VOLUME 8 ISSUE 1 2022

ISSN 2454-3055

INTERNATIONAL JOURNAL OF ZOOLOGICAL INVESTIGATIONS

Forum for Biological and Environmental Sciences

Published by Saran Publications, India

International Journal of Zoological Investigations Vol. 8, No. 1, 24-31 (2022)

International Journal of Zoological Investigations
Contents available at Journals Home Page: www.ijzi.net
Editor-in-Chief: Prof. Ajai Kumar Srivastav
Published by: Saran Publications, Gorakhpur, India

ISSN: 2454-3055

Diversity and Abundance of Insect Pollinators in Orchards and Agricultural Ecosystems in Paharpani Nainital, Uttarakhand, India

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Received: 12th December, 2021; **Accepted:** 1st January, 2022; **Published online:** 6th January, 2022

https://doi.org/10.33745/ijzi.2022.v08i01.003

Abstract: Insect pollinators are important keys to success of the agro-ecosystems. This research aims to study diversity and abundance of insect pollinators in orchards and agricultural land uses. Study was carried out from March 2019 to February 2020 to explore the diversity of insect pollinators. Insect flower visitors/pollinators were recorded from 07.00 to 17.00 h. A total of 460 individuals belonging to 35 insect species and 5 orders viz. Lepidoptera, Hymenoptera, Coleoptera, Diptera and Hemiptera were collected from the study sites. The highest diversity of pollinators was (H'=2.24), Evenness (E=0.76; highest value is 1), margalef's Richness Index (d= 4.25), and Dominance Index (D=0.94). Higher foraging activities of insect pollinators occurred in the morning and afternoon. The present study focused on identifying pollinator species in orchards and agricultural ecosystems, and is expected to provide baseline information to plan future research in the field of pollination.

Keywords: Diversity, Abundance, Richness, Diversity indices, Pollinators, Orchards, Agricultural ecosystems

Citation: Arya Deeksha, Goswami Deepika, Rekha, Bisht Manisha, Arya Geetika and Kaushal B. Raj: Diversity and abundance of insect pollinators in orchards and agricultural ecosystems in Paharpani Nainital, Uttarakhand, India. Intern. J. Zool. Invest. 8 (1): 24-31, 2022.
https://doi.org/10.33745/ijzi.2022.v08i01.003

Introduction

Insects are the most dominating and diverse group of organisms occupying various types of ecosystems and perform many ecological functions (Sodhi *et al*., 2010). Slightly over one million of insect species have been described, of which five insect orders are the most abundant in their levels of species richness: Hymenoptera, Diptera, Coleoptera, Lepidoptera and Hemiptera (Jach and Balke, 2008).

Pollination is an essential regulating, supporting and cultural ecosystem service (Chagnon *et al*., 2015). Insect pollinators and flowering plants have mutual relationships. Interaction between plant and pollinator can help pollination, especially in plants that are self-incompatible (Aizen and Feinsinger, 2003). Pollinating services are provided by a wide range of organisms including birds, bats, other mammals and insects (Willmer *et al*., 1994; Buchmann and Nabhan, 1997; Allen- Wardel *et al*., 1998; Klein *et al*., 2007; Bhowmik *et al*., 2014; Siregar *et al*., 2016), with insects being the most common. Various insect groups which are of

prime significance in pollination of different agricultural, horticultural and herbal crops mainly belong to the insect orders Lepidoptera, Hymenoptera, Diptera, Coleoptera, Hemiptera, Thysanoptera and Neuroptera (Kearns *et al*.,1998; Mitra *et al*., 2008; Subedi and Subedi, 2019).

Although many studies on the diversity of pollinator insects of various crops have been carried out (Mitra and Parui, 2002; Pateel and Sattagi, 2007; Tara and Sharma, 2010; Bhowmik *et al*., 2014), very little information is available on insect pollinators of mountainous agro-ecosystems of Kumaun region.

