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Entomofaunal diversity in fruit orchards along the altitudinal gradients of district Nainital, Uttarakhand (India)

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Abstract
A study on the insect diversity in different eco-climatic altitudes of western Himalayan fruit orchards revealed that at an altitude of 1900-2200m, a total of 3,928 individuals belonging to 112 species of insect fauna from 31 families and 8 insect orders were recorded, of which 20 were abundant, 32 common, 41 uncommon and 19 were rare to the area. Lepidoptera was the most abundant order with 53 species belonging to 8 families followed by Hymenoptera (20 species), Coleoptera (14 species), Diptera (9 species), Orthoptera (8 species), Odonata (4 species), Hemiptera and Heteroptera (2 species each). Higher values of richness, abundance and diversity were recorded for the habitats at lower altitudes. Along with the altitudinal gradient, presence of vegetation and water was also found to be a very important factor for abundance and diversity of insects.

Keywords: Altitudinal gradient, insect diversity, richness, abundance

Introduction
Orchards are considered to be very suitable habitat for insects as orchards provide a good niche and also the source of food to the insects. Fruit set of most plants depends on successful pollination by wind or animals, but herbivory, nutrient availability, and microclimatic conditions may also be important (Eriksson and Ehrlén, 1992) [4]. Approximately 80 percentage of all flowering plant species are specialized for pollination by animals, mostly insects.
So far, about 100,000 species of insects are known from India, which constitute two third of the total fauna (Alfred *et al.* 1998) [2], but global biodiversity assessment estimates it to be 10-15 times more than this number (Thakur *et al.* 2008) [13]. However, 59,353 species under 619 families of 27 orders are known in India, which represents 6.08% of global insect diversity (Ghosh, 1990) [6].
Very little work has been done on the changing pattern of insect diversity along the altitudinal gradients and of fruit orchards in western Himalayas especially in Uttara Khand. The studies of insect fauna in orchards not only help in knowing the species composition of insects at different altitudes but also helps in knowing the diversity of insect pollinators and flower visitors present in the orchard and their abundance. The present study is an attempt to answer the question whether the altitude and plant diversity plays any role in determining the insect distribution.

Materials and Methods
Study area: The present study was conducted from October 2009 to September 2011 in Mukteshwar area (Ramgarh Block), of district Nainital, India. The entire area represents characteristic high altitudes environ and falls within an altitudinal range of 2,000-2,300 m. and is surrounded by fruit orchards and thick coniferous forest. For the present study, 4 study sites were selected which are as follows:

Site 1 (*Talla Ramgarh*): This site is about 10 Km from the Malla Ramgarh and about 45 Km from Mukteshwar. Talla Ramgarh lies between latitude $29^0 25' 22.2''$ N., and longitude $79^0 33' 38.6''$ E. It is situated at an altitude of 2,000 m, while the orchards are spread between 1,900 to 2,010 m asl. This site has orchards of apple, peach and khumani, dominated by peach).

Site 2 (*Naini View*): This is about 40 Km from the Nainital City and is situated at N $29^0 25' 03.6''$ and E $79^0 33' 22.3''$ at an altitude of 2,100 m asl. A new orchard of apple is being planted here.

Site 3 (*Cheepa*): It is situated at N $29^0 26' 07.4''$ and E $79^0 36' 22.8''$ and is at an altitude of 2,200 m asl. This site is close to road which leads to Mukteshwar. It has apple and peach orchards.

Site 4 (*Mukteshwar*): This site is about 55 Km from Nainital. It is situated at latitude 29^0 28′ 56.7″ N and longitude 79^0 38′ 42.0″ E and is at the highest altitude which is 2,292 m asl. It is surrounded by fruit orchards and thick coniferous forest it was developed by the Britishers as Research and Education Institute (IVRI) in 1893. The area has orchards of apple and citrus, being maintained by the IVRI.
The different study sites are located at a distance of at least 10 to 15 Km from each other.

Sampling of insects: Sampling of insects was conducted every 30 days interval from November 2009 to October 2011. At each site a specific orchard of known area was selected for sampling every month and sampling was done between 08.30 hours to 11.00 hours and then 14.00 hours to 16.30 hours. All vegetation within an orchard was swept, including grasses, herbs, shrubs, bushes and trees up to a height of 2 m.
For collecting the insects, hand picking, sweeping and beating methods were used which have successfully been used by various workers (Jonathan, 1990, Arora, 1990 and Ghosh, 1990, respectively). These were transferred in bottles containing cotton soaked with ethyl acetate. The specimens were later separated into different taxonomic groups. All specimens were pinned and oven dried at 60 ºC for 72 h to prevent decomposition. Specimens that were not readily identified using available taxonomic keys were identified by the Entomological Section of Forest Research Institute or the Regional Centre of Zoological Survey of India, Dehradun.

