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Evaluation of pollinator diversity and relative abundance of native insect pollinators in apple orchards of Seraj valley in Himachal Pradesh: A preliminary study

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Abstract
A study was conducted to investigate the diversity and quantity of insect pollinators in the apple orchards of Seraj valley, HP. The current study comprised 56 insect pollinator species from 25 families, grouped into eight orders: Hymenoptera, Diptera, Lepidoptera, Coleopteran, Hemiptera, Neuroptera, Thysanoptera, and Orthoptera. Overall, the study region had the highest abundance of 1127 individuals (*Apis cerana*, *Apis mellifera*, and *Ceratina* sp.), accounting for 76% of the family contribution. The most prevalent orders were Hymenoptera, Diptera, and Lepidoptera, with 18, 17, and 11 species, respectively, whereas Hemiptera, Thysanoptera, and Neuroptera had only one species in each. Pollinator diversity did not differ significantly amongst species caught using sweep net methods. Muscidae has the highest pollinator diversity (0.59/5 sweeps), followed by Halictidae (0.52/5 sweeps), Syrphidae (0.51/5 sweeps), and Bibionidae (0.30/5 sweeps). The family apidae (*Apis mellifera* and *Apis cerana*) was found to be the most prominent in apple orchards (4.08/100 flowers), followed by the families syrphidae (3.41/100 flowers), halictidae (1.70), and tephritidae (1.51/100 flowers). Insect visitors sampled using several sampling methods demonstrated that for sampling pollinator diversity, all methods must be used together because no single method is completely reliable.

Keywords: Pollinators, diversity, abundance, apple, Himachal Pradesh

1. Introduction
Pollination is a necessary prerequisite for fertilization and fruit/seed set. If there is no pollination, there is no fertilization, and no fruits. It is estimated that approximately 85% of the world's flowering plant species rely on animals, primarily insects, for pollination (Ollerton *et al.*, 2011) [14], and the overall yearly economic worth of crop pollination worldwide is about $153billion (Gallai *et al.*, 2009) [4]. Pollination also benefits society by boosting food security and improving living conditions. Native insect pollinators (species of insects that are indigenous to a particular location) perform a vital but underestimated role in crop pollination. Bees are an extremely diversified group. A number of recent studies in agricultural systems imply that native bees play an essential role in crop pollination (*Kremen et al.*, 2002; Winfree *et al.*, 2007) [11, 22].
The apple has recently emerged as the most profitable temperate fruit crop in the Himalayan zone. Himachal Pradesh is well-known for producing apples not only in the country but also around the world, earning the nickname "Apple State". Apple production accounts for up to 60–80% of total household income in the districts of Kullu, Shimla, Kinnaur, and Mandi, as well as other temperate fruit growing areas of the Hindu Kush Himalayas (Partap and Partap, 2002) [16]. It accounts for around 48% of the total producing area and 78% of total fruit production. The annual production averages about 2.5 crore boxes. Despite an increase in the area planted with apples in recent years, apple yield per hectare has declined. To enhance apple production in the state, strategies must be modified and new inputs explored, such as making full use of underutilized and environmentally friendly resources like bee pollination (Mattu, 2017) [12].

Honeybees are the most significant pollinators in Himalayan apple orchards, accounting for the great majority of pollinating insects (Dag, 2008) [2]. However, little is known about the significance of various insect visitors, including honeybees, in pollination horticulture crops in India, particularly Himachal Pradesh (Raj *et al.*, 2012) [18]. Therefore, present investigation was conducted in order to know the diversity and relative abundance of different insect species visiting apple crop in Kullu hills of Western Himalaya.

2. Materials and Methods

During 2023, research was conducted in the Seraj Valley at the College of Horticulture and Forestry Thunag in Mandi, Himachal Pradesh. The diversity and abundance of insect visitors to apple blossoms were measured in the selected orchard using sweep net capture and scan sampling methods. Observations were conducted on three sunny days at the start, middle, and end of the bloom cycle. On three bright days, the number of insects that visited 100 flowers at the experimental site was counted for scan sampling reasons. The sampling was done by carefully moving between plants along a preset path. Insect visitation were counted by examining each blossom in order. Sweep net captures were obtained during transect walks amongst the ground plants. Five insect collection net sweeps were conducted at random five locations evenly spaced around the crop area. Both sampling procedures were observed at three different day hours (1000, 1200, and 1500 h): the start of bloom, full bloom, and the end of bloom. Data on insect pollinator diversity were merged in order and statistically analyzed to generate pollinator diversity indices, species richness, and evenness in each sampling method separately. The Shannon diversity index was calculated (Shannon, 1948) [20] using the following formula:

