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A study of abundance and diversity of flower-visiting insects on marigold (*Tagetes erecta* L.) and sunflower (*Helianthus annuus* L.) at Rajshahi University Campus, Rajshahi, Bangladesh

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Abstract
Sunflowers and marigolds hold cultural and commercial significance while serving as important nectar sources for insects and contributing to ecosystem services. This study examined flower-visiting insect abundance, diversity and distribution in sunflower and marigold gardens at Rajshahi University Campus, Bangladesh. In sunflower gardens, we identified six orders, eight families, and twelve species of flower-visiting insects. Marigold gardens comprised six orders, eleven families, and fourteen species of insects. Hymenoptera (57.89%) and Diptera (45.71%) were the most abundant insect orders in sunflower and marigold, respectively. Apidae and Syrphidae were the predominant families in both gardens, with a combined share of 71.93% and 57.14% of the counted insects, respectively. The most dominant species was *A. dorsata* and *E. quinquestriatus* in sunflower and marigold garden, respectively. Notably, three species of flower-visiting insects were recorded as the most common visitors both in sunflower (*A. dorsata, A. cerana,* and *Eristalis* sp.) and marigold (*A. dorsata, Eristalis* sp., and *E. quinquestriatus*) gardens according to their abundance. Shannon's diversity index indicated medium biodiversity in both gardens (2.09 and 2.42), attributed to certain species' abundance. Additionally, both gardens exhibited high species richness (Menhinick index, 1.59 and 1.67) and similar individual distributions (Pielou's index, 0.84 and 0.92).

Keywords: *A. dorsata, Eristalis* sp., and *E. quinquestriatus*

Introduction
Pollination is an important ecosystem service that contributes to biodiversity preservation and ensures the survival of plant species, especially crop plants. Pollinators are critical to the ecosystem's and agriculture's long-term viability and continuity [1]. Insects pollinate over 80% of commercial crops [2], and bees, wasps, butterflies, moths, flies, and beetles are the most common insects among the pollinators [3]. More than 100 crop species provide 90% of the food supply in over 146 countries, and 71 are bee-pollinated, according to the Food and Agriculture Organization [4]. Around 85 percent of the world's flowering plant species rely on animals for pollination, the majority of which are insects [5], and the total annual economic value of crop pollination is estimated to be around $153 billion [6]. Any loss of biodiversity is a reason for concern. Still, the loss of pollinating insects could be especially problematic because of the possible consequences for plant reproduction and, thus food security. Many agricultural crops and natural plant populations rely on pollination, which is frequently provided by pollinator colonies that are wild and unmanaged [2, 7]. In Europe, there has been recent evidence of a 70% decline in insect-pollinated wildflowers in the United Kingdom and the Netherlands, as well as a shift in pollinator community composition since the 1980s. Habitat damage and land use intensification have been associated with pollinator reduction and loss of pollination services [8].

Tagetes erecta L. (African or American Marigolds), belonging to the family Asteraceae, are most common in the plant kingdom and known as Gada or Genda ful in Bangladesh. Marigolds are tall, erect-growing plants that can reach a height of three feet. The flowers are big and globe-shaped. Flowers can grow up to 5 inches in diameter. African marigolds are excellent bedding plants, and their flowers range in color from yellow to orange [9].

Thousands of bright yellow and orange *Tagetes* flowers are used in garlands to decorate religious statues and buildings in South Asia. They're also utilized as decorations and offerings during funerals, marriages, and other religious events. *Tagetes* are important for different pharmacological activities like antibacterial, antimicrobial, antioxidant, hepatoprotectivity, insecticidal, mosquitocidal, nematicidal, wound healing, analgesic, and larvicidal activity [10-15].