Measuring diversity of insects
The insect data collected in the field over the study period was analyzed and charted for species richness (the number of species), abundance (the number of individuals), and equitability (evenness) using a diversity index (Simpson's diversity index).

(i) Simpson's index (D) = sum(p_i^2)

$$D = \sum_{i=1}^{S} p_i^2$$

Where, p is the proportional abundance of the i^{th} species, given by

$$p_i = n_i / N \qquad i = 1, 2, 3, \ldots\ldots, S$$

Where n_i is the number of individuals for all S species and N is the known total number of individuals for all S species in population. With this index, 0 represents infinite diversity and 1, no diversity, that is, the bigger the value of D, the lower the diversity.

(ii) Simpson's index of diversity: 1 – D
It gives the probability that two randomly selected individuals in the zone belong to the same subspecies.

(iii) Simpson's reciprocal index: 1/D
It gives the number of equally common subspecies that will produce the observed Simpson's index.

(a) Shannon - Weaver Index
Using Shannon's diversity index (Shannon - Weaver, 1949) or Shannon - Weaver diversity (H') the species and seasonal diversity of insect pollinators was calculated as follows:

(i) Species diversity

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

(ii) Seasonal diversity:

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

Where,
H'(S) = symbol for the diversity in a sample of S species or kinds
S = the number of species in the sample
Pi = relative abundance of i^{th} species or kinds measures, = n_i/N and
qj = nj / N; N = total number of individuals of all kinds
n_i = number of individuals of i^{th} species, ln= log to base 2

Results and Discussion
Taxonomic and Species composition of insect fauna collected from study area:
The taxonomic composition of insects recorded during the study period and their presence or absence in various sites from all the four study sites has been given in Table 1. A total of 3,928 individuals belonging to 112 species of 31 families and 8 orders were recorded during the study period 2009-2011. Maximum number of species were recorded from Nymphalidae family (22 species) followed by Pieridae and Lycaenidae (9 species each). Hymenoptera was found to be the second dominant order with 20 species in which family Apidae and Vespidae had 5 species each. Minimum numbers of species (2 species each) were recorded from Hemiptera and Heteroptera.
Among the total insects recorded Lepidoptera was found to be the most dominant order with 53 species constituting about 47.32% of the total abundance followed by Hymenoptera (20 species, 17.86%), Coleoptera (14 species, 12.5%), Diptera (9 species, 8.04%), Orthoptera (8 species, 7.14%), Odonata (4 species, 3.57%), Heteroptera (2 species, 1.79%) and Hemiptera (2 species, 1.79%) shown in Table 2.

Table 1: Taxonomic composition of insect fauna collected from four study sites with different altitudes.

Taxonomic Composition	Site 1 (2000m)	Site 2 (2100m)	Site 3 (2200m)	Site 4 (2292m)	Total species
1. LEPIDOPTERA (8 Family, 53 Species)					
1. Family – Nymphalidae	**16**	**9**	**18**	**11**	**22**
1. *Neptis yerburys* But.	+	+	+	+	
2. *Vanessa indica* Herbrt.	+	+	+	+	