A) Diversity index (H) = -Σ (pi ln (pi)), where,
   pi =proportion of I^{th} species
   ln= natural logarithm
B) Richness (H max) = log of total number of groups/ species
C) Eveness (J) = H/H max
D) Dominance (D) = 1-J

Insect visitors collected via various sampling methods were separated into eight groups based on their order distribution, namely Hymenoptera, Diptera, Lepidoptera, Coleoptera, Hemiptera, Neuroptera, Thysanoptera, and Orthoptera (Table 1). The Simpson diversity index was calculated using the following formula

$$\text{Diversity index (D)} = \frac{1}{-\Sigma\, pi^2}$$

In the Simpson index,
p is the proportion (n/N) of individuals of one particular species found (n) divided by the total number of individuals found (N),
Σ is still the sum of the calculations, and s is the number of species.

3. Results and Discussion

3.1 Diversity of insect pollinators in the apple orchards

Insect visits were collected from the apple orchard using various sampling methods (scan sampling and sweep nets). The current study included 56 insect pollinator species from 25 families. Apple orchards were generally represented by eight orders: Hymenoptera, Diptera, Lepidoptera, Coleopteran, Hemiptera, Neuroptera, Thysanoptera, and Orthoptera (table 1). The order Hymenoptera includes ten families: Apidae, xylocopidae, Bombidae, Megachilidae, Helictidae, Scolidae, Tenthredinidae, Vespidae, Sphecidae, and Ichneumonidae. The order Diptera included five families: Syrphidae, Tephritidae, Calliphoridae, Bibionidae, and Muscidae. The Lepidoptera order includes Pieridae, Arctiidae, Nymphalidae, and Noctuidae. The Orthoptera order represents two families. Tettigonidae & Acrididae. The remaining orders belong to one family. Similar to our findings Hussain *et al*. (2012) [7] found that 9 insect species in five genera belonged to the order Hymenoptera based on rank abundances, while Ganie *et al*. (2014) [5] discovered 21 insect pollinators from 12 families and three orders, Hymenoptera, Diptera, and Lepidoptera, in various apple orchards in the Kashmir valley. Overall, maximum abundance of 1127 individuals (*Apis cerana*, *Apis mellifera*, and *Ceratina*) was found in the studied area, which corresponded to a 76% family contribution, order hymenoptera and Dipterain the order of their respective dominance. Our findings are similarly consistent with those of Saeed *et al*. (2012) [19], who discovered that the pollinator population consisted of 15 insect species from three orders and ten families, with bees being the most abundant (435 individuals). Our findings are further supported by the findings of Abrol *et al*. (2005) [1] and Hulsmans *et al*., 2023 [6] who found that the order hymenoptera was the majority group throughout the examination. Syrphidae account for 54% of family contributions in the apple orchards investigated. The Bombidae and Xylocopidae families had the lowest abundance (2 individuals). The variation of abundance in percent family contribution among other groups (Table 1) followed the pattern: Megachilidae (4%), Halictidae (12%), Scolidae (2%), Tenthredinidae (1%), Vespidae (1%), Sphecidae (2%), Ichneumonidae (2%), Tephritidae (5%), Calliphoridae (11%), Bibionidae (17%), Muscidae (13%), Pieridae (28%), Arctiidae (37%), Nymphalidae (24%), Noctuidae (11%), Coccinelidae (34%), Pentatomidae (21%), Chrysopidae (16%), Thripidae (16%), Tettigonidae (6%) and Acrididae (7%).