The objectives of the present investigation was to explore the species richness, abundance, species diversity and foraging activities of insect pollinators of agro-ecosystems of mountainous areas of Uttarakhand, India.

Materials and Methods

Study area:

The present study was conducted in agricultural lands and fruit orchards located at Paharpani area (2044 masl, 29° 25'38N, 79° 42'41E) in Nainital district of Uttarakhand from March 2019 to February 2020.

Orchards- Fruits grown are: *Malus domestica* B., *Pyurus communis* L., *Prunus persica* (L.), *Prunus domestica* L., *Prunus americana* L. (Fig. 1).

Agricultural land- Crops grown are: *Brassica sinapis* L., *Coriandrum sativum* L., *Solanum tuberosum* L., *Cucumis sativus* L., *Pisum sativum* L., *Allium cepa* L., *Raphanus sativus* L., *Phaseolus vulgaris* L., *Capsicum annum* L. (Fig. 2).

Sampling and collecting of insects:

For collecting the insects, net sweeping method were used which have successfully been used by various workers (Jonathan, 1990; Arora, 1990; Ghosh, 1990). The collected insects were transferred into bottles containing ethyl acetate soaked cotton. All the specimens were brought to the laboratory for further studies. The specimens were stretched, pinned and oven dried at 60 C for 72 h and then set into wooden boxes and labeled. Sampling of insects was conducted regularly every month from March 2019 to February 2020.

Statistical Analysis:

Diversity indices were calculated:

(i) Shannon- Wiener equation (1949):

$$H'(S) = -\sum_{i=1}^{s} pi \log pi$$

Where, pi = fraction of entire population made up of species; S = total number of species; i = proportion of species

(ii) Evenness Index (Hill, 1973):

$$E = H/\ln S$$

Where, S = total number of species; H = Index of species;

(iii) Margalef's Index (Margalef,1970):

$$d = (S-1)/\ln N$$

Where, S = the total number of species; N = the total number of individuals in sample

(iv) Simpson Dominance index (1949):

$$D = 1-\Sigma n(n-1)/\Sigma N(N-1)$$

Where, n = the number of individuals of each different species; N = the total number of individuals of all the species.

Results and Discussion

Diversity and foraging activities of insects:

The pollinator insects of orchards and agricultural ecosystems included 460 individuals belonging to 35 species of 15 families and 5 insect orders (Table 1). Figure 3 shows some of the collected pollinators insect species. Among collected pollinator insects, Lepidoptera (19

Fig. 1: Orchards.

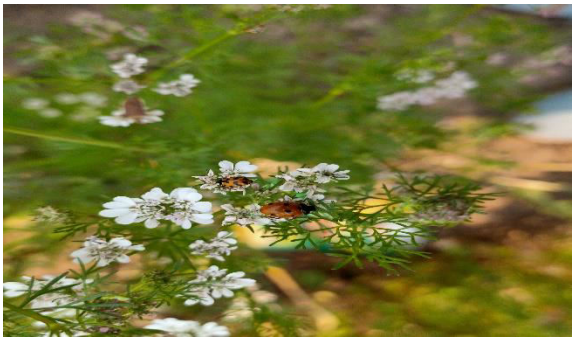
Fig. 2: Agricultural-land.

Table 1: Species richness and relative abundance (%) of insect fauna collected from the study area

