations in individual species populations. Such a structure is vital for ecological stability, especially in agroecosystems vulnerable to climate variability, habitat degradation, and pesticide exposure. Furthermore, the presence of secondary pollinators such as flies and butterflies suggests redundancy in pollination services, which can act as a buffer during periods of bee decline. These findings provide a strong basis for advocating pollinator conservation strategies, such as preserving nesting habitats, minimizing chemical inputs, and promoting biodiversity-friendly farming practices. Understanding pollinator dynamics is essential not only for enhancing *L. cylindrica* yield but also for supporting broader efforts in sustainable agriculture and food security.

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