3.2 Diversity and abundance of native insect pollinators

Overall, maximum abundance of family syrphidae (represented by *Episyrphus balteatus*, *Sphaerophoria indiana*, *Metasyrphus corolla*, *Scaeva*sp., *Eupeodes* sp., *Metasyrphus confrater*, *Ischiodon scutellaris*, *Eristalis* spp. Followed by family Arctidae and Apidae and least abundance was documented by the family Xylocopidae and Bombidae (contributed by a single species). In terms of species composition, Hymenoptera, Diptera, and Lepidoptera were the most dominating orders, accounting for 18, 17, and 11 species, respectively. while Hemiptera, Thysanoptera, and Neuroptera were the least prevalent, with only one species in each order (Table 1). Similar to our investigation Kaundal *et al.*, 2022 [10], Kaundal and Thakur, 2020 [9]; Raj *et al.* (2012 [18] also found Hymenopterans and Dipterans as the most predominant insect species on apple blossom. Park *et al*. (2012) [15] also noted a remarkable diversity of native bee species in the orchards, adding that native bees were particularly abundant in the apple orchards. Pollinators diversity showed no significant difference between species captured by sweep net methods. Highest pollinator diversity was recorded in family Muscidae (0.59/ 5 sweeps) followed by the family Halictidae (0.52/ 5 sweeps) syrphidae (0.51/ 5 sweeps) and Bibionidae (0.30/ 5 sweeps). The range of different insect visitors lies between 0.01 (Xyclocopidae and scolidae) to 0.59 / 5 sweeps (Halictidae). Abundance of insect visitors was recorded by scan sampling methods revealed that (Figure 6) family apidae (*Apis mellifera* and *Apis cerana)* was dominant in Apple orchard 4.08/100 flowers followed by family syrphidae (3.41 / 100 flower) halictidae (1.70) and tephritidae (1.51 / 100 flower).

Table 1: List of insects collected by different sampling methods

Order	Family	Scientific Name	Percent family Population contribution	Percent Order Population contribution
Hymenoptera	Apidae	*Apis mellifera*	76%	59%
		Apis cerana		
		Ceratina sp.1		
		Ceratina sp.2		
	Xylocopidae	*Xylocopa* sp.	0%	
	Bombidae	*Bombus* sp.*1*	0%	
		*Bombus*sp.*2*		
	Megachilidae	*Megachile* sp.	4%	
	Halictidae	*Halictus* sp.	12%	
		Lasioglossum sp.		
		Sphecodes sp.		
	Scoliidae	*Scolia* sp.1	2%	
		Scolia sp. 2		
	Tenthredinidae	*Athalia sp.*	1%	
	Vespidae	*Vespa* sp.1.	1%	
		Polistes sp.		
	Sphecidae	*Sphex* sp.	2%	
	Ichneumonidae	*Megarhyssa* sp.	2%	
Diptera	Syrphidae	*Episyrphus balteatus*	54%	
		Sphaerophoria indiana		32%
		Metasyrphus corolla		
		Scaeva sp.		
		Eupeodes sp.		
		Metasyrphus confrater		
		Ischiodon scutellaris		
		Eristalis sp.1		
		Eristalis sp.2		
	Tephritidae	*Bactrocera* sp.1	5%	
		Bactrocera sp.2		
	Calliphoridae	*Chrysomya megacephala*	11%	
		Caliphora sp.		
	Bibionidae	*Bibio* sp.	17%	
		Plecia sp		
	Muscidae	*Musca* sp.	13%	
		Musca domestica		
Lepidoptera	Pieridae	*Colias electo musina*	28%	
		Colias sp.		3%
		Delias sp.		
		Pieris brassicae		
		Pontia daplidice		
	Arctiidae	*Amata* sp.	37%	
	Nymphalidae	*Aglais* sp.	24%	
		Junonia sp.1		
		Danaus sp.		
		Vanessa sp.		
	Noctuidae	*Helicoverpa* sp.	11%	
Coleoptera	Coccinelidae	*Hippodamia variegata* (Goeze)	34%	
		Cheilomenes sexmaculata		
		Oenopia sp.		
		Coccinella septempunctata		2%
Hemiptera	Pentatomidae	*Nezara viridula*	21%	1%
		Bagrada sp.		
Neuroptera	Chrysopidae	*Chrysoperla carnea*	16%	1%
Thysanoptera	Thripidae	*Thrips* sp.	16%	1%
Orthoptera	Tettigonidae	*Neoconocephalus* sp.	6%	1%
	Acrididae	*Schistocerca americana*	7%	1%

