

# Species Richness and Diversity of Insects in an Agro-ecosystem in Bhabar region of Uttarakhand

## Abstract

The aim of the presented study was to estimate the species richness and diversity of insects were investigated in an agro-ecosystem in Bhabar region of Uttarakhand. In total, 992 individuals were collected representing 7 orders (Lepidoptera, Coleoptera, Hemiptera, Hymenoptera, Orthoptera, Diptera and Odonata), 30 families and 91 species that included herbivores, predators, omnivores and saprophages. The most dominant order was Lepidoptera with a relative abundance of (46.15%) and, the least was Diptera (6.59%). The five most abundant families by numbers of individuals were Pieridae (14.8%), Nymphalidae (13.9%), Lycaenidae (6.1%), Papilionidae (5.9%), and Libellulidae (5.4%). The five most diverse families by species were Nymphalidae (13), Pieridae (9), Lycaenidae (8), Papilionidae (7), and Libellulidae (6). The diversity index showed significant Diversity ( $H'=1.832$ ), Evenness ( $E=0.9449$ ) and Margalef species richness ( $d=2.076$ ) of insect fauna. Diversity indices of insect orders showed that Lepidoptera was the most diverse ( $H'=1.641$ ), Dipterans had highest Evenness ( $E=0.9449$ ), and Coleopterans had the maximum species richness Margalef's Index ( $d=2.056$ ). There were 720 individuals of insect pollinators visitors were observed, which belonged to 62 species in 4 orders (Lepidoptera, Coleoptera, Hymenoptera, and Hemiptera).

**Keywords** Species diversity, Species abundance, Shannon Index ( $H'$ ), Pollinators/Visitors, agro-ecosystem.

## Introduction

The insects are known to be the most successful and diverse animals on earth. They comprise more than 75% of the known species and have adapted for almost every conceivable type of environment, almost everywhere (Westfall & Tennesen, 1996). Insects are important because of diversity, ecological role and their influence on agriculture (Adetundan *et al.*, 2005).

The diversity of fauna associated with agro ecosystems are well documented and include pests, predators, parasitoids, insect pollinators and non-economic importance species (Woolwine & Reagen, 2001; Cherry & Robert, 2009; Banu *et al.*, 2016; Sayuthi *et al.*, 2018; Emmanuel & Anuluwa, 2019; and Naz *et al.*, 2020). However, the beneficial entomofauna i.e. pollinators, predators, parasitoids and decomposers are highly susceptible to the adverse effects of farming practices, particularly the indiscriminate use of fertilizers and chemical insecticides (Altieri & Nicholls, 2004; Tilman *et al.*, 2006).

Pollination is an important process in maintaining healthy and bio diverse ecosystem. Insects constitute one among many groups of pollinating agents, as the association between insects and flowers are well established (Free, 1993; Kearns *et al.*, 1998; Bhowmik *et al.*, 2014).

The aim of this investigation was to study abundance, species richness, trophic guilds, diversity indices, and diversity of insect Pollinators/visitors in a agricultural ecosystem of Bhabar region in district Nainital, Uttarakhand, and this is very first time that this work was carried out.

## **Material and Methods:**

### **The study area**

Geographically, village Sawal Deh is located in the sub-tropical zone at 29.40<sup>0</sup>N latitude and 79.12<sup>0</sup>E longitude at an altitude of 320 m in the Bhabar region of Uttarakhand. The study area has sub-humid tropical climate and is situated in the foothills of central Himalayas. The climatic data indicates hot dry summer and cold winter. The maximum temperature reaches up to 39 °C (May) in summer, and minimum 8.0 °C (January) in winter. The maximum humidity ranged from 23% (May) to 78% (August). The average rainfall was 1734 mm and 75.8% of rainfall occurred in the rainy season. On this basis, the year can be divided into three seasons, namely rainy (July to October), winter (November to February) and summer (March to June).

Three crops are grown in a year: July to October (Paddy/Soybean), November to April (wheat/mustard) and seasonal vegetables (May-June).

The agricultural field are under manage tillage in the shallow layers of the soil (5 cm). The agro-ecosystems are highly productive, resources rich (water and nitrogen input form irrigation and livestock) and experience a fair amount of disturbance due to anthropogenic activities throughout the growing season.