Sunflower (*Helianthus annuus L.)*, belonging to the family Asteraceae and known as Surjyamukhi in Bangladesh, has round flower heads that, in combination with the ligules, look like the sun [16]. Sunflowers are a relatively proven and good oil seed crop in Bangladesh. It is a potential source of high-quality edible oil and ranks second to soybeans as an oil crop worldwide. Sunflowers are usually tall annual or perennial plants that can reach a height of 300 cm (120 in) or more in some species. Each "flower" is actually a disc made up of microscopic flowers that come together to make a larger fake flower that attracts pollinators better. The seeds are used as a source of edible oil and chicken feed. It can be used to make vanaspati, a type of vegetable ghee, in place of groundnut oil. Insect pollinators play a crucial role in enhancing sunflower seed production [17]. There is no information available at this time about the diversity and abundance of insects that visit particular flowers in Bangladesh. This study examined the abundance and diversity of insects that visit flowers in the marigold and sunflower gardens on the Rajshahi University Campus, Rajshahi, Bangladesh.

Materials and Methods

The study was conducted in the flower garden of marigolds and sunflowers at Rajshahi University Campus, Rajshahi, Bangladesh. Rajshahi University is on a 305-hectare campus in Motihar, 3 kilometers from the Rajshahi city center. The geographical distribution of Rajshahi University is 24.37 latitude and 88.637 longitudes. Insect pollinators in marigold and sunflower were observed within the years 2021-2022. To observe insect pollinators, both marigold and sunflower gardens were divided into small plots, and the length and width of each plot were 7 meters and 2 meters, respectively. Ten plots were considered for both flowers. The selected plots were observed thrice a week from 11 a.m. to 1:30 p.m. for six weeks. The pollinators were monitored using mobile cameras and visual observation during the flowering stage. A sweep net was used to collect flower-visiting insects, and representatives of the insect species sampled were sorted out, pinned in a wooden insect box, preserved as dry specimens, observed under a microscope, and identified with the help of a dichotomous key and matching museum specimens. The species were identified and sorted by tallying their photographs with various booklets, guidelines, and literature papers [18-20]. The butterflies were identified using the booklet provided by ICIMOD [21]. Similarly, honeybees were identified by tallying their photographs with the guidelines given by Panthi [22]. The status of collected pollinators was divided into four categories influenced by Mahdi *et al.* [23-25]. The data was analyzed using Microsoft Excel Office 2019 and PAST 0.43 statistical software [26]. Relative abundance was calculated using the following formula [27]:

$$Relative\ Abundance\ (RA) = \frac{Number\ of\ individuals\ for\ a\ particular\ species}{Total\ captured\ individuals} \times 100$$

Different diversity indices were used to measure the diversity, dominance, richness, evenness, and relationship between individual and species numbers of the counted flower-visiting insects as follows.

Context	Index
Shannon Diversity Index [28]	$H' = -\sum_{i=1}^{S} p_i \ ln \ p_i$
Simpson Diversity Index [29]	$1 - D = \sum_{i=1}^{S} p_i^2$
Menhinick Richness Index [30]	$D_{Mn} = \frac{S}{\sqrt{N}}$
Pielou's Index [31]	$J' = \frac{H'}{H_{max}}$
Fisher's Diversity Index [32]	$S = \alpha \ln (1 + \frac{N}{\alpha})$
Buzas and Gibson's Evenness Index [33]	$E = e^H/S$