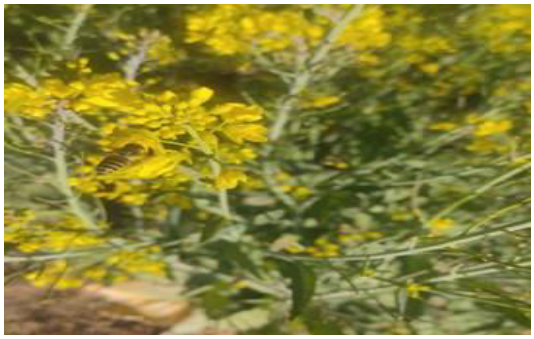
S. No.	Species	Common Name	No. of individuals	Relative abundance (%)
Order-Lepidoptera Family: Pieridae				
1.	*Pieris canidia indica* (Evans)	Indian Cabbage White	15	3.26
2.	*Gonepteryx rhamni nepalensis* (Doubleday)	Common Brimstone	8	1.74
3.	*Colias fieldii* (Menetries)	Dark Clouded Yellow	13	2.83
4.	*Aporia agathon* (Gray)	Great Blackvein	6	1.30
5.	*Pontia daplidice* (Linnaeus)	Bath White	8	1.74
Family: Lycaenidae				
6.	*Heliophorus androcles* (Doubleday and Hewitson)	Green Sapphire	12	2.61
7.	*Heliophorus sena* (Kollar)	Sorrel Sapphire	5	1.09
8.	*Dodona durga* (Kollar)	Common Punch	8	1.74
9.	*Lycaena pavana* (Kollar)	White-Bordered Copper	24	5.22
10.	*Pseudozizeeria maha* (Kollar)	Pale Grass Blue	9	1.96
11.	*Euchrysops cnejus* (Fabricius)	Gram Blue	4	0.87

Family: Nymphalidae				
12.	*Aglais cashmiriensis* (Kollar)	Indian Tortoiseshell	12	2.61
13.	*Acraea issoria* (Hubner)	Yellow Coster	7	1.52
14.	*Collerebia nirmala* (Moore)	Common Argus	5	1.09
15.	*Callerebia scanda* (Kollar)	Pallid Argus	8	1.74
16.	*Lasiommata schakra* (Kollar)	Common Wall	8	1.74
17.	*Ypthima inica* hewitson	Lesser Three Ring	5	1.09
Family: Papilionidae				
18.	*Papilio polytes* (Linnaeus)	Common Mormon	8	1.74
Family: Hespiridae				
19.	*Borbo bevani* Moore	Bevan's swift	6	1.30
Order- Hymenoptera Family: Apidae				
20.	*Apis mellifera* Linnaeus	Western honey bee	14	3.04
21.	*Apis dorsata* Fabricius	Giant honey bee	12	2.61
22.	*Apis cerana indica (Fabricius)*	Indian honey bee	18	3.91
23.	*Bombus ternarius* Say	Orange belted bumblebee	12	2.61
24.	*Bombus hypnorum* Linnaeus	The tree bumblebee	5	1.09
25.	*Xylocopa spp.* Linnaeus	Carpenter bee	3	0.65
Family: Vespidae				
26.	*Vespa mandarinia* Smith	Asian giant hornet	8	1.74
Order- Coleoptera Family: Coccinellidae				
27.	*Coccinella septumpnctata* (Linnaaeus)	Lady bird	90	19.57
28.	*Oenepia spp.* (Linnaeus)	Lady bird beetle	12	2.61
Family: Meloidae				
29.	*Mylabris spp.* (Linnaeus)	Blister beetle	20	4.34
Order- Diptera Family: Tachinidae				
30.	*Archytas spp.* (Walker)	Tachinid fly	5	1.09
Family: Syrphidae				
31.	*Syrphus spp.* (Linnaeus)	Hoverfly	30	6.52
Family: Asilidae				
32.	*Philodicus spp.* (Latreille)	Robber fly	12	2.61
Family: Muscidae				
33.	*Musca domestica* Linnaeus	Housefly	10	2.17
Order- Hemiptera Family: Lygaeidae				
34.	*Lygaeus spp.* Lucas	Black-and-Red-bug	30	6.52
Family: Pentatomidae				
35.	*Erthesina fullo* (Thunberg)	Yellow spotted stink bug	8	1.74
			460	**100**

species; 37.2% of total individuals) was the most abundant order followed by Hymenoptera (7 species, 15.7% of total individuals), Diptera (4 species, 12.4% of total individuals), Coleoptera (3 species, 26.5% of total individuals) and Hemiptera (2 species, 8.3% of total individuals). Five Lepidopteran families-- Pieridae (14.3%), Lycaenidae (17.1%), Papilionidae (2.9%),