### **Collection of Insects**

Sampling of insects was conducted at an interval of 30 days from March, 2018 to February, 2020. The insects were collected by "Sweep Sampling Method", as per Gadagkar *et al.* (1990) and hand picking (Jonathan, 1990). The net sweeps were used to collect the insects. The nets used in sweeping were made of thick cotton cloth with a diameter of 30 cm at mouth and a bag length of 60 cm. A randomly selected area of each study sites was divided into a quadrat of 10x10 m. Hand picking method was used for larger, ground living insects and insects living under the stones.

Collected insects were identified with the help of keys and through the available literature. Insects were then separated into different orders and families and to the species level. The representative species were preserved in the laboratory. The species which could not be

identified in the laboratory were sent to the Forest Research Institute, Dehradun for identification.

The trophic level of an organism is the position, which it occupies in a food chain. Different insect species occupy different trophic positions in a food chain in the cropland ecosystem, according to their dissimilar food habitats viz. phytophagous, predators, omnivores, saprophages and decomposers. The collected insect species were identified and placed into five trophic levels.

### Diversity Indices

Using Shannon-Wiener Diversity Index this index, species and seasonal diversity of insect was calculated as follows (1963):

(A) Species diversity: 
$$H'(S) = -\sum_{i=1}^s p_i \log p_i$$

(B) Seasonal diversity: 
$$H'(P) = -\sum_{j=1}^s q_j \log q_j$$

Where,

$p_i = n_i/N$  and  $q_j = n_j/N$

$n_i$  = Number of individuals of a species at a time  $i$

$n_j$  = Number of individual present in a season  $j$

$N$  = Size of whole community

$\Sigma$  = Number of species/ Number of seasons

$S$  = Total number of species

$P$  = Number of seasons

### (C) Evenness (Buzas and Gibson's Evenness) $E_2$ :

$$E_2 = e^{H/S}$$

Where,  $S$  is the number of taxa and  $H$  is the Shannon Index

## (D) Margalef's Species Richness Index (d):

Species richness was calculated using Margalef's Index (1970)

$$\text{Margalef's Index (d)} = (S-1) / \ln N$$

Where, S = total number of species

N = total number of individuals in sample

ln = natural logarithm

## Results and Discussion

### Diversity and abundance of Insect Fauna

Table 1: Diversity and Relative Abundance (%) of insect species and trophic components in the study site (Sawal Deh) during March, 2018 to February, 2020

S. No.	Taxonomic Composition	Trophic level	No. of individuals	Relative Abundance (%)	No. of individuals	Relative Abundance (%)
<b>ORDER: LEPIDOPTERA</b>						
<b>Family: Pieridae</b>						
1.	<i>Pieris brassicae</i> (Linnaeus)	Phytophagous	16	3.80	22	3.85
2.	<i>Pieris canidia indica</i> (Sparrman)	Phytophagous	5	1.19	10	1.75
3.	<i>Eurema brigitta</i> Cramer	Phytophagous	4	0.95	8	1.40
4.	<i>Gonepteryx rhamni</i> (Linnaeus)	Phytophagous	5	1.19	7	1.23
5.	<i>Catopsilia pyranthe</i> (Linnaeus)	Phytophagous	11	2.61	16	2.80
6.	<i>Catopsilia pomona</i> (Fabricius)	Phytophagous	12	2.85	18	3.15
7.	<i>Cepora nerissa phryne</i> Fabricius	Phytophagous	0	0.00	2	0.35
8.	<i>Aporia agathon</i> (Gray)	Phytophagous	0	0.00	2	0.35
9.	<i>Leptosia nina</i> (Fabricius)	Phytophagous	3	0.71	6	1.05
<b>Family: Nymphalidae</b>						
10.	<i>Vanessa indica</i> Herbst	Phytophagous	5	1.19	8	1.40
11.	<i>Symbrenthia hippoclus</i> (Cramer)	Phytophagous	2	0.48	3	0.53
12.	<i>Aglais cashmiriensis</i> (Kollar)	Phytophagous	5	1.19	7	1.23
13.	<i>Cynthia cardui</i> Linnaeus	Phytophagous	1	0.24	2	0.35
14.	<i>Precis lemonias lemonias</i> Linnaeus	Phytophagous	18	4.28	21	3.68
15.	<i>Precis almana</i> (Linnaeus)	Phytophagous	5	1.19	10	1.75