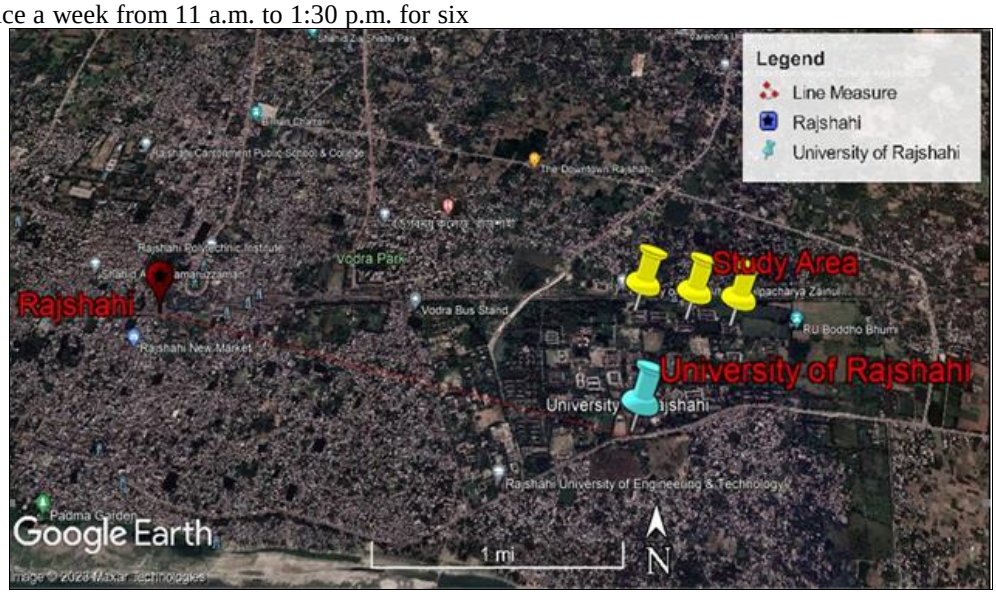

Fig 1: Map showing the study area at the University of Rajshahi, Rajshahi, Bangladesh

Result

During the survey, we recorded six orders, eight families, and twelve species of flower-visiting insects in the sunflower garden and six orders, eleven families, and fourteen species in the marigold garden (Table 1, 2). The most dominant species was *A. dorsata* in the sunflower garden (Table 1). In the marigold garden, the most dominant species was *E. quinquestriatus* (Table 2). Notably, honey bees and hoverflies (*A. dorsata, A. cerana, Eristalis* sp., *and E. quinquestriatus*) were prevalent in both gardens. We recorded three species of flower-visiting insects as the most common visitors both in sunflower (*A. dorsata, A. cerana, and Eristalis sp.*) and marigold (*A. dorsata, Eristalis* sp., *and E. quinquestriatus*) gardens according to their abundance. Additionally, we recorded two flower-visiting insect species as fairly common visitors in the sunflower garden and four in the marigold garden. The numbers of the least common visitor insect species were seven and six in sunflower and marigold gardens, respectively. *Apis cerana* was the only common visitor insect in the marigold garden (Table 1, 2).

Table 1: Relative abundance and status of flower-visiting insects belonging to different insect orders and families on sunflowers. Status: MCV, Most Common Visitor (> 9 sightings); CV, Common Visitor (6-9 sightings); FCV, Fairly Common Visitor (3-5 sightings); LCV, Least Common Visitor (1-2)

Order	Family	Name of Species	No. of Individuals (Mean of 10 plots) (7m×2m)	Relative Abundance (RA%)	Status
Hymenoptera	Apidae	*Apis dorsata*	15	26.32	MCV
		A. cerana	10	17.54	MCV
		Xylocopa latipes	4	7.02	FCV
	Vespidae	*Vespa velutina*	4	7.02	FCV
Diptera	Syrphidae	*Eristalis sp.*	12	21.05	MCV
Lepidoptera	Nymphalidae	*Danaus chrysippus*	2	3.51	LCV
		D. plexippus	1	1.75	LCV
	Papillionidae	*Papilio polymnestor*	2	3.51	LCV
Hemiptera	Pyrrhocoridae	*Dysdercus cingulatus*	2	3.51	LCV
Coleoptera	Coccinellidae	*Harmonia sp.*	2	3.51	LCV
		Exochomus sp.	2	3.51	LCV
Odonata	Gomphidae	*Ictinogomphus rapax*	1	1.75	LCV
6	8	12	57	100.00	

Table 2: Relative abundance and status of flower-visiting insects belonging to different insect orders and families on marigolds. Status: MCV, Most Common Visitor (> 9 sightings); CV, Common Visitor (6-9 sightings); FCV, Fairly Common Visitor (3-5 sightings); LCV, Least Common Visitor (1-2 sightings)