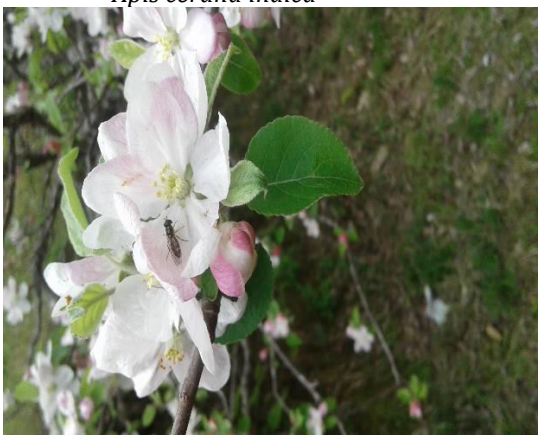


Coccinella septempunctata



Apis cerana indica

Aglais cashmiriensis



Syrphus spp.

Fig. 3: Some insects collected from the study site.

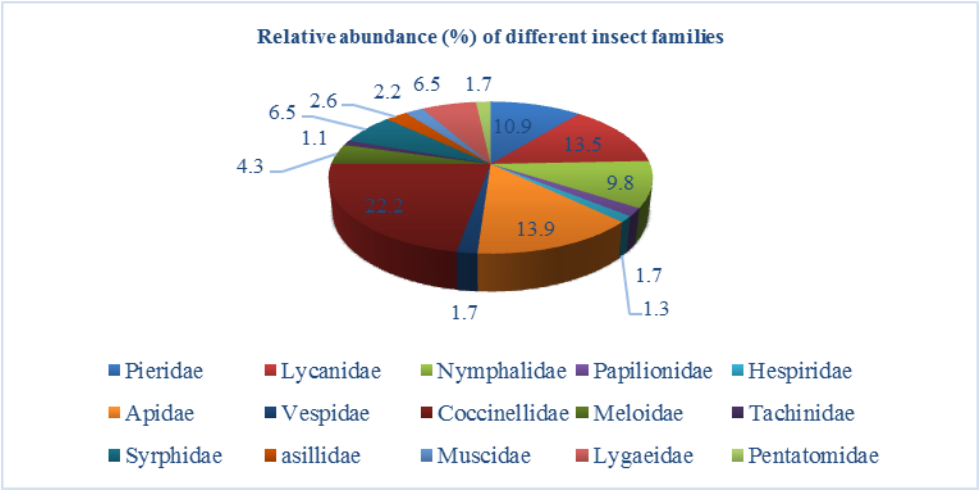


Fig. 4: Relative abundance of individuals (%) of different families.

Table 2: Number of species, abundance and relative abundance (%) of different insect orders and their families

S. No.	Order	Family	No. of species	Relative abundance (%)	No. of individuals	Relative abundance (%)
1.	Lepidoptera	Pieridae	5	14.3	50	10.9
		Lycaenidae	6	17.1	62	13.5
		Nymphalidae	6	17.1	45	9.8
		Papilionidae	1	2.9	8	1.7
		Hesperiidae	1	2.9	6	1.3
2.	Hymenoptera	Apidae	6	17.1	64	13.9
		Vespidae	1	2.9	8	1.7
3.	Coleoptera	Coccinellidae	2	5.7	102	22.2
		Meloidae	1	2.9	20	4.3
4.	Diptera	Tachinidae	1	2.9	5	1.1
		Syrphidae	1	2.9	30	6.5
		Asilidae	1	2.9	12	2.6
		Muscidae	1	2.9	10	2.2
5.	Hemiptera	Lycgaeidae	1	2.9	30	6.5
		Pentatomidae	1	2.9	8	1.7
			35	100	460	100