3.3 Pollinator diversity indices computed for different methods of insect collection

To evaluate species diversity and relative abundance, four diversity indices were calculated: richness, evenness, Shannon-Weiner index, and Simpson index (Table 2). The pollinator diversity indices calculated for various methods of collection differed. Sweep net capture methods had higher pollinator diversity (1.23) than scan sampling (0.94). A total of 1937 and 570 insect visitors were recorded. The distribution of insect visits was consistent across different sampling methods (2.08). Sweep net capture (0.59) had a higher level of evenness among the eight groups of insect visitors than scan sampling (0.45). Approximately 55% of insect visitors were dominant among all insects captured in scan sampling. Sweep net methods dominated by 41 percent of insects.

Table 2: Shannon- Weiner Diversity Index computed for different methods of insect collection

Biodiversity Component	Result of Shannon- Weiner Diversity Index computed for different methods of insect collection	
	Scan Sampling	Sweep Net Capture
Diversity (H)	0.94	1.23
Maximum Diversity (H max)	2.08	2.08
Eveness (j)	0.45	0.59
Dominance (D)	0.55	0.41

Simpson Index

Mudri-Stojnic *et al*. (2012) [13] found similar results, reporting pollinator diversity indices ranging from 0 to 4.6. Various workers have also estimated different Shannon Weiner diversity index ranges (138). For example, the Shannon Weiner diversity index ranged from 2.262 to 2.945 for hymenopterans pollinating Himalayan foothills (Hussain *et al.*, 2012) [7], and from 1.478 to 2.653 for Hymenoptera and Diptera in semi-natural settings (Mudri-Stojnic *et al.*, 2012) [13].

The Simpson index is a dominance index since it prioritizes common or dominant species. In this situation, a few uncommon species with a small number of representatives have no effect on diversity. Simpson's Index (D) is calculated using the number of species and their relative dominance. The determined Simpson index values for the scan and sweep net capture sampling methods were 0.49 and 0.36, respectively.

Table 3: Simpson's Diversity Index computed for different methods of insect collection

Biodiversity Component	Result of Simpson's Diversity Index computed for different methods of insect collection	
	Scan Sampling	Sweep Net Capture
Simpson' s Diversity Index(D)	0.49	0.36
Dominance index(1-D)	0.51	0.64
Simpson's Reciprocal Index (1/D)	2.03	2.79

Insect visitors sampled by several sampling methods indicated that for sampling pollinator diversity, all approaches must be used together because no single method is completely reliable. Traps feature various recognized biases, including collecting less bumble bees and honeybees (Tolar *et al.*, 2005) [21]. Pan traps, on the other hand, are useful for catching little bee species that are sometimes missed during transect walks since they are inexpensive, dependable, and easy to operate (Devi, 2017) [3]. The study's findings show that maintaining a natural ecosystem suitable for native pollinators can secure the survival of these crucial native insects in apple orchards, resulting in large fruit set.

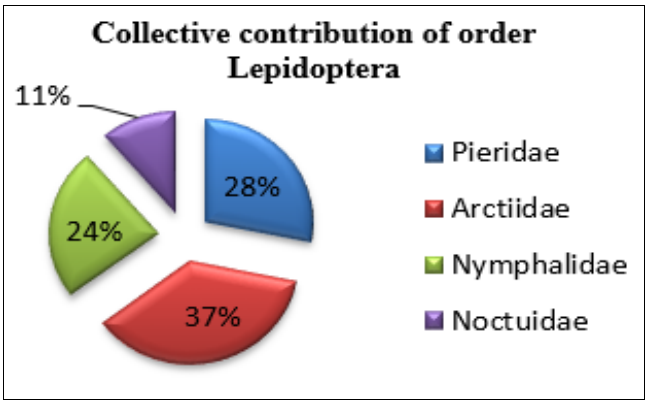

Fig 2: Diagrammatic illustration of the% species composition of order by different Sampling methods