3. *Pyramis cardui cardui* Linn.	+	+	+	+	
4. *Atella p. phalanta* Drury.	–	–	+	–	
5. *Sephisa dichroa*	–	–	+	–	
6. *Precis iphita siccata* Stichel.	+	–	+	+	
7. *Vanessa cashmiriensis*	–	+	–	–	
8. *Pieris iphata–iphata* Cramers.	+	–	+	+	
9. *Rahinda hardonia* Stoll.	+	+	–	+	
10. *Paridis alidoneus*	+	–	+	+	
11. *Precis lemonias lemonias* Linn.	–	+	+	–	
12. *Elymnias hypermnestra undularis* Drury.	+	+	+	–	
13. *Cupha erymanthis*	+	–	–	–	
14. *Neptis* sp.	+	–	+	+	
15. *Danaus chrysippus*	+	–	–	+	
16. *Euploea core core* Cramer	+	–	+	+	
17. *Pararge schakra* Kollar	+	+	+	–	
18. *Callerebia scandal scandal* Watkins	–	–	+	–	
19. *Precis almana almana* Linn.	+	–	+	–	
20. *Aglais cashmirensis aesis* Fruhstorfer	–	+	+	+	
21. *Cynthia cardui* Linnaeus	+	–	+	–	
22. *Symbrenthia brabira* Moore	+	–	+	–	
2. Family – Pieridae	**5**	**4**	**7**	**7**	**9**
23. *Pieris canidia indica* Spar.	+	+	+	+	
24. *Pieris brassicae* Linn.	+	+	+	+	
25. *Genopteryx rhamni nepalensis* Debl.	–	–	+	+	
26. *Terias hecabe hecabe* Linn.	+	+	+	–	
27. *Catopsilia florella* Fabr.	–	–	–	+	
28. *Aporia agathan caphisa* Moore.	–	–	+	+	
29. *Colias fieldi Ministries*	–	+	–	+	
30. *Pareronia valeria hippia*	+	–	+	–	
31. *Catopsilia* sp.	+	–	+	+	
3. Family – Danaidae	**3**	**2**	**1**	**1**	**3**
32. *Danaus chrysippus* Linn.	+	+	–	–	
33. *Danaida plexippus* Linn.	+	+	–	–	
34. *Danius algae* Stall.	+	–	+	+	
4. Family – Satyridae	**1**	**0**	**0**	**0**	**1**
35. *Ypthima* sp.	+	–	–	–	
5. Family – Lycaenidae	**9**	**6**	**5**	**4**	**9**
36. *Lampides bacticus* Linn.	+	+	+	+	
37. *Chilaria kina* Hewiston.	+	+	+	+	
38. *Heodes pavana* Koll.	+	+	–	–	
39. *Heliophorus sena* Koll.	+	+	–	–	
40. *Loxura atymnus* Cramer.	+	–	–	+	
41. *Heliophorus* sp.	+	+	+	+	
42. *Arhopala rama*	+	–	–	–	
43. *Lycaena pavana* Kollar	+	+	+	–	
44. *Celatoxia marginata* de Nicéville	+	–	+	–	
6. Family – Papilionidae	**7**	**3**	**5**	**3**	**7**
45. *Byasa varuna astorian* Wd.	+	+	–	–	
46. *Papilio polytes romulus* Cramer.	+	+	–	–	
47. *Graphium* sp.	+	–	+	+	
48. *Parides* sp.	+	+	+	+	
49. *Papilio machaon* Linn.	+	–	+	+	
50. *Paridis alidoneus* Doubday	+	–	+	–	
51. *Atrophaneura latreillei latreillei* Donovan	+	–	+	–	
7. Family – Erycinidae	**1**	**0**	**0**	**0**	**1**
52. *Dodona durga* Kollar.	+	–	–	–	
8. Family– Syntomidae	**1**	**0**	**0**	**1**	**1**
53. *Ceryx imaon* cramer	+	–	–	+	
2. HYMENOPTERA (6 Family, 20 Species)					
1. Family – Apidae	**5**	**3**	**5**	**3**	**6**
54. *Apis cerana indica*	+	+	+	+	
55. *Apis laboriosa* Smith.	+	+	–	–	
56. *Apis dorsata* Fa.	+	–	+	+	
57. *Apis mellifera*	–	+	+	–	
58. *Bremus* sp.	+	–	+	+	
59. *Crocisa ramosa* Lepel.	+	–	+	–	
2. Family – Bombidae	**1**	**0**	**1**	**1**	**1**
60. *Bombus* sp.	+	–	+	+	