16.	<i>Ariadne merione</i> (Cramer)	Phytophagous	5	1.19	2	0.35
17.	<i>Euthalia patala</i> Kollar	Phytophagous	4	0.95	5	0.88
18.	<i>Symphaedra nais</i> (Forster)	Phytophagous	1	0.24	2	0.35
19.	<i>Ypthima</i> sp.	Phytophagous	9	2.0	8	1.40
20.	<i>Neptis sankara</i> Kollar	Phytophagous	0	0.00	2	0.35
21.	<i>Danaus chryssippus</i> (Linnaeus)	Phytophagous	5	1.19	6	1.05
22.	<i>Euploea core</i> (Cramer)	Phytophagous	2	0.48	0	0
<b>Family: Lycaenidae</b>						
23.	<i>Heliophorus androcles</i> (Doubleday & Hewitson)	Phytophagous	0	0.00	2	0.35
24.	<i>Heliophorus sena</i> Kollar	Phytophagous	2	0.48	3	0.53
25.	<i>Talicauda nyseus</i> (Guerin-Meneville)	Phytophagous	5	1.19	6	1.05
26.	<i>Leptotes plinius</i> (Fabricius)	Phytophagous	4	0.95	8	1.40
27.	<i>Neopithecops zalmora</i> Butler	Phytophagous	5	1.19	2	0.35
28.	<i>Zizeeria</i> sp	Phytophagous	8	1.90	10	1.75
29.	<i>Zemeros flegyas</i> Cramer	Phytophagous	0	0.00	1	0.18
30.	<i>Catochrysops strabo</i> Fabricius	Phytophagous	2	0.48	3	0.53
<b>Family: Papilionidae</b>						
31.	<i>Atrophaneura aristolochioae</i> Fabricius	Phytophagous	5	1.19	4	0.70
32.	<i>Papilio polytes</i> (Linnaeus)	Phytophagous	6	1.43	8	1.40
33.	<i>Graphium doson axionides</i> (Page and Treadway)	Phytophagous	0	0.00	2	0.35
34.	<i>Papilio romulus</i> Linnaeus	Phytophagous	5	1.19	6	1.05
35.	<i>Papilio cyrus</i> Linnaeus	Phytophagous	4	0.95	5	0.88
36.	<i>Papilio demoleus</i> (Linnaeus)	Phytophagous	2	0.48	4	0.70
37.	<i>Papilio stichius</i> Linnaeus	Phytophagous	3	0.71	5	0.88
<b>Family: Hesperidae</b>						
38.	<i>Telicota</i> sp.	Phytophagous	5	1.19	7	1.23
39.	<i>Polytremis eltola</i> Hewitson	Phytophagous	3	0.71	4	0.70
<b>Family: Erebidae</b>						
40.	<i>Amata</i> sp.	Phytophagous	5	1.19	8	1.40
41.	<i>Ceryx imaon</i> Cramer	Phytophagous	5	1.19	7	1.23
42.	<i>Erebus</i> sp.	Phytophagous	7	1.66	6	1.05

