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Diversity and relative abundance of insects in agricultural ecosystem of Bajoon, Nainital district, Uttarakhand, India

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Abstract
A global worry today is producing enough food to feed a population that is expanding. The world's arable land area cannot be further increased because almost all of its fertile land is already in use. Ensuring high-quality harvests while maintaining environmental compatibility in agricultural production is a global concern. When it comes to the diversity and quantity of their species, insects have achieved remarkable accomplishment. Insects are the largest and most diverse group of organisms which play an important role in agriculture. A study was conducted in Bajoon, Nainital District to understand the diversity of insects in the area by using sweep net method and the handpicking method and analysis by respected equation and indexes. The study recorded 738 number of individuals which divided into 5 orders, namely ptera, Hymenoptera, Coleoptera, Diptera, and Orthoptera. Lepidoptera was the most‘
dominant order, and Nymphalidae was the most dominant family with 6 species, followed by Pieridae and Danaidae with 2 species each, and Papilionidae with 1 species. The Shannon-Wiener diversity index was highest in site, at (H’=2.835). Evenness was highest at (E=0.8519), and the Margalef’s Richness Index was (d=3.64). This paper examines the important role that insects generally play in ecosystems and how the services that insects provide can improve agricultural ecosystems and also this study aimed to identify insect species in agriculture and provide baseline information for future research.

Keywords: Diversity, abundance, richness, agriculture, ecosystem

Introduction
Insects provide critical ecological functions in terrestrial ecosystems. They are most diverse and abundant invertebrates on the planet. They have been extensively studied in many areas such as biomechanics, climate change, developmental biology, ecology, evolution, genetics, and physiology. Due to their diverse and varied characteristics, they are renowned among the entomologist, and their conservation poses a significant challenge (Jalali and Ojha, 2015) [9]. Globally, there are approximately 5.5 million insect species around the world (Stork, 2018) [23]. In India, there are roughly 63,760 species of insects belonging to 29 orders and three classes, with eight orders making up 94% of the insect fauna, while the remaining 21 orders are represented by small numbers (6% of species), accounting for almost 7% of global insect diversity (Linta, P. 2020) [10]. They are found in all habitat types and play significant roles in the function and stability of terrestrial and aquatic ecosystems (Mäkelin *et al*., 2020). Insects have an incredible ability to succeed and multiply in almost any available space on our planet. Insects play a crucial role in the ecosystem by performing various ecological functions (Sodhi *et al*., 2010b) [22]. Insects are important due to their diverse nature, ecological significance, and impact on agriculture, human health, and natural resources (Berenhaum, 1995; Adetundan *et al*., 2005; Premalatha *et al*., 2011) [3, 18]. They serve as the biological foundation for terrestrial ecosystems, and biotic communities are crucial for providing ecological functions and ecosystem services (Naeem *et al*., 2012). In order to better understand management factors related to agrobiodiversity and ecosystem services provision, this article aims to construct a global classification of agricultural land management systems. Modelling biodiversity and ecological services globally can be enhanced by this kind of work.

Materials and Methods
Study Area
The present study was conducted in agricultural lands and fruit orchards located at the Bajoon, area (29.3714° N and 79.4183°S) in Nainital district, Uttarakhand. Forest mixed agricultural vegetation found in the study site. It is situated 17 km away from Nainital. The total geographical area of village is 72.89 hectares. It beneficial from a moderate climate, mid -level altitude (520 feet above sea level). Major of the area is cover with agriculture and Commercial area. The main vegetation contains *Pisum sativam*, *Raphanus sativus*, *Brassica compresties*, *Coriandrum sativum*, *Triticum aestivum*, *Oryza sativa*, *Berberis asiatica*, *Rubus ellipticus* and *Cedrus deodara* are grown as shown in Fig.1 and 2.

Methodology
Collection and Identification
The insects were collected using two methods: the sweep method and the handpicking method, as described by Gadakar in 1990. After collecting the insects, they were transferred into jars containing cotton soaked in ethyl acetate. These jars were brought to the laboratory for further examination. The specimens were then stretched, pinned, and oven-dried before being placed in wooden boxes. Finally, the collected samples were subjected to further identification procedures. After the identification, the insects were labelled properly. The insects which are identified by using dichotomous Key, the available literature and the G.B Pant university.

Fig 1: The study area

Fig 2: Map of study area

Data Analysis

Diversity indices were calculated

1. Shannon- Wiener equation (Luo *et.al* 2023) [11]

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

Where, pi = fraction of entire population made up of species;

S = total number of species;

i = proportion of species

2. Evenness Index (Hill, 1973) [8]

$E = H/ \ln S$

Where, S = total number of species;

H = Index of species;

3. Margalef's Index (Margalef, 1970) [14]

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

Where, S = the total number of species;

N = the total number of individuals in sample

Data Analysis was done based on their abundance and habit through Shannon-Wiener diversity indices, Evenness indices as well as Marglef's indices for richness by using PAST4.04 software.