3. Family – Vespidae	**5**	**2**	**5**	**4**	**6**
61. *Vespa magnifica*	+	–	–	+	
62. *Vespa mandarinia*	+	+	+	+	
63. *Vespa velutina*	+	–	+	–	
64. *Vespa flaviceps*	–	–	+	–	
65. *Vespa auraria*	+	+	+	+	
66. *Polistes maculipennis* Saussure.	+	–	+	+	
4. Family – Scolidae	**4**	**2**	**3**	**5**	**5**
67. *Scolia venusta* Smith.	–	–	–	+	
68. *Campsomeris asiatica himalaya* Bar.	+	+	+	+	
69. *Phalerimeris phalerata phalerata* Saus.	+	–	+	+	
70. *Polistes hebraeus* Fabr.	+	+	+	+	
71. *Elias* sp.	+	–	–	+	
5. Family – Ropalidae	**1**	**1**	**0**	**0**	**1**
72. *Ropalidia ferugenea* Fa.	+	+	–	–	
6. Family – Eumenidae	**1**	**1**	**0**	**0**	**1**
73. *elta dimidiatipennis* Saus.	+	+	–	–	
3. COLEOPTERA (4 Family, 14 Species)					
1. Family – Scarabidae	**3**	**4**	**4**	**4**	**6**
74. *Anomala* sp.	+	+	–	–	
75. *Catharsius molossus* Linn.	–	–	+	+	
76. *Onthophagus* sp.	+	+	+	+	
77. *Brahimina* sp.	–	–	+	+	
78. *Chiloba acuta* Wied.	+	+	–	–	
79. *Anamola* sp.	–	+	+	+	
2. Family – Chrysomelidae	**1**	**1**	**0**	**0**	**1**
80. *Altica* sp.	+	+	–	–	
3. Family – Coccinelidae	**4**	**2**	**4**	**4**	**5**
81. *Coccinella septumpunchtata* L. var. divaridata	+	+	+	+	
82. *Coccinella* sp.	+	+	–	+	
83. *Cheilomenes sexmaculata*	+	–	+	+	
84. *Oenopia* sp.	–	–	+	+	
85. *Hippodamia* sp.	+	–	+	–	
4. Family – Meloidae	**1**	**0**	**1**	**2**	**2**
86. *Mylabris cichonni* Linn.	–	–	–	+	
87. *Mylabris pustulata* Thun.	+	–	+	+	
4. ORTHOPTERA (3 Family, 8 Species)					
1. Family – Acrididae	**4**	**2**	**4**	**5**	**6**
88. *Catantops humilis humilis* Serv.	+	–	–	–	
89. *Schistocerca gregaria* Forsk.	–	–	+	+	
90. *Xenocatantops karnyi* Kirby.	–	+	+	+	
91. *Oedipoda* sp.	+	+	+	+	
92. *Chorthippus* sp.	+	–	+	+	
93. *Spathosternum pr. prasiniferum* Walk.	+	–	–	+	
2. Family – Tettigonidae	**1**	**1**	**1**	**1**	**1**
94. *Aulacoborthrus leutipus* Walker	+	+	+	+	
3. Family – Gryllidae	**1**	**0**	**0**	**1**	**1**
95. *Gryllus domusticus* Linn.	+	–	–	+	
5. HEMIPTERA (2 Family, 2 Species)					
1. Family – Lygaeidae	**1**	**1**	**1**	**0**	**1**
96. *Lygaeus equestris* Linn.	+	+	+	–	
2. Family – Reduviidae	**1**	**1**	**0**	**1**	**1**
97. *Rhynocoris reuteri* Dist.	+	+	–	+	
6. HETEROPTERA (2 Family, 2 Species)					
1. Family– Pyrrhocoridae	**0**	**0**	**1**	**0**	**1**
98. *Physopelta* sp.	–	–	+	–	
2. Family– Pentatomidae	**0**	**1**	**0**	**0**	**1**
99. *Erthesina fullo* Thunb.	–	+	–	–	
7. ODONATA (2 Family, 4 Species)					
1. Family– Libellulidae	**1**	**1**	**2**	**1**	**3**
100. *Crocothemis servilia servilia* Drury	–	–	–	+	
101. *Orthetrum sabina sabina* Drury	+	+	+	–	
102. *Symtrum commixtum*	–	–	+	–	
2. Family– Coenogrionidae	**1**	**1**	**0**	**0**	**1**
103. *Ceriagrion coromandelianum*	+	+	–	–	
8. DIPTERA (4 Family, 9 Species)					
1. Family – Syrphidae	**1**	**1**	**2**	**1**	**2**
104. *Syrphus fulvifacies* Brunetti	+	+	+	+	

105. *Ascarcina ericetorum* Fabr.	–	–	+	–	
2. Family – Aslidae	**1**	**2**	**2**	**3**	**4**
106. *Stenopogan oldroydi* Josephs and Paurl	–	–	+	+	
107. *Microstylum bicolor* Macq.	–	+	–	+	
108. *Philodicus javanus* wied.	–	+	+	+	
109. *Microstylum bicolor* Macq.	+	–	–	–	
3. Family – Tabanidae	**1**	**1**	**0**	**0**	**1**
110. *Philoliche* sp.	+	+	–	–	
4. Family – Muscidae	**2**	**1**	**2**	**2**	**2**
111. *Musca domestica*	+	+	+	+	
112. *Musca nebula*	+	–	+	+	
Total	84	53	74	65	112

Species Present = + Species Absent = –

Table 2: Number of insect species belonging to different insect orders recorded from different study sites during November 2009 to October 2011.

