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INSECT POLLINATOR ASSEMBLAGE ON TEMPERATE FRUIT CROPS IN KUMAUN HIMALAYA

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ABSTRACT

Kumaun Himalaya harbors a number of temperate fruits crops such as apple, peach, apricot, plum, pear and kiwi that support the fruit growers of the Uttarakhand state. The present study was conducted in temperate fruit orchards located in hills of Nainital district of Kumaun Himalayan region of Uttarakhand state. Information on the distribution of insect pollinators led to many important details. A total of 92 species insect pollinators under 59 genera of 25 families and four orders were recorded. Lepidoptera was the most dominant order whereas Coleoptera was the least dominant. The results revealed that *Apis cerana* F. was the most abundant species. As per Margalef's index, species richness of pollinators was observed to be maximum in apple.

Key words: Temperate fruits, apple, peach, apricot, plum, pear, kiwi, insects, pollinators, species diversity, richness, dominance, Lepidoptera, Coleoptera

Pollination is an important ecosystem service for the maintenance and conservation of biodiversity. Wind, water, and gravity as abiotic, and insects, birds, bats and small mammals as biotic agents provide this service (Sharma and Mitra, 2012; Mattu and Bhagat, 2015). The pollination is declining due to reduction in pollinators (Moisset and Buchmann, 2011; Bhattacharyya and Chakraborty, 2014). Pollination is prerequisite for the efficiency of the vast majority of the yields in agrarian and horticultural ecosystems. This is carried out mostly by insects which are the prime agents of pollination (Riaz et al., 2018). Diversity of pollinators benefit society by improving living conditions and increasing food security. The relationship between flowering plants and the flower visiting insects is essential for the conservation of terrestrial ecosystem. Any loss of biodiversity is a matter of public concern, but pollinator losses, especially insects, may be disturbing due to potential impacts on flowering plant reproduction of and hence on food security (Khan and Khan, 2004; Solar et al., 2009; Mattu and Nirala, 2016). Many insects are of prime significance in the pollination of horticultural and agricultural crops- these include Hymenoptera (bees, ants and wasps), Diptera (flies, mosquitoes etc.), Lepidoptera (butterflies and moths), Coleoptera (beetles and weevils) and Thysanoptera (thrips). Of these Hymenoptera are the most important and abundant (Mattu and Bhagat, 2015). Honeybees form major proportion of insect pollinators on different temperate fruit crops (McGregor, 1976; Mishra et al., 1976; Verma and Chauhan, 1985; Verma, 1990; Free, 1993; Mattu and Mattu, 2010; Joshi and Joshi, 2010a&b; Raj et al., 2012; Sharma et al., 2013; Mattu and Bhagat, 2016). Variation in abundance, density and diversity of insect pollinators in the temperate fruit orchards of India and forest ecosystems of the different parts of world have been explored (Verma and Chauhan, 1985; Larsan et al., 2001; Mishra et al., 2004; Joshi and Joshi, 2010a&b; Takur and Mattu, 2010; Mattu et al., 2012; Raj et al., 2012; Ganie et al. 2013; Pandey et al., 2013; Raj and Mattu, 2014; Arya, 2015; Mattu and Bhagat, 2015; Sathe and Gophane, 2015; Mattu and Nirala, 2016; Garibaldi et al., 2016; Kapkoti et al., 2016; Dar et al., 2017; Altaf et al., 2017; Arya et al., 2018; Riaz et al., 2018). However, no attempts have so far been made to study the species composition, abundance, distribution, and diversity of insect pollinators in temperate fruit crops of the Kumaun hills of Uttarakhand. The present study provides details on species composition, abundance, distribution, and diversity of insect pollinators in temperate fruit crops of Kumaun hills, Western Himalaya, Uttarakhand, India.

MATERIALS AND METHODS

The study was conducted in blooming seasons of selected fruit crops (apricot, apple, kiwi, peach, plum, pear) in the hilly region of the Nainital district of Uttarakhand during 2019. Eight fruit orchards, namely