Results

The diversity and Relative abundance of insect species observed in the selected habitats are shown in images (Fig.3 and 4). Table 1 shows the checklist of species collected during the study period of March 2022 to August 2022. It includes a total of 21 species from 5 orders and 12 families. Lepidoptera was the most dominant order with 11 species from 4 families. Hymenoptera had 5 species from 3 families, while Coleoptera and Orthoptera each had 2 species from 2 families. Diptera had only 1 species from 1 family. Through the above data we can conclude that the order lepidoptera is dominant because they are good pollinator, food resource, ecological indicator and help in nutritional cycle in environment. On other hand order Diptera contain least no. of individual which slightly conclude that food chain, water quality and decomposition process is affecting. This also proof that the slightly more area is covered by commercial area which is directly or indirectly affecting the environment. The percentage contribution of the relative number of individuals and species of different families of butterflies collected from the study area is presented in Table 2 and Fig. 2.

The Shannon Index of Diversity is a comprehensive measure of diversity as it considers both the number of species and their abundance (Luo *et.al* 2023) [11]. Evenness takes into account the distribution of species and their number across gradients, while Margalef's Richness Index indicates species richness. The Shannon-Wiener Diversity Index (H') ranged from 2.176 to 2.835, with the highest diversity (H'=2.835) recorded in June. Evenness (E) was high (E=0.851), indicating a balanced distribution of species. Margalef's Richness Index was also high (d=3.64),

indicating a high species richness in the study area (refer to Table 3 for further information). The Shannon Index of Diversity is considered the most comprehensive measure of diversity because it considers both the number of species and their abundance (Pepper, 1999). Evenness takes into account the distribution of species and their number across gradients, while Margalef's Richness Index indicates species richness. The Shannon-Wiener Diversity Index (H') ranged from 2.176 to 2.835, with the highest species diversity (H'=2.835) recorded in June which shows that the number of insects higher in comparative to the area covered by it. Evenness (E) also returned high values (E=0.851) which indicate that the all species have similar distribution in study area. Margalef's Richness Index also showed high values (d=3.64), indicating high species richness in the study area (Table 3).

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-Nymphalidae				
1.	*Vanessa cashmirensis* Kollar	Indian Tortoishell	36	4.88
2.	*Vanessa indica*Herbrt	Red Indian Admiral	39	5.28
3.	*Junonialemonians*Linneus	Lemon Pansy	43	5.83
4.	*Neptismahendra* Moore	Himalayan Sailor	9	1.22
5.	*Junoniaiphita*Cramer	Chocolate Pansy	23	3.12
6.	*Vanessa cardui* Linnaeus	The painted Lady	42	5.69
Family- Pieridae				
7.	*Pieris canidia indica* Evans	Indian Cabbage	70	9.49
8.	*Catopsiliapyranthe* Linnaeus	White Emigrant	23	3.12
Family- Papilionidae				
9.	*Papilio protenor* Cramer	Spangle	12	1.63
Family- Danaidae				
10.	*Paranticaaglea Stoll*	Glassy Tiger	7	0.95
11.	*Euploea Core Cramer*	Common Crow	13	1.76
Order- Hymenoptera Family-Apidae				
12.	*Apis dorsata*	Giant Honey bee	25	3.39
13.	*Bombus spp.*	Bumble Bee	41	5.56
14.	*Apis Mellifera*	Honey Bee	67	9.08
Family- Vespidae				
15.	*Polistes sp.*	Yellow Paper Wasp	5	0.68
Family- Formiciadae				
16.	*Componotus sp.*	Indian Black Ant	52	7.05
Order- Coleoptera Family- Coccinellidae				
17.	*Coccinellaseptumpunctata*	Lady beetle	103	13.96
Family- Chrysomilidae				
18.	*Altica sp.*	Flea Beetle	9	1.22
Order- Diptera Family- Muscidae				
19.	*Musca domestica*	House Fly	60	8.13
Order- Orthoptera Family- Gryllidae				
20.	*Gryllus sp.*	Field Cricket	24	3.25
Family- Tettigonidae				
21.	*Elimaea sp.*	Bush Cricket	35	4.74
			738	100

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

Order	Family	No. of species	Relative abundance (%)	No. of individuals	Relative abundance (%)
Lepidoptera	Nymphalidae	6	28.57	192	26.02
	Pieridae	2	9.52	93	12.60
	Papilionidae	1	4.76	12	1.63
	Danaidae	2	9.52	20	2.71
Hymenoptera	Apidae	3	14.29	133	18.02
	Vespidae	1	4.76	5	0.68
	Formacidiae	1	4.76	52	7.05
Coleoptera	Coccinellidae	1	4.76	103	13.96
	Chrysomelidae	1	4.76	9	1.22
Diptera	Muscidae	1	4.76	60	8.13
Orthoptera	Gryllidae	1	4.76	24	3.25
	Tettigonidae	1	4.76	35	4.74
		21	100.00	738	100.00

Table 3: Species diversity and species richness of insect fauna

Months	Shannon Index (H')	Evenness (E)	Margalef's Index (d)
March	2.438	0.817	2.934
April	2.566	0.813	3.067