	<b>ORDER: COLEOPTERA</b>					
	<b>Family: Scarabaeidae</b>					
43.	<i>Phyllophaga</i> sp.	Phytophagous	4	0.95	7	1.23
	<b>Family: Chrysomelidae</b>					
44.	<i>Sagra femorata</i> (Drury)	Phytophagous	2	0.48	1	0.18
45.	<i>Mimastra</i> sp.	Phytophagous	5	1.19	8	1.40
46.	<i>Raphidopalpa foveicollis</i> (Lucas)	Phytophagous	10	2.38	7	1.23
	<b>Family: Coccinellidae</b>					
47.	<i>Coccinella septempunctata</i> (Linnaeus)	Predator	8	1.90	11	1.93
	<b>Family: Elateridae</b>					
48.	<i>Adelocera</i> sp.	Phytophagous	7	1.66	9	1.58
	<b>Family: Meloidae</b>					
49.	<i>Mylabris cichorii</i> Linnaeus	Predator	0	0.00	6	1.05
	<b>ORDER: HYMENOPTERA</b>					
	<b>Family: Apidae</b>					
50.	<i>Apis cerena</i> Fabricius	Phytophagous	8	1.90	12	2.10
51.	<i>Apis dorsata</i> Fabricius	Phytophagous	5	1.19	9	1.58
52.	<i>Bombus</i> spp.	Phytophagous	6	1.43	8	1.40
	<b>Family: Formicidae</b>					
53.	<i>Camponotus</i> sp.	Predator	8	1.90	10	1.75
54.	<i>Lasius niger</i> (Linnaeus)	Predator	11	2.61	21	3.68
	<b>Family: Sphecidae</b>					
55.	<i>Isodontia apicalis</i> (F. Smith)	Predator	1	0.24	0	0.00
56.	<i>Sceliphron caucasicum</i> Dalla Torre	Predator	5	1.19	8	1.40
57.	<i>Sceliphron coromandelicum</i> Lepeletier	Predator	7	1.66	8	1.40
	<b>Family: Vespidae</b>					
58.	<i>Vespa cincta</i> Fabricius	Predator	5	1.19	5	0.88
59.	<i>Polistes</i> sp.	Predator	2	0.48	3	0.53
60.	<i>Vespa</i> sp.	Predator	5	1.19	9	1.58
	<b>Family: Xylocopidae</b>					
61.	<i>Xylocopa auripennis</i> Lepeletier	Phytophagous	8	1.90	10	1.75
	<b>ORDER: ORTHOPTERA</b>					
	<b>Family: Acrididae</b>					
62.	<i>Patanga japonica</i> Bolivar	Phytophagous	2	0.48	1	0.18

63.	<i>Ceracris fasciata</i> Brunner von Wattenwyl	Phytophagous	5	1.19	7	1.23
64.	<i>Spathosternum p. prasiniferum</i> Walker	Phytophagous	2	0.48	5	0.88
65.	<i>Acridium melanocorne</i> Linnaeus	Phytophagous	5	1.19	0	0.00
	<b>Family: Gryllidae</b>					
66.	<i>Gryllus</i> sp.	Omnivore	6	1.43	7	1.23
67.	<i>Teleogryllus testaceus</i> Walker	Omnivore	2	0.48	3	0.53
	<b>Family: Tettigonidae</b>					
68.	<i>Elimaea</i> sp.	Phytophagous	7	1.66	9	1.57
69.	<i>Neoconocephalus</i> sp.	Phytophagous	6	1.43	8	1.40
	<b>ORDER: ODONATA</b>					
	<b>Family: Libellulidae</b>					
70.	<i>Crocothemis servilia servilia</i> Drury	Predator	0	0.00	2	0.35
71.	<i>Orthetrum chrysis</i> (Burmeister)	Predator	5	1.19	7	1.23
72.	<i>Neurothemis ramburii</i> (Brauer)	Predator	4	0.95	5	0.88
73.	<i>Orthemis ferruginea</i> (Fabricius)	Predator	2	0.48	3	0.53
74.	<i>Orthetrum pruinosum</i> (Burmeister)	Predator	7	1.66	8	1.40
75.	<i>Orthetrum taeniolatum</i> Schneider	Predator	6	1.43	5	0.88
	<b>Family: Gomphidea</b>					
76.	<i>Paragomphus lieantus</i> (Selys)	Predator	5	1.19	8	1.40
	<b>ORDER: DIPTERA</b>					
	<b>Family: Muscidae</b>					
77.	<i>Musca</i> sp.	Saprophage	6	1.43	8	1.40
	<b>Family: Calliphoridae</b>					
78.	<i>Calliphora</i> sp.	Saprophage	4	0.95	5	0.88
	<b>Family: Tipulidae</b>					
79.	<i>Tipula himalayensis</i> Brunetti	Predator	5	1.19	4	0.70
80.	<i>Tipula</i> sp.	Predator	4	0.95	5	0.88
	<b>Family: Asilidae</b>					
81.	<i>Philodius javanus</i> Wied.	Predator	0	0.00	2	0.35
82.	<i>Stenopogan oldroydi</i> Josephs & Pauri	Predator	0	0.00	1	0.18
	<b>ORDER: HEMIPTERA</b>					
	<b>Family: Fulgoridae</b>					
83.	<i>Lycorma delicatula</i> (White)	Phytophagous	0	0.00	2	0.35