Ramgarh, Mukteshwar, Dhanachuli, and Paharpani, each with two orchards were focused. Ramgarh (29°26.642′N,79°36.235′E, 2305 masl) is bounded by fruit orchards on terraces cut into hilly sides surrounded by oak and coniferous forests. The vegetation of the surroundings is enriched by the presence of *Quercus leucotricophora*, followed by *Cedrus deodara*, *Rhododendron arboreum*, *Acer oblongum* with scattered *Eucalyptus regnans*, *Berberis asiatica*, *Berbaris vulgare, Berberis chitria, Artimesia anua, Berbaris chitria, Dhatura fatuosa, Anaphalis triplinens, Rosa lasiocarpus, Erigeron* sp. and *Cynadon dactylon* as the understory and ground flora. Five fruits crops apples, peaches, pears, apricots, and plum were selected from here, situated in the Satbunga and Khabrar village. Mukteshwar (29°27′ N, 79°39′ E, 2286 masl) has a variety of flora dominated by *Quercus incana*, *Pinus roxburghii*, *C. deodara*, *R. arboreum* as the canopy; *Pyracantha enulata*, *Rubus ellipticus*, *R. lasiocarpus*, *Pyrus pashia*, *Berberis aristata*, *B. asiatica*, *B. vulgare, R.lasiocarpus, Indigofera gerardiana,* and *Desmodium* sp. as the understory; whereas species of *A.triplinens, Anaphalis* sp., *Leucas*, *Senecio*, *Dicliptera*, *Valeriana*, *Viola*, *Bergenia*, *Erigeron* sp. *Cynadon dactylon,* and various other grasses form the ground flora. Apples, peaches, pears, apricots, cherry, plum, walnut, and citrus on terraces cut into the hillsides are the crops here.

The two fruit orchards selected are located inside the Central Institute of Temperate Horticulture, Regional station, Mukteshwar. Apples, peaches, pears, apricots and plum were selected (29°23.802′ N, 79°39.443′ E, 2115 masl); here agriculture mainly consists of potato mixed with seasonal vegetables and is bounded by temperate fruit tree orchards. A large portion of the land is converted into orchards for growing apples, peaches, pears, apricots, plum, walnut and citrus on terraces cut into the hillsides. The area has a spare cover of *C. deodara*, *Q.incana*, *R. arboreum*, *A. oblongum*, *Aesculus indica*, *Myrica esculenta, P. roxburghii*, *Juglens regia,* and *R.ellipticus Berberis asiatica*, *B.vulgare, R.lasiocarpus, A.anua, Berbaris chitria, Dhatura fatuosa, Anaphalis triplinens, Erigeron* sp. as the understory and ground flora. Six fruit crops like apples, peaches, pears, apricots, plum and Kiwi were selected in the Dhanachuli village. Paharpani (29°38'N, 79°52'E, 1900-1950 masl) from here is the best known location of temperate fruit orchards of apple, plum, peach, pear, plum, apricot, walnut, citrus and kiwi; and here area is surrounded by thick dense forest characterized by four major tree associations of oak forest, oak-pine mixed forest, oak scrub and chir-pine mixed forest. The vegetation is mainly dominated by Banj (*Quercus leucotricophora*, *Q. lanata* and *Q. glauca*), *P. roxburghii*, *C.deodara*, *A.indica*, *R.arboreum*, *Lyonia ovalifolia*, *Myrica nagi, J. regia* and *P.pashia*. Among the shrubs and herbs, *Rubus biflorus*, *R. ellipticus*, *Berberis asiatica*, *B. vulgans, Pyracantha crenulata*, *Lantana camara, A. anua, Indigofera* sp., *Desmodium* sp., *A. triplinens, R.lasiocarpus, D. fatuosa, Erigeron* sp. and *C. dactylon* are common. Six fruits crops like apples, peaches, pears, apricots, plum, and kiwi were selected in this Paharpani area.

Observations of insect pollinators (direct sighting) were carried out in the selected blocks between 8:00 to 16:00 hours during February- May, 2019 when the orchards were in full bloom. The collected samples of insect pollinators were then confirmed by the literature available. The identification of sampled insects was done with literature and insect guides available in the Department of Zoology, D S B Campus, Kumaun University, Nainital. The insect specimens which could not get identified in the laboratory were identified by scientists in the Entomological Section, Forest Research Institute, Dehradun and Northern Regional Station, Zoological Survey of India, Dehradun. Various diversity indices were calculated using the software program PAST version 3.4. Bray-Curtis cluster analysis (quantitative analysis) was performed to find out the similarity of insects using the software program Biodiversity Pro (McAleece et al., 1997).