Site No.	Site 1		Site 2		Site 3		Site 4		Total	
Order	**Species**	**%**	**Species**	**%**	**Species**	**%**	**Species**	**%**	**Species**	**%**
Lepidoptera	43	51.19	24	45.28	36	48.65	27	41.54	53	47.32
Hymenoptera	17	20.24	9	16.98	14	18.92	13	20.00	20	17.86
Coleoptera	9	10.71	7	13.21	9	12.16	10	15.38	14	12.50
Orthoptera	6	7.14	3	5.66	5	6.76	7	10.77	8	7.14
Hemiptera	2	2.38	2	3.77	1	1.35	1	1.54	2	1.79
Heteroptera	0	0.00	1	1.89	1	1.35	0	0.00	2	1.79
Odonata	2	2.38	2	3.77	2	2.70	1	1.54	4	3.57
Diptera	5	5.95	5	9.43	6	8.11	6	9.23	9	8.04
Total Species	84	75	53	47.32	74	66.07	65	58.04	112	

Total abundance and Density of entomofauna collected from the study area

The data on abundance of different study sites has been presented in Table 3 and Table 4. In the present study a total of 3,928 individuals were collected during the two years of study period (2009-2011).

During the first year of study (2009-2010) a total of 1,927 individuals were collected in all the four study sites. Maximum abundance (565 individuals) was recorded from Site 1 (Talla Ramgarh) and minimum abundance was recorded from Site 4 (Mukteshwar) whereas, during the second year of study i.e. 2010-2011, a total of 2,021 individuals were collected of which maximum abundance (619 individuals) was recorded again in Site 1 (Talla Ramgarh), and minimum in Site IV (393).

In terms of density maximum insect density during 2009-2010 was recorded in Site 1, i.e Talla Ramgarh (113 insects/ha), whereas, it was recorded maximum in the month of April, 2010 (13.60 insects/ha). The minimum insect density was recorded to be 48 insects/ha in site 2 (Naini View) and 0.80 insects/ha in the month of January of the year 2010 (Table 3).

For the year 2010-2011 the maximum insect density was recorded again in the month of April, 2011 (17.20 insects/ha), whereas, it was maximum for Site 1 i.e. Talla Ramgarh (123.80). The minimum insect density per hectare was recorded in the month of January 2011 (0.90 insects/ha) and it was recorded 46.80 insects/ha in site 2 (Naini View) as shown in Table 4.

The insect abundance and density was recorded to be decreasing as we move to higher altitude. Thus it is clear from the present study that the abundance and diversity decreases with the increase in altitude and altitude play a major role in insect abundance and diversity. In the present it was observed that in spite of having lower altitude Site 2 was found to be having least insect density this may be due to lack of other factors such as water and floristic diversity. Temperature and Humidity were also recorded on every sampling date but not much difference was found in both the parameters but there was a difference in floristic diversity (Table 5) and availability of water in the study sites. This may be the cause of decline in the insect fauna abundance and diversity of Site 2.

Table 3: Variation in Abundance and density (ha^{-1}) of herbivorous insects collected during 2009-2010.

			Monthly Abundance and Density 2009-2010												Total
			2009		2010										
S. No.	**Site**		**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	
1	Site 1	Abundance	43	21	18	19	53	68	66	62	58	57	52	48	565
	05 ha.	Density	8.60	4.20	3.60	3.80	10.60	13.60	13.20	12.40	11.60	11.40	10.40	9.60	113.00
2	Site 2	Abundance	28	10	8	11	58	87	68	49	47	45	36	33	480
	10 ha.	Density	2.80	1.00	0.80	1.10	5.80	8.70	6.80	4.90	4.70	4.50	3.60	3.30	48.00
3	Site 3	Abundance	44	18	12	15	34	76	71	68	56	46	43	44	527
	08 ha.	Density	5.50	2.25	1.50	1.88	4.25	9.50	8.88	8.50	7.00	5.75	5.38	5.50	65.88
4	Site 4	Abundance	24	14	10	13	18	54	48	42	38	33	29	32	355
	06 ha.	Density	4.00	2.33	1.67	2.17	3.00	9.00	8.00	7.00	6.33	5.50	4.83	5.33	59.17
	TOTAL	Abundance	139	63	48	58	163	285	253	221	199	181	160	157	1927
	29 ha.	Density	4.79	2.17	1.66	2.00	5.62	9.83	8.72	7.62	6.86	6.24	5.52	5.41	66.45

Table 4: Variation in Abundance and density (ha^{-1}) of herbivorous insects collected during 2010-2011.