	<b>Family: Pantatomidae</b>					
84.	<i>Nezara viridula</i> Linnaeus	Phytophagous	7	1.66	9	1.57
85.	<i>Murgantia histrionic</i> (Hahn)	Phytophagous	5	1.19	6	1.05
86.	<i>Dalpada</i> sp.	Phytophagous	6	1.43	7	1.23
87.	<i>Halyomorpha</i> sp.	Phytophagous	3	0.71	4	0.70
	<b>Family: Coreidae</b>					
88.	<i>Cletus punctulatus</i> (Dallas)	Phytophagous	2	0.48	4	0.70
	<b>Family: Alydidae</b>					
89.	<i>Leptocorisa varicornis</i> Fabricius	Phytophagous	5	1.19	6	1.05
90.	<i>Leptocorisa</i> sp.	Phytophagous	2	0.48	2	0.35
	<b>Family: Largidae</b>					
91.	<i>Physopetata gutta</i> Brum	Phytophagous	7	1.66	8	1.40
	<b>Total</b>		<b>421</b>	<b>100</b>	<b>571</b>	<b>100</b>

Diversity and abundance of insect fauna collected are presented in Table 1. A total of 91 species belonging to 30 families, 7 orders, and 992 individuals were collected. Maximum number of species belonged to the order Lepidoptera (42), followed by Hymenoptera (12), Hemiptera (9), Orthoptera (8), Coleoptera (7) and Diptera (6).

Species richness was higher in summer (50 species) and rainy season (39 species) than in winter (6 species). Species richness was significantly correlated with maximum temperature ( $r=0.879$ ;  $P\leq 0.01$ ,  $df=12$ ), minimum temperature ( $r=0.777$ ;  $P\leq 0.05$ ,  $df=12$ ), and rainfall ( $r=0.285$ ;  $P\leq 0.05$ ,  $df=12$ ).

Maximum number of individuals belonged to Lepidoptera (462), followed by Hymenoptera (174), Hemiptera (85), Coleoptera (85), Orthoptera (67), Odonata (67) and Diptera (44). Higher number of insects were collected during summer and rainy season and lower in winter season. Abundance of insects was significantly correlated with maximum temperature ( $r=0.875$ ;  $P\leq 0.01$ ,  $df=12$ ), minimum temperature ( $r=0.765$ ;  $P\leq 0.01$ ,  $df=12$ ) and rainfall ( $r=0.31$ ;  $P\leq 0.05$ ,  $df=12$ ).

### Trophic guilds

Four trophic groups were identified on the basis of feeding habits of insects collected: Phytophagous, predators, omnivores and saprophages. On the basis of number of species collected, Phytophagous (71.4%) were dominant followed by predators (20.9%), omnivores (5.5%), and saprophages (2.2%). On the basis of number of individuals collected, Phytophagous (72.9%) were predominant followed by predators (20.5%), omnivores (4.3 %) and saprophages (2.3%). A total of species of bioregulator (predators were collected in the present study. The guild structure of insects collected are shown in Figs. 1 and 2.



March	1.399	0.5787	1.674	1.322	0.5357	1.595	1.535	0.6629	1.576
April	1.176	0.4629	1.616	1.267	0.5072	1.567	1.469	0.6204	1.534
May	1.499	0.6395	1.801	1.552	0.6743	1.638	1.556	0.6771	1.534
June	1.832	0.892	1.941	1.56	0.6799	1.842	1.705	0.7862	1.627
July	1.603	0.7099	1.941	1.658	0.75	1.82	1.611	0.7152	1.638
August	1.707	0.7878	1.941	1.727	0.8037	1.764	1.661	0.7521	1.638
September	1.561	0.6803	2.076	1.658	0.7499	2.076	1.57	0.6868	1.731
October	1.719	0.7974	2.076	1.722	0.7993	2.003	1.663	0.7534	1.716
November	0.5623	0.8774	0.7213	0	1	0	0	1	0
December	0	1	0	0	1	0	0	1	0
January	0.6365	0.9449	0.9102	0.5623	0.8774	0.7213	0.6931	1	0.5581
February	1.04	0.9428	1.443	0.6931	1	1.443	0.673	0.9801	0.6213

The Shannon-Wiener Diversity Index ( $H'$ ), Evenness ( $E$ ) and Margalef's species richness ( $d$ ) of insect fauna collected were computed and are presented in Table 2.