Order	Family	Name of Species	No. of Individuals (Mean of 10 plots) (7m×2m)	Relative Abundance (RA%)	Status
Hymenoptera	Apidae	*Apis dorsata*	11	15.71	MCV
		A. cerana	7	10.00	CV
	Vespidae	*Vespa velutina*	4	5.71	FCV
Diptera	Syrphidae	*Eristalis quinquestriatus*	12	17.14	MCV
		Eristalis sp.	10	14.29	MCV
	Calliphoridae	*Pollenia sp.*	5	7.14	FCV
	Muscidae	*Musca domestica*	5	7.14	FCV
Lepidoptera	Nymphalidae	*Danaus chrysippus*	4	5.71	FCV
		D. plexippus	2	2.86	LCV
	Pieridae	*Catopsilla florella*	2	2.86	LCV
Hemiptera	Pyrrhocoridae	*Dysdercus cingulatus*	2	2.86	LCV
Coleoptera	Coccinellidae	*Exochomus sp.*	2	2.86	LCV
Odonata	Libellulidae	*Libellula sp.*	2	2.86	LCV
	Gomphidae	*Ictinogomphus rapax*	2	2.86	LCV
6	11	14	70	100.00	

The most abundant flower-visiting insect order was Hymenoptera in the sunflower garden, which shared (57.89%) over half of the total counted individuals (Fig 2). In contrast, Diptera (45.71%) shared almost half of the total counted individuals in the marigold garden and was determined to be the most dominant order among the counted taxa (Fig 2).

Diptera was the second largest order, sharing 21.05% of individuals in sunflower, while Hymenoptera shared 31.42% of individuals in marigold as the second largest order. Odonata and Hemiptera were the least dominant taxa in both study sites (Fig 2).

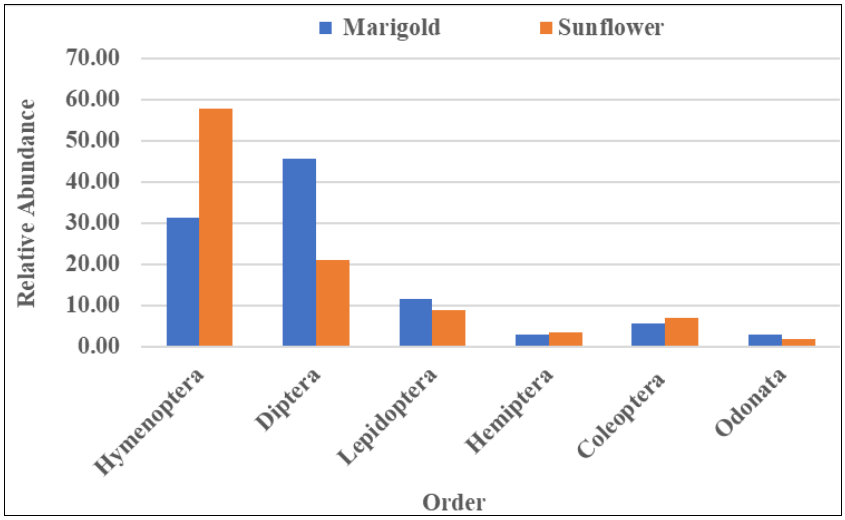

Fig 2: Order-wise relative abundance of flower-visiting insects on marigolds and sunflowers in Rajshahi University Campus.

Regarding the overall collection of flower visitors, no significant difference was recorded between the selected gardens (P = 0.46) (Table 3). In terms of order, between the two flower gardens, we found no significant differences in the number of flower-visiting insects in Hymenoptera (P = 0.21) and Hemiptera (P = 0.34). However, significant differences were detected in the following taxa: Diptera (P = 0.0009), Lepidoptera (P = 0.05), Coleoptera (P = 0.008), and Odonata (P = 0.009) (Table 3).