			Monthly Abundance and Density 2010-2011												Total
			2010		2011										
S. No.	Site		Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	
1	Site 1	Abundance	42	21	17	22	58	86	76	72	66	62	52	45	619
	05 ha.	Density	8.40	4.20	3.40	4.40	11.60	17.20	15.20	14.40	13.20	12.40	10.40	9.00	123.80
2	Site 2	Abundance	26	12	9	11	62	72	64	52	44	48	36	32	468
	10 ha.	Density	2.60	1.20	0.90	1.10	6.20	7.20	6.40	5.20	4.40	4.80	3.60	3.20	46.80
3	Site 3	Abundance	44	14	10	17	32	68	72	66	60	56	54	48	541
	08 ha.	Density	5.50	1.75	1.25	2.13	4.00	8.50	9.00	8.25	7.50	7.00	6.75	6.00	67.63
4	Site 4	Abundance	26	11	9	7	38	51	54	48	39	42	36	32	393
	06 ha.	Density	4.33	1.83	1.50	1.17	6.33	8.50	9.00	8.00	6.50	7.00	6.00	5.33	65.50
	Total	Abundance	138	58	45	57	190	277	266	238	209	208	178	157	2021
	29 ha.	Density	4.76	2.00	1.55	1.97	6.55	9.55	9.17	8.21	7.21	7.17	6.14	5.41	69.69

As maximum (97 species) were recorded from the site 4 but still less species were recorded from that site due to higher altitude but beside having low altitude Site 2 had low number of insects due to low floristic diversity (43 species). It is clear from the present study that altitude is the primary cause of decline of insect diversity as it kept on decreasing as we move to higher altitudes on the other hand other factors such as floristic diversity also play a very important secondary role. This might be because the insects have more choices in the off seasons of the orchards for foraging if more plants are present near the orchards. Thus floristic diversity is the other important parameter in determining the insect diversity in an orchard. Thus it is beneficial to plant more flowering trees and plants in and around the orchards so that insects could forage on them in the adverse conditions.

Table 5: Plant species recorded from different study sites during study period (2009-11).

S. No	Flora Scientific Name	Site 1	Site 2	Site 3	Site 4
TREES					
1	*Xanthoxylum achanothopodum*	–	+	+	+
2	*Lyonia ovalifolia*	–	–	+	+
3	*Punica granatum*	–	–	–	+
4	*Datura fastuosa*	+	–	–	–
5	*Betula utilis*	+	–	–	+
6	*Artemisia sps.*	–	–	+	+
7	*Prunus cerasoides*	+	+	–	–
8	*Quercus glauca*	–	–	–	+
9	*Ficus* spp.	+	–	–	–
10	*Emblica officinalis*	–	–	–	+
11	*Mangifera indica*	+	–	–	–
11	*Azadirachta indica*	+	–	–	+
12	*Quercus floribunda*	+	+	+	+
13	*Quercus leucotrichophora*	–	–	+	+
14	*Quercus semecarpifolia*	–	+	+	+
15	*Taxus wallichiana*	–	–	+	+
16	*Ficus auriculata*	–	–	–	+
17	*Myrica esculenta*	+	–	+	+
18	*Juglans regia*	–	–	–	+
19	*Cedrus deodara*	+	–	+	+
20	*Rhododendron arboreum*	+	+	+	+
21	*Rhododendron barbatum*	+	–	+	+
22	*Pinus longifolia*	+	+	+	+
23	*Pyrus malus*	+	+	+	+
24	*Cupressus torulosa*	–	+	–	+
25	*Citrus reticulate*	–	–	–	+
26	*Pyrus communis*	+	+	+	+
27	*Prunus domestica*	+	–	+	–
28	*Prunus persica*	+	+	+	+
29	*Aconitum heterophyllum*	+	–	+	+
30	*Alnus nepalensis*	+	+	–	+
31	*Phyllanthus emblica*	–	–	+	–
32	*Centella asiatica*	–	–	–	+
34	*Prunus armeniaca*	–	+	+	–
35	*Acacia catechu*	–	+	–	+
36	*Citrus aurantifolia*	–	–	+	+
37	*Citrus limon*	+	–	–	–
38	*Jacaranda mimosifolia*	+	–	–	+
39	*Cinnamomum tamala*	–	–	+	+
40	*Zanthoxylum armatum*	+	–	+	+
41	*Pyrus pashia*	–	+	–	+
42	*Betula alnoides*	–	–	+	+
43	*Indigofera* spp.	+	+	–	+
44	*Aesculus indica*	–	–	+	+
45	*Fraxinus micrantha*	–	–	+	+
46	*Platanus orientalis*	–	+	–	+
47	*Rosa moschata*	+	–	+	+
48	*Cupressus torulosa*	–	–	–	+
49	*Salix acmophylla*	+	–	–	+
50	*Juglans regia*	–	–	+	+
51	*Populous ciliate*	–	–	–	+
52	*Cedrela toona*	+	+	–	–
53	*Ilex dipyrena*	+	+	–	–
54	*Morus alba*	–	–	+	+
55	*Pinus roxburghii*	+	+	+	+
56	*Pinus excels*	–	–	–	+
57	*Litsea umbrosa*	+	–	+	+
58	*Murraya koenigii*	–	–	+	–
59	*Lyonia ovalifolia*	+	+	+	+
60	*Citrus aurantifolia*	+	–	–	–
61	*Citrus limon*	+	–	–	–
SHRUBS					
1	*Anaphalis triplinervis*	+	–	–	+
2	*Berberis vulgaris*	–	–	–	+
3	*Punica granatum*	+	–	+	+
4	*Artemisia annua*	–	–	–	+
5	*Ocimum sanctum*	+	+	+	+
6	*Morchella esculenta*	–	–	–	+
7	*Musa paradisiaca*	+	–	+	–
8	*Cannabis sativa*	+	+	–	–
9	*Berberis asiatica*	+	+	+	+
10	*Urtica dioica*	+	+	+	+
11	*Urtica parviflora*	+	–	–	–
12	*Drosera peltata*	–	–	–	+
13	*Pyracantha crenulata*	+	–	–	+
14	*Rubus foliolosum*	–	–	–	+
15	*Rubus niveus*	–	–	–	+
16	*Agave Americana*	+	–	–	–
17	*Tagetes erecta*	+	+	+	+
18	*Jacaranda mimosifolia*	+	–	–	+
19	*Rhamnus variegata*	+	–	+	+
20	*Lycopersicon esculentum*	–	–	+	+
21	*Solanum tuberosum*	+	+	+	+
22	*Rosa domestica*	+	–	+	+
23	*Rubus lasiocarpus*	+	+	+	+
24	*Sida cordifolia*	–	–	–	+
25	*Rosa macrophylla*	+	–	–	–
26	*Indigofera geradiana*	–	–	+	–
27	*Berberis chitria*	+	+	–	+
28	*Berberis aristata*	–	–	+	–
29	*Solanum* spp.	+	–	+	–
30	*Spiraea canescens*	+	–	–	–