Table 3: Diversity indices of insect pollinators

Months	Species Richness (S)	Abundance (N)	Relative Abundance (%)	Shannon Index (H')	Evenness (E)	Margalef's Index (d)	Dominance Index (D)
March	4	14	3.2	0.56	0.40	1.14	0.78
April	13	99	22.9	1.95	0.76	2.61	0.81
May	10	43	10.0	1.42	0.62	2.39	0.90
June	13	74	17.1	1.59	0.62	2.79	0.91
July	4	26	6.0	1.39	1.00	0.92	0.70
August	5	26	6.0	1.61	1.00	1.23	0.78
September	20	87	20.1	2.24	0.74	4.25	0.94
October	12	50	11.6	1.27	0.51	2.81	0.92
November	3	7	1.6	0.00	0.00	1.03	0.76
December	2	6	1.4	0.69	1.00	0.56	0.53
January	0	0	0	0	0	0	0
February	0	0	0	0	0	0	0

Nymphalidae (17.1%) and Hespiridae (2.9%); two Hymenopteran families-- Apidae (17.1%) and Vespidae (2.9%); two Coleoptera families-- Coccinellidae (5.7%) and Meloidae (2.9%), four Dipteran families-- Syrphidae (2.9%), Asilidae (2.9%), Muscidae (2.9%), and Tachinidae (2.9%); and two Hemipteran families-- Lycaeidae (2.9%) and Pentatomidae (2.9%) were recorded (Table 2; Fig. 4).

Among the recorded 35 species, all insects were found active throughout the day but peak foraging activity was different for different orders. Lepidopterans were active during afternoon and less active in the morning.

Hymenopterans and Dipterans were active during day time. Foraging activities of Coleopterans and Hemipteran insects remained relatively constant throughout the day in both agro-ecosystems.

Various studies have reported insect pollinators mainly belonging to the insect orders as recorded in the present study also (Free, 1993; Kearns *et al*., 1998; Das *et al*., 2018; Subedi and Subedi, 2019).

Diversity Indices:

Shannon Index of Diversity is considered to be the most complete measure of diversity because it takes into account both numbers of species richness and abundance of each species (Pepper, 1999). Evenness takes into account the distribution of species and their number across gradients, and Margalef's Richness Index indicates species richness.

The Shannon-Wiener Diversity Index (H'), Evenness (E), Margalef's Richness Index(d), and Dominance Index (D) were computed in relation to months and Relative Abundance (%) of individuals (Table 3).

Species diversity (H') varied from 0 to 2.24. Maximum species diversity (H'=2.24) was recorded in September, and minimum (zero) in January.

Evenness (E) returned high values (E=0.76; Maximum value is 1) indicating that no species was dominant in terms of abundance. Margalef's Richness Index returned high values (d=4.25) indicating high species richness in the study area. Dominance Index (D) varied from 0 to 0.94, and the values are reciprocal to Evenness Indices.

Diversity of insect pollinators fluctuates with season. Insect pollinators were abundant in spring, summer and rainy season but were absent in winter because of cold weather conditions.

The results obtained for Diversity Indices in the present study are comparable to other reported values for insect pollinators in different agro-ecosystems (Arya *et al*., 2014; Usha and John, 2015; Subedi and Subedi, 2019).

Conclusion

A total of 460 individuals belonging to 35 species of 15 families and 5 orders were recorded from the agro-ecosystems. Biodiversity indices showed relatively moderate diversity values of insect pollinators. The decline in pollinators' diversity could result in serious threat to crop pollination by reducing the crop yield. Though it was a preliminary attempt to make a report of insect pollinators of orchards and agro-ecosystems of mountainous areas, it will undoubtedly help the future workers as a baseline data of pollinators in the area. Hence, pollinators friendly cultivation practices should be practiced for the conservation and management of insect pollinators for higher production of crops.

Acknowledgements

The authors are grateful to the Head, Department of Zoology, D. S. B. Campus, Kumaun University, Nainital, for providing the necessary facilities.

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