May	2.743	0.817	3.455
June	2.835	0.851	3.64
July	2.611	0.801	3.556
August	2.176	0.800	2.414

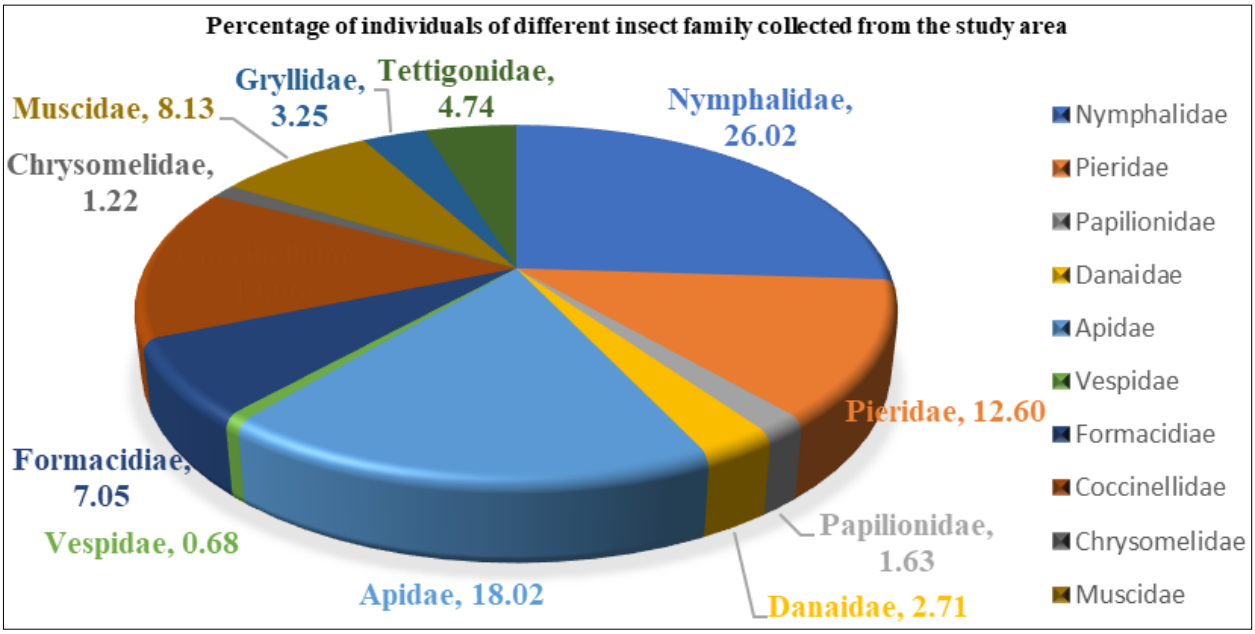

Fig 3: Relative abundance of individuals (%) of different families

Vanessa Cashmirensis *Vanessa indica* *Parantica aaglea* *Pieris canidia indica*

Junonia lemonians *Neptis mahendra* *Polistes sp.* *Musca domestica*

Componotus sp *Gryllus sp.* *Coccinella septumpunctata* *Apis sp.*

Fig 4: Insects collected from the Study Area

Discussion

This study indicates that the insect fauna dominates crop fields. However, very few workers have explored the abundance, populations and diversity of insects in agricultural ecosystems. Maramis *et al*. (2016) [13] reported a total of 39 individuals from 6 orders and 6 families. Similarly, Das *et al*. (2018) [4] studied the diversity of insect pollinators of Rabi crops in the surrounding areas of Barpeta Town in Assam, India. In Kuwait, Wasnia Al Houty (2009) [25] recorded 273 genera, 116 families, and 19 orders of insects during the study period. Atmowidi*et al*. (2007) reported 19 species of insects belonging to 11 families and 5,955 insects from Bogor, Indonesia. Tewari *et al*. (2006) [24] explored 26 species of butterflies belonging to the Pieridae family from the Kumaun region, Uttaranchal. Dev *et al*. (2009) [5] studied the diversity, species richness, and abundance of insects in crops from Kumaun, Uttarakhand. Similar to the present study, various studies have reported insect orders as the major group of insects (Rekha *et al*., 2021; Paulson *et al*., 2020; Meena *et al*., 2017; Sanwal*et al*., 2017) [19,16,15].

Conclusion

A study conducted in the slightly agricultural ecosystems of Bajoon Nainital, Uttarakhand revealed a total of 738 individuals belonging to 21 species of 12 families and 5 orders. The study highlighted that Lepidoptera was the most diverse insect order in the area, followed by Hymenoptera which had the maximum number of crop visitors. Although the diversity of Coleopterans, Orthopterans, and Dipterans was relatively less, their contribution cannot be neglected. The average number of insects present suggests that the region is only marginally biologically and ecologically balanced, which could be a sign of an inadequately healthy ecosystem. But when we further conclude the area in respect to relative abundance is directly or indirectly affecting the nature and also affecting the food chain of the surrounding ecosystem. We also little bit sure that the local people is using the pesticide and insecticides which directly or indirectly affecting the land and insects both.

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