31	*Abelmoschus* spp.	–	–	+	–
32	*Euonymus pendulus*	+	–	+	–
33	*Leptodermis lanceolata*	+	–	+	–
34	*Buddleja paniculata*	–	–	+	–
35	*Rhamnus variegata*	+	–	+	–
36	*Lonicera quinquelocularis*	+	–	+	–
37	*Hypericum patulum*	+	–	+	–
38	*Viburnum cotinifolium*	+	–	+	–
39	*Carex* spp.	–	–	+	–
40	*Clematis montana*	+	–	–	–
41	*Coriaria nepalensis*	+	–	+	–
42	*Rumex hastatus*	–	–	+	–
43	*Geranium* spp.	+	+	–	+
44	*Butea frondosa*	–	+	–	+
45	*Sarcococca hookeriana*	+	+	–	+
46	*Rubus biflorus*	+	–	–	+
47	*Buddleja paniculata*	–	+	–	+
HERBS					
1	*Sporoplus* spp.	–	–	–	+
2	*Origanum vulgare*	+	+	–	+
3	*Trifolium repens*	+	–	–	+
4	*Thalictrum pauciflorum*	–	+	–	+
5	*Gerium* spp.	+	–	–	+
6	*Gnaphalium luteo album*	–	+	–	+
7	*Chrysanthemum* spp.	+	–	–	+
8	*Cynodon dactylon*	+	+	+	+
9	*Erigeron* spp.	–	–	–	+
10	*Lantana camara*	+	–	+	–
11	*Antirrhinum* spp.	–	+	–	+
12	*Orchis latifolia*	+	–	–	+
13	*Brassica juncea*	+	+	+	+
14	*Pisum sativum*	–	+	+	+
15	*Triticum vulgare*	–	+	–	+
16	*Hordeum vulgare*	+	–	–	+
17	*Coriandrum sativum*	+	+	+	+
18	*Brassica campestris*	–	–	–	+
19	*Chrysopogon gryllus*	+	–	+	–
20	*Datura fastuosa*	–	+	–	+
PARASITE					
1	*Dendrophthoe falcate*	+	+	+	+
2	*Balanophora involucrata*	–	–	–	+
BAMBOO					
1	*Dendrocalamus strictus*	–	–	–	+
CLIMBER					
1	*Tropaeolum majus*	–	–	+	+
2	*Cucumis melo*	–	–	+	+
Total		74	43	66	97

Species Present (+) Species Absent (–)

Shannon-Wiener Index

The Shannon - Wiener index was calculated to determine the diversity of insect pollinators in the study area as shown in Table 6.