Table 3: T-Test (two samples assuming equal variances) shows the order-wise differences in the number of flower-visiting insects between sunflower and marigold (s = significant, ns = not significant)

Context	*P*-value
Hymenoptera (Sunflower vs. Marigold)	0.21^{ns}
Diptera (Sunflower vs. Marigold)	0.0009^{s}
Lepidoptera (Sunflower vs. Marigold)	0.05^{s}
Hemiptera (Sunflower vs. Marigold)	0.34^{ns}
Coleoptera (Sunflower vs. Marigold)	0.008^{s}
Odonata (Sunflower vs. Marigold)	0.009^{s}
Sunflower vs. Marigold (overall)	0.46^{ns}

During the study period, we observed that Apidae (50.88%) and Syrphidae (21.05%) shared over two-thirds of individuals in the sunflower garden, while they (Apidae 25.71% and Syrphidae 31.43%) shared about 60% of individuals in the marigold garden among the observed taxa. Pieridae, Pyrrhocoridae, Coccinellidae, Libellulidae, and Gomphidae were the least common families, and each of the taxa shared 2.86% of individuals in the marigold garden, while Gomphidae shared 1.75% of individuals in the sunflower garden as the least common family (Fig 3).

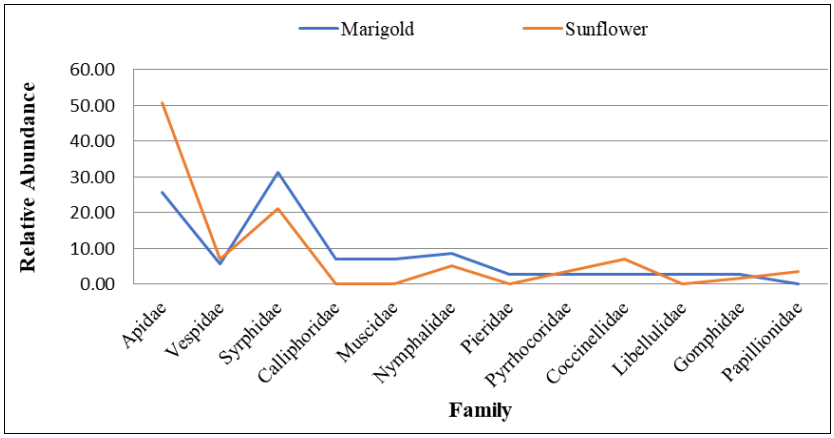

Fig 3: Faily-wise relative abundance of flower-visiting insects on marigolds and sunflowers in Rajshahi University Campus.

Simpson's (1-D) index had values of 0.84 and 0.89 and equitability_J (Pielou's index) of 0.84 and 0.92 in sunflower and marigold gardens, respectively, indicating a similar distribution of individuals. The values of Shannon's diversity

index (2.09 and 2.42) showed that both flower gardens had medium biodiversity. Species richness was high according to the observed values of the Menhinick index (1.59 and 1.67) in both flower gardens. The values of Fisher's alpha in sunflower (4.64) and marigold (5.26) gardens revealed the perfect relationship between the number of species and total individuals (Fig 4).