RESULTS AND DISCUSSION

A total of 2488 individuals of insect pollinators belonging to 92 species of 59 genera under 25 families and four orders were recorded (Table 1). Fig. 1 provides the variation in the number of species and individuals; Lepidoptera was the most dominant with 53 species accounting for 57.60%; followed by Hymenoptera

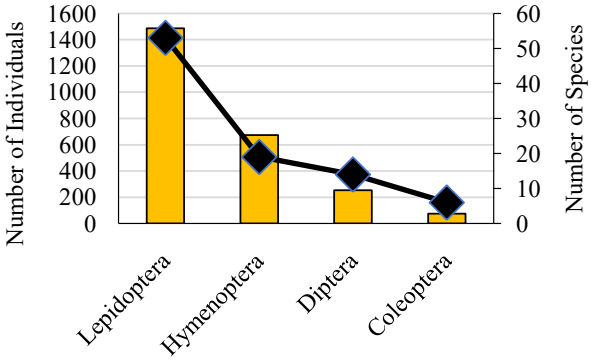

Fig. 1. Species richness/ individuals of pollinator insects of insect orders

Table 1. Species composition, distribution, and relative abundance of insect pollinators

S. No.	Species	Apple	Peach	Pear	Apricot	Plum	Kiwi	Relative Abundance
	Lepidoptera							
	Nymphalidae							
1.	*Acraea issoria* (Hubner)	-	-	-	-	+	-	0.60
2.	*Aglias caschmirensis* (Kollar)	+	+	+	+	+	+	4.42
3.	*Argynnis hyperbius* (L.)	+	-	-	-	-	-	2.41
4.	*Aulocera swaha* (Kollar)	-	-	-	+	+	+	1.60
5.	*Danaus chrysippus* (L.)	-	-	-	+	-	-	0.80
6.	*Danaus genutia* (Cramer)	+	+	-	-	+	-	0.60
7.	*Issoria lathonia* (L.)	+	+	+	+	+	+	1.60
8.	*Euploea core* (Cramer)	-	-	-	-	+	-	0.60
9.	*Euthalia aconthea* (Cramer)	-	-	-	-	-	+	0.40
10.	*Lasiommata schakra* (Kollar)	-	-	-	-	-	+	0.20
11.	*Neptis sankara* (Kollar)	+	-	-	-	-	-	1.00
12.	*Symbrenthia lilaea* Moore	-	+	-	-	-	-	0.20
13.	*Venessa cardui* (L.)	+	+	+	+	+	+	3.01
14.	*Venessa indica* (Herbst)	+	+	+	-	+	+	2.00
15.	*Ypthima nareda* (Kollar)	-	-	+	-	-	-	1.00
	Family: Pieridae							
16.	*Aporia agathon* (Gray)	+	+	+	-	-	-	1.60
17.	*Catopsilia pomona* F.	+	+	-	+	-	-	2.00
18.	*Catopsilia pyranthe* (L.)	+	-	-	-	-	-	1.60
19.	*Colias electo fieldii* Menetries	-	+	-	-	-	-	2.00
20.	*Colias erate* (Esper)	+	-	-	-	-	-	1.00
21.	*Delias belladonna* (F.)	+	+	+	-	-	-	1.00
22.	*Delias sanaca* (Moore)	-	-	-	-	+	-	0.80
23.	*Eurema andersoni* (Moore)	+	-	-	-	-	-	0.60
24.	*Eurema blanda* (Boisduval)	-	+	-	-	-	-	0.60
25.	*Eurema brigata* (Stoll)	-	-	+	+	-	-	0.40
26.	*Eurema lata* (Boisduval)	-	-	-	+	-	-	0.20
27.	*Gonepteryx mahaguru* Gistel	+	-	+	-	+	-	1.60
28.	*Gonepteryx rhamni* (L.)	+	+	-	+	-	-	2.41
29.	*Pieris brassicae* (L.)	+	+	+	+	+	+	4.74
30.	*Pieris canidia* (Sparrman)	+	+	+	+	+	+	4.01
31.	*Pontia daplidice* (L.)	+	-	-	-	-	-	0.20
	Papilionidae							
32.	*Atrophaneura aidoneus* Doubleday	-	-	+	-	-	-	1.20
33.	*Byasa polyeuctes* (Doubleday)	-	-	-	+	-	-	0.60
34.	*Graphium eurous* (Leech)	-	+	-	-	-	-	1.00
35.	*Graphium nomius* (Esper)	+	-	-	-	-	-	0.40
36.	*Papilio bianor* Cramer	-	-	-	-	+	-	0.20
37.	*Papilio demoleus* L.*	-	-	-	-	-	+	0.40
38.	*Papilio machon* L.	+	+	+	+	+	-	0.60
39.	*Papilio polyctor* Boisduval	-	+	-	-	-	-	0.40
40.	*Papilio polytes* L.*	-	-	-	-	-	+	0.36
	Lycaenidae							
41.	*Heliophorus sena* (Kollar)	-	-	-	-	-	+	1.60
42.	*Lampides boeticus* (L.)	-	-	-	-	+	-	1.20
43.	*Lycaena pavana* (Kollar)	+	+	-	-	-	-	0.80
44.	*Lycaena phlaeas* (L.)		+	-	-	-	-	0.60
45.	*Udara albocaeruleus* (Moore)	+	-	-	-	+	-	0.20
46.	*Talicada nyseus* (Guerin-Meneville)	-	-	-	-	-	+	0.28
	Riodinidae							
47.	*Abisara bifasciata* Moore	-	+	-	-	-	-	0.48
48.	*Dodona durga* (Kollar & Redtenbacher)	+	-	-	+	-	-	0.73
	Family: Sphingidae							
49.	*Daphnis nerii* (L.)	-	-	-	+	-	-	0.20
50.	*Macroglossum affictitia* Butler	+	+	-	-	-	-	1.28
51.	*Macroglossum nycteris* Kollar	+	+	-	-	-	-	1.00
	Saturnidae							
52.	*Actias selene* Hubner	-	-	-	-	-	+	0.40