The Shannon diversity index ranged from 0 in December to 1.832 in June in the present study which means the insect fauna was moderately rich in the study area.

Insect diversity index is usually in conventional agro-ecosystems is usually low because the agriculturists use a monoculture system, the use of chemical fertilizers and pesticides. As a result of this treatment beneficial insects including non-target insects get killed (Altieri & Letoumeau, 1982). Biodiversity indices were highest in agro ecosystems under organic management with species richness index with of 4.68 and  $D$  of 2.34 (Sorribas *et al.*, 2016). However, high maximum index of 5 has been reported for terrestrial ecosystems (Usha & John, 2015).

Buza's Evenness which takes into account the distribution of species and their number, ranged from 0.5072 (April) to 0.9801 (February (highest value is 1) indicating no species was dominant in terms of abundance.

Margalef's Richness Index ranged from 0 in November to 2.076 in September which indicates moderate species richness.

Table 3: Relative abundance, Species diversity and species richness of insect orders in the study site (Sawal Deh) during March, 2018 to February, 2020

Order	Relative Abundance (%)	Shannon Index ( $H'$ )	Evenness ( $E$ )	Margalef ( $d$ )
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Lepidoptera	46.15	1.641	0.8601	1.338
Hymenoptera	13.20	1.545	0.938	1.61
Coleoptera	7.69	1.475	0.8743	2.056
Hemiptera	9.89	1.427	0.8333	1.82
Orthoptera	8.79	1.04	0.9428	0.9618
Odonata	7.69	0.4101	0.7535	0.5139
Diptera	6.59	1.33	0.9449	1.679
Total	100.0	8.8681	6.1469	9.9787

Table 3 shows the pooled relative abundance based on orders and their diversity indices. It is evident that Lepidopteran insects had the highest diversity index ( $H'=1.641$ ), Dipterans had highest Evenness ( $E=0.9449$ ) and Coleopterans had maximum species richness Margalef's Index ( $d=2.056$ ).

### Diversity of insect pollinators

In total, 720 individuals of insect pollinators belonging to 62 species, 4 orders, and 16 families were recorded (Table 1). Four orders of insect pollinators found were Lepidoptera (family Pieridae, Nymphalidae, Lycaenidae, Papilionidae, Hesperidae, Erabidae), Coleoptera (family Chrysomelidae, Coccinellidae, Meloidae), Hymenoptera (family Formicidae, Apidae, Vespidae, Xylocopidae). Among them Lepidoptera with 462 individuals (64.2%) was the most dominant insect order visiting the crops followed by Hymenoptera with 145 individuals (20.1%), Coleoptera with 58 individuals (8.1%) and Hemiptera with 55 individuals (7.6%). Family Pieridae (20.4%) was the most abundant of all families.

Insect pollinators of all four orders were found to be active throughout the day, but peak foraging activity was different for different orders. Lepidopterans were only flower visitors and active during afternoon but less active in the morning. Hymenopterans and dipterans were active during day time. Foraging activities of coleopterans and hemipterans remained relatively constant throughout the day.

Various studies have shown that insects constitute one among many groups of pollinators and have mutual relationship with flowering plants. Insect pollinators play a significant role in the pollination of agricultural, horticultural and medicinal herbal crops, mainly belong to the insect orders: Hymenoptera, Lepidoptera, Coleoptera, Diptera, Thysanoptera, Hemiptera and Neuroptera (Sihag, 1988; Free, 1993; Mitra *et al.*, 2008; Bhowmik *et al.*, 2014; Subedi & Subedi, 2019; Singh & Mall, 2020). Our results are very similar to those reported studies.

Pollinators recorded in the present study through their good management could be utilized for increasing the yield of crops in the agro ecosystem studied.