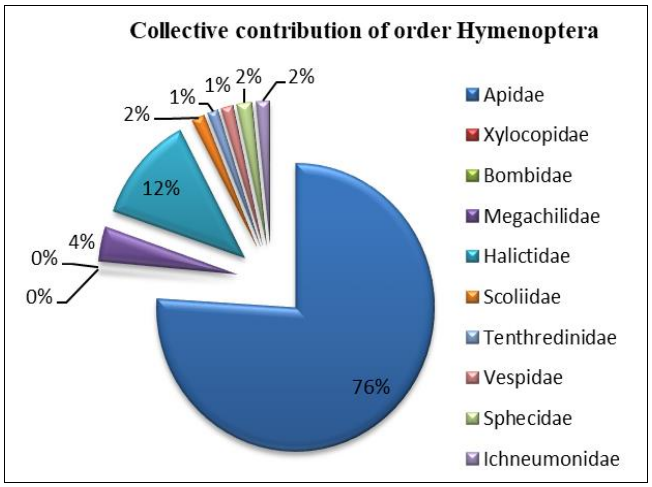

Fig 1: Diagrammatic illustration of the% species composition of order Hymenoptera by different sampling methods

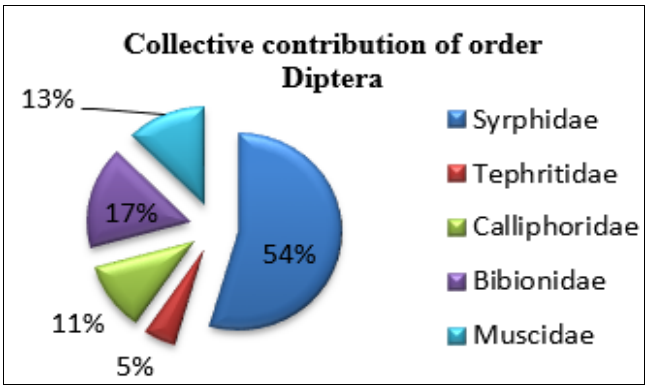

Fig 3: Diagrammatic illustration of the% species composition of order Dipteraby different sampling methods

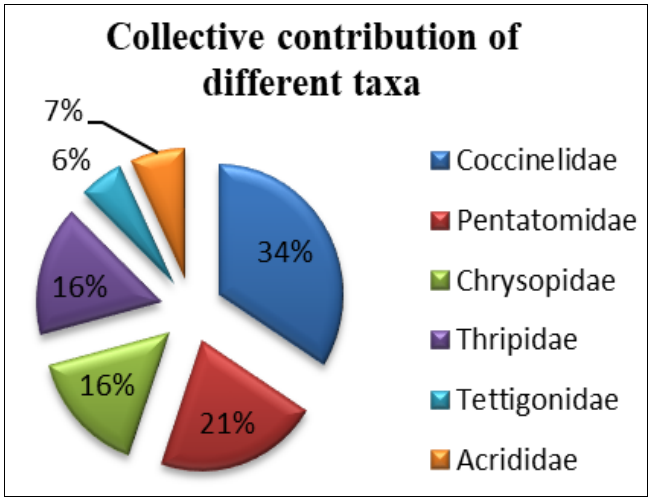

Fig 4: Diagrammatic illustration of the Collective contribution of different taxa

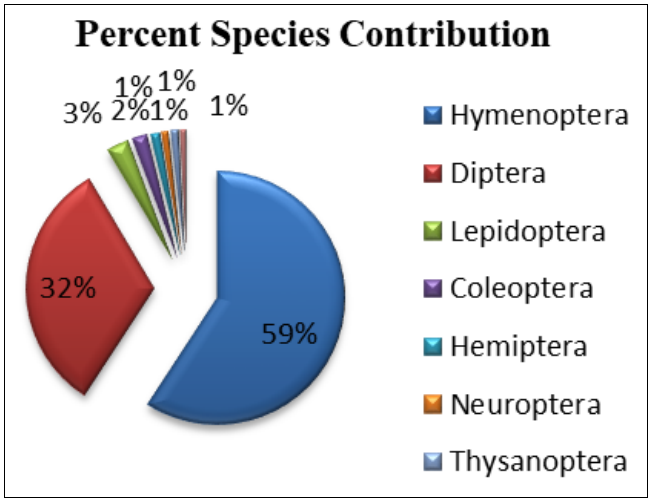

Fig 5: Diagrammatic representation of percent species composition of various taxa