During the first year of study (2009-2010) the maximum Shannon Diversity (H') was recorded in the month of April (1.32664) and minimum value was recorded in the month of January (1.09634), Whereas, during the second year of study (2010-2011) the maximum value of H' was recorded again in the month of April (1.31309) and minimum value was recorded in the month of January (1.08841). The mean Shannon diversity (H') for the year 2009-2010 (1.220858) was recorded slightly higher in comparison to 2010-2011 (1.22028), whereas, the mean diversity was recorded maximum in the month of April (1.319879) and minimum in the month of January (1.092374). Kaushal and Vats (1981) [10] reported that the species diversity of insects in tropical grassland for two different habitats was 1.0836 and 1.0856 respectively. Ent and Shaw (1998) reported the alpha diversity of Hymenoptera, which was 1.665 in both U.S.A. and Canada, 5.291 and 20.822 in Mexico and Costa Rica.

Simpson's Index

As shown in Table 7, during 2009-2010 the maximum species richness (D) was recorded in the month of March (0.28365) while its minimum value was recorded in the month of November (0.12585). In the second year of study (2010-2011) maximum richness was recorded in the month of February (0.27757) and minimum in the month of November (0.12091). The annual richness (0.25654) recorded in the second year of study was higher than in the first year (0.25636).

Table 6: Monthly mean Shannon diversity (H') of insect in the study sites during 2009-2011.

S. No	Month	2009-2010	2010-2011	Mean Diversity
1	November	1.208832	1.20115	1.20499
2	December	1.118323	1.10728	1.112802
3	January	1.09634	1.08841	1.092374
4	February	1.111204	1.10588	1.108541
5	March	1.232357	1.24892	1.240637
6	April	1.326664	1.31309	1.319879
7	May	1.305474	1.30591	1.305693
8	June	1.28192	1.28647	1.284197
9	July	1.264231	1.26446	1.264348
10	August	1.248773	1.26367	1.256221
11	September	1.229522	1.2386	1.234063
12	October	1.226658	1.21956	1.22311
Mean Diversity		1.220858	1.22028	1.220571

Table 7: Monthly values of Simpson Index recorded during 2009-2011.

	D		1-D		1/D	
Month	**2009-2010**	**2010-2011**	**2009-2010**	**2010-2011**	**2009-2010**	**2010-2011**
November	0.12585	0.12091	0.87415	0.87909	7.94615	8.27034
December	0.20712	0.19812	0.79288	0.80188	4.82818	5.04733
January	0.25887	0.25556	0.74113	0.74444	3.86301	3.91304
February	0.24743	0.27757	0.75257	0.72243	4.04156	3.60271
March	0.28365	0.26416	0.71635	0.73584	3.5255	3.78558
April	0.25451	0.25543	0.74549	0.74457	3.92913	3.91499
May	0.25209	0.25118	0.74791	0.74882	3.9669	3.98114
June	0.25529	0.2537	0.74471	0.7463	3.91718	3.94172
July	0.25263	0.25773	0.74737	0.74227	3.95841	3.88004
August	0.2547	0.25177	0.7453	0.74823	3.92625	3.97196
September	0.25668	0.255	0.74332	0.745	3.89587	3.92158
October	0.25298	0.25396	0.74702	0.74604	3.95287	3.93762
Total Mean	0.25636	0.25654	0.74364	0.74346	3.90078	3.89806

The values of 1–D (the probability that two randomly selected individuals in the zone belong to the same subspecies) was recorded maximum in the month of November (0.87415), while it was recorded minimum in the month of March (0.71635) during 2009-2010. In the following year, the maximum was recorded in the month of November (0.87909) while, the minimum was recorded in February (0.72243). The annual average value of 1-D during 2010-2011 (0.74346) was low as compared to 2009-2010 (0.74364). The values of 1/D (the number of equally common subspecies that will produce the observed Simpson's index) during 2009-2010 was recorded maximum in the month of November (7.94615), while it was recorded minimum in the month of March (3.5255). Similarly during 2010-2011 the maximum value of 1/D was obtained in the month of November (8.27034), while the minimum value was obtained in the month of February (3.60271). The mean value of 1/D was recorded higher (3.90078) in 2009-2010 in comparison to 2010-2011 (3.89806). Similar kind of results have been reported by Kaushal and Vats (1981) [10]; Gupta and Vats (1983) [7], Gadagkar *et al.* (1990) [5], Vashishth *et al.* (2002) [14], Kalita and Barua (2002) [9] and Tewari and Kaushal (2007) [12].

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