In the present study, low and higher temperature, and rainfall influence the species richness and abundance of insects and are similar to the findings of Abbas *et al.* (2014), Nadia *et al.* (2015), and Garia *et al.* (2016, 2017).

## Conclusions

A total of 992 individuals representing 7 orders, 30 families and 91 species in the agro ecosystem were collected. Phytophagous were the most dominant trophic group in terms of number of species and abundance of individuals collected. Significant Diversity Index ( $H'=1.832$ ), Evenness ( $E=0.9449$ ) and Margalef's Index ( $d=2.076$ ) of insect fauna were recorded. Pollinators visiting the agro ecosystem belonged to the order Lepidoptera, Coleoptera, Hymenoptera and Hemiptera. Through, it is a preliminary report on insect pollinators in the study area, it will certainly help the future workers as a baseline data of the pollinators and pollination of crops in the agro ecosystem of this area.

## References:

1. Abbas, S.A., Rana, A., Mahmood-ul-hassan M., Rana, N., Kausar, S. and M. Iqbal. (2014). Biodiversity and dynamics of macro-invertebrate populations in wheat-weeds agro-ecosystem of Punjab. *Journal of Animal and Plant Science*, 24(4), 1146-1156.
2. Adetundan, S. A., Ofuya. T. I. and J. A. Fuwape. (2005). Environmental effects of insects herbivores and logging on tree species diversity in Akure Forest Reserve (Apomu). *Nigeria Tropical Agriculture*, 9(1and2), 12–18.
3. Altieri, M. A. and C. Nicholls. (2004). *Biodiversity and Pest Management in Agroecosystems*. Boca Raton: C R C Press.
4. Altieri, M. A. and D. K. Letourneau. (1982). Vegetation management and biological control of ecosystems. *Crop Protection*, 1, 405-430.
5. Atencio, R., Goebel, F. R. and R. J. Miranda. (2018). Entomofauna Associated with Sugarcane in Panama. *Sugar Technology*. <http://doi.org/10.1007/s12355-018-0661-8>
6. Banu. J., Dayana, M. and M. R. D. Rose. (2016). Diversity of Insects in Sugarcane Field at Chinnamanur, Theni District, Tamil Nadu. *International Journal for Innovative Research in Multidisciplinary Field*, 2(10), 651-655.
7. Bhowmik, B., Mitra, B. and K. Bhadra. (2014). Diversity of Insect Pollinators and

- Their Effect on the Crop yield of *Brassica juncea* L., NPJ-93, From Southern West Bengal. *International Journal of Recent Scientific Research*, 5(6), 1207-1213.
8. Cherry, R. and G. Robert. (2009). The effect of harvesting and replanting on arthropod ground predators in Florida sugarcane. *IFAS Extension: University of Florida*.
  9. Chouangthavy, B., Sanguansub, S. and N. Kamata. (2017). Species Composition, Richness and Diversity of beetles (Coleoptera) in Agricultural Ecosystem: In: 9 th Nakhom Pathom Rajabhat University National Academic Conference. PP 1-7.
  10. Dev, P., Tewari, M. and B. R. Kaushal. (2009). Diversity and abundance of insects in a cropland of central Himalayan Bhabar region of Kumaun, Uttarakhand. *Entomon*, 34(1), 11-21.
  11. Emmanuel, O. and Y.O. Anuoluwa. (2019). A Study on the Diversity and Relative Abundance of Insect Funa in Wukari, Taraba State, Nigeria. *International Journal of Advanced Biological and Biomedical Research*, 7(2), 141-153.
  12. Free, J. B. (1993). *Insect Pollination of Crops*. Academic Press, London.
  13. Gadagkar, R., Chandrashekhara, K. and P. Nair. (1990). Insect species diversity in the tropics: Sampling Method and Case Study. *Journal of Bombay Natural History Society*, 87(3), 328-353.
  14. Garia, A., Goswami, D., Pande, H. and B. R. Kaushal. (2016). Species Richness, Abundance and Diversity of Insect Community in Pine Forest of Kumaun Himalaya, Uttarakhand. *Academic Journal of Entomology*, 9(2), 26-35.
  15. Garia, A., Goswami, D., Pande, H. and B.R. Kaushal. (2017). Insect species diversity and abundance in oak forest of Kumaun Himalaya, Uttarakhand. *Entomon*, 42(1), 13-22.
  16. Ghani, A. and S. Maalik. (2019). Assessment of Diversity and relative abundance of insect fauna associated with *Triticum aestivum* from district Sialkot, Pakistan. *Journal of King Saud University-Science*. [www.sciencedirect.com](http://www.sciencedirect.com)
  17. Godfray, H. C. (2002). Challenges For Taxonomy. *Nature*, 417, 17-19.