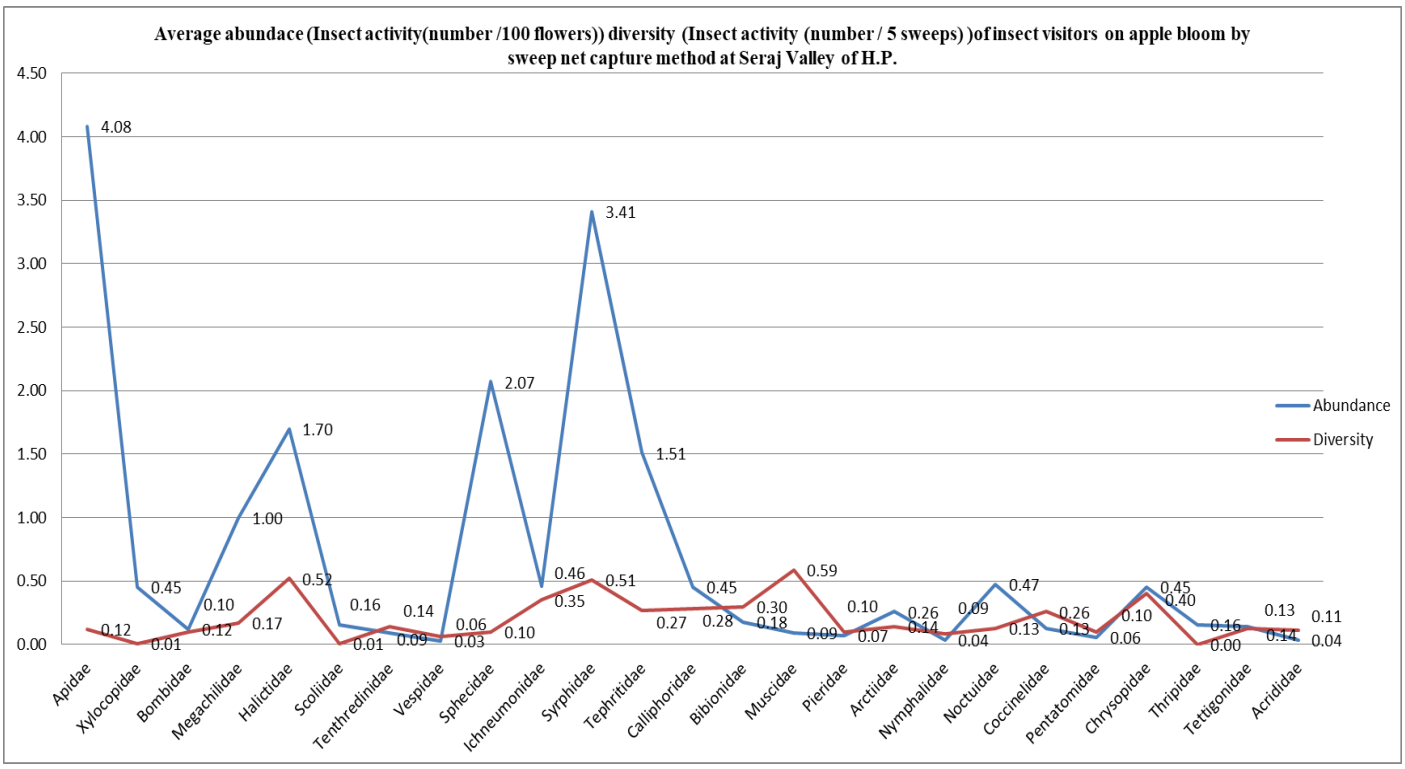

Fig 6: Average abundance (Insect activity (number /100 flowers)) and diversity (Insect activity (number / 5 sweeps)) of insect visitors on apple bloom by sweep net capture method at Seraj Valley of H.P

4. Conclusion

In conclusion, a significant number of insect visitors are observed visiting apple blooms, according to observations made on the diversity of insects using two different sampling techniques (scan sampling and sweep net). Hymenopteran pollinators were prevalent among diverse pollinators, with *A. cerana* and *A. mellifera* dominating apple bloom. Diptera and Lepidoptera were the most common orders, with 20 species apiece, whilst Hemiptera, Thysanoptera, and Neuroptera had only one species each. Insect abundance and diversity as demonstrated by many sampling methods are critical for determining pollinator diversity, as no single method is 100% reliable.

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