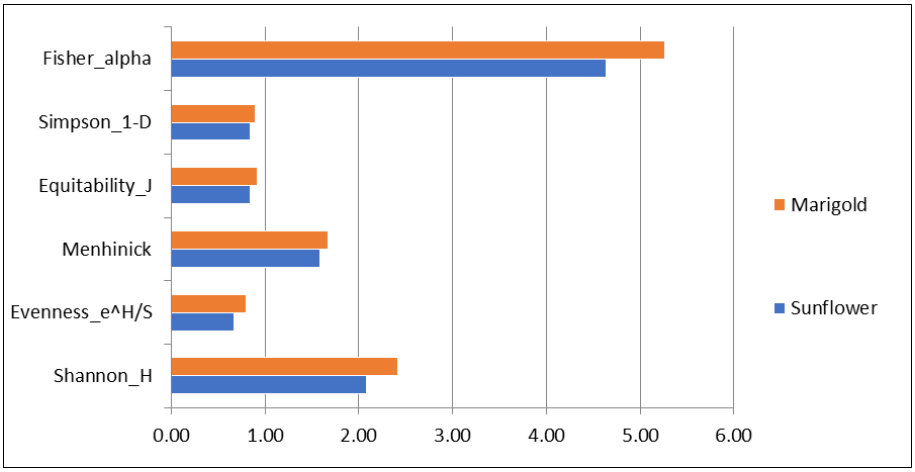

Fig 4: Values of different diversity indices of flower-visiting insects on marigolds and sunflowers in Rajshahi University Campus.

Discussion

Observations made on sunflowers and marigolds revealed that six orders of flower-visiting insects were recorded, which were as follows: Hymenoptera, Diptera, Lepidoptera, Hemiptera, Coleoptera, and Odonata. Hymenoptera (57.89%) dominated the sunflower, while Diptera (45.71%) dominated the marigold, and together they accounted for nearly two-thirds of the total insects in both flower gardens. On the other hand, Odonata and Hemiptera were the least dominant taxa in both study sites. Mattu and Nirala [34] conducted their study on insect pollinators on apple crops and recorded Hymenoptera and Diptera as the most dominant taxa. Hymenoptera and Diptera were also found to be the most abundant taxa by Dubey *et al.* [35], sharing about 85% of individuals among the recorded taxa in the litchi garden. Hennig and Ghazoul [36] and Baldock *et al.* [37] found the highest abundance of Diptera in marigolds, which supports our finding.

Based on our findings, it is suggested that Apidae was the most abundant family in the sunflower and Syrphidae in the marigold garden, and together they shared about 72% and 57% of the recorded individuals in the selected gardens, respectively. Jadhav *et al.* [38] showed Apidae as the most frequent visitors (88.85%) while studying the flower-visiting insects on sunflowers, which validate our findings. Another study by Orford *et al.* [39] revealed the attraction of Syrphidae to yellow flowers and showed the high abundance of insects belonging to this family in marigold flowers. They also found that the Syrphidae's pollen load was not significantly different from that of Hymenoptera, which clearly suggests that the Dipteran groups are just as crucial for efficient pollination as Hymenoptera.

During this study, it was recorded *A. dorsata*, *A. cerana*, and *Eristalis* sp. were the most common visitor insect species in the sunflower garden, where *A. dorsata*, *Eristalis* sp., *and E. quinquestriatus* in the marigold garden according to their abundance. Additionally, we recorded six least common visitor insect species in sunflower and seven least common visitor species in marigold gardens. During the study on flower-visiting insects in sunflowers, Jhadav *et al.* [38], Satyanarayana and Seetharam [40] and Moreti *et al.* [41] documented major insect pollinators on sunflower capitula as *A. dorsata*, *A. cerana*, *A. florea*, *Milipona* sp., and *Xylocopa* sp., which conforms with our findings. The presence of floral incentives like attractive color, nectar guides, forage sources, and tripping efficiency can be linked to bee dominance. The current results are consistent with observations provided by Jhadav *et al.* [38] and Swaminathan and Bharadwaj [42], who identified *A. dorsata* as the most abundant bee species.

The study also discovered a significant difference between two flowers in the number of flower-visiting insects from various orders. They may favor the existence of floral incentives such as appealing color, flower size, nectar guidance, feed sources, and tripping efficiency, which may explain why there are differences. The Shannon's Diversity Index values showed that both sunflowers and marigolds have a medium diversity of insect visits. It might be because certain species were abundant on the Rajshahi University Campus during the sunflower and marigold blossoming periods.

Conclusion

The survey of flower-visiting insects in the sunflower and marigold gardens revealed no significant difference in the overall collection of flower visitors. However, distinct preferences were observed in terms of the dominant orders and families of flower-visiting insects in each garden. The findings highlight the importance of considering plant species and their specific attractiveness to different groups of flower-visiting insects in garden management and conservation efforts.

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