18. Kearns, C. A. Inouye, D. W. and N. M. Waser. (1998). Endangered mutualism: The conservation of plant pollinator interactions. *Annual Review of Ecological Systems*, 29, 83-112.
19. Margalef's, R. (1970). Temporal succession and spatial heterogeneity in phytoplankton. In: *Perspectives in Marine biology*, Buzzati- Traverso (ed.), Univ. Calif. Press, Berkeley 323-347.
20. Mitra, B., Banerjee, D., Mukherjee, M., Bhattacharya, K. and P. Pauri. (2008). Flower visiting flies (Diptera: Insecta) of Kolkata and Surroundings, (Pictorial handbook). India: Zoological Survey of India (ZSI), Kolkata.
21. Mokam, D. G., Champlain, D. L. and C. F. B. Bilong. (2014). Patterns of Species Richness and Diversity of Insects Associated with Cucurbit Fruits in the Southern Part of Cameroon. *Journal of Insect Science*, 14(248), 1-9.
22. Nadia, A., Ashraf, I., Hussain, T. and I. Ahmad. (2015). Studies on the Diversity and Relative Abundance of Orthoptera and Lepidoptera species in Urban and Crop Areas of Dera Ghazi Khan. *American-Eurasian Journal of Agriculture and Environmental Science*, 15(8), 1693-1699.
23. Naz, H., Usmani, M. K., Ali, M., Mobin, S. and M. I. Khan. (2020). Acridoid diversity, species composition and distributional pattern in tarai region of Uttarakhand, India. *International Journal of Tropical Insect Science*.  
<https://doi.org/10.1007/s42690-020-00239-z>
24. Sayuthi, M., Husni, Hakim L., Hasnah, Rusdy A. and T. Chamzurni. (2018). Composition and biodiversity of insect species in wheat cultivation in Gayo highland, Indonesia. *International Journal of Tropical Biomedical Research*, 3(1), 25-29.
25. Shannon, C. E and W. Wiener. (1963). *The Mathematical theory of communications*, University of Illinois Press, Champaign.
26. Singh, M., and P. Mall. (2020). Diversity and foraging behaviour of insects on mustard crop at Tarai region of Uttarakhand. *International Journal of Chemical*

Studies, 8(1), 2556-2559.

27. Sorribas, J., Gonzalez, S., Gento, D. A. and R. Vercher. (2016). Abundance, movements and biodiversity of flying predatory insects in crop and non-crop agroecosystems. *Agronomy and Sustainable Development*, 36(34), 1-9.

28. Speight, M. R., Hunter, M. D. and A.D. Watt. (2008). *Ecology of Insects: Concepts and Applications*. Wiley-Blackwell, Singapore.

29. Subedi, N. and I. P. Subedi. (2019). Pollinator Insects and their impact on crop yield of mustard in Kusma, Parbat, Nepal. *Journal of Institute of Science and Technology*, 24(2), 68-75.

30. Tilman, D., Reich, P. and J. Knops. (2006). Biodiversity and ecosystem stability in a decade-long grassland experiment. *Nature*, 441 (7093), 629-632.

31. Usha, A.U. and V. K. John. (2015). A study on insect diversity of a selected area in Wadakkanchery (Thrissur, Kerala). *The Journal of Zoology Studies*, 2(3), 38-50.

Westfall, M. J. Jr. and K. J. Tennessen. (1996). "Odonata", *An Introduction to the Aquatic Insects of North America* 3, 164-211.

32. Woolwine, A. E. and T. E. Reagen. (2001). Potential of winter cover crops to increase abundance of *Solenopsis invicta* (Hymenoptera: Formicidae) and other arthropods in sugarcane. *Environmental Entomology*, 30(6), 1017-1020.