(contd.)

(Table 1 contd...)

	Family: Erebidae							
53.	*Syntomoides imaon* Cramer	+	-	-	-	-	-	0.48
	Hymenoptera							
	Apidae							
54.	*Apis cerana* F.	+	+	+	+	+	+	5.62
55.	*Apis dorsata* F.	+	+	+	+	+	-	4.01
56.	*Apis mellifera* L.	+	+	+	+	+	+	2.81
57.	*Apis laboriosa* Smith	+	-	-	-	-	-	1.20
58.	*Xylocopa bentoni* Cockerell	+	-	-	-	-	-	1.00
59.	*Xylocopa auripennis* Lepeletier	-	+	-	-	-	-	1.00
60.	*Bombus haemorrhoidalis* Smith	+	+	+	+	+	-	0.72
61.	*Bombus* sp.	+	+	+	-	-	-	0.40
	Vespidae							
62.	*Eumenes petiolata* F.	+	-	-	-	-	-	1.60
63.	*Polistes rufolineatus* Cameron	+	-	-	-	-	-	2.41
64.	*Polistes maculipennis* Saussure	-	+	-	-	-	-	1.40
65.	*Vespa basalis* Smith	+	+	-	-	-	-	0.60
	Scoliidae							
66.	*Capsomeris* sp.	+	+	-	-	-	+	1.44
67.	*Scolia affinis* Guerin	-	-	+	-	-	-	0.80
68.	*Scolia venustata* Smith	+	-	-	-	-	-	0.40
	Formicidae							
69.	*Componotus* sp.	-	+	+	+	-	-	0.28
70.	*Camponotus compressus* (F.)	+	-	-	-	-	-	0.12
	Family: Halictidae							
71.	*Halictus spp.*	-	-	+	-	+	-	0.40
	Sphecidae							
72.	*Ammophila atripes* Smith	-	-	-	+	-	-	0.80
	Diptera							
	Syrphidae							
73.	*Eristalis cerealis* F.	-	-	+	+	-	-	1.40
74.	*Eristalis himalayensis* Brunetti	+	-	-	-	-	-	0.36
75.	*Eristalis tenax* (L.)	+	+	+	+	+	+	0.80
76.	*Episyrphus balteatus* (De Geer)	+	-	+	-	+	-	1.00
77.	*Syrphus fulvifacies* Brunetti	+	+	+	+	+	+	1.60
	Tachinidae							
78.	*Gonia rufitibialis* Walker	-	+	-	-	-	-	1.80
79.	*Gonia* sp.	+	-	-	-	-	-	0.24
	Tabanidae							
80.	*Phililiche longirostris* (Hardwicke)	-	+	-	-	-	-	0.12
81.	*Tabanus orientis* Walker	+	-	-	-	+	-	0.28
82.	*Hybomitra* sp.	-	-	-	-	+	-	0.16
	Calliphoridae							
83.	*Lucilia sericata* Meigen	+	-	-	-	+	-	0.64
	Muscidae							
84.	*Musca domestica* L.	+	-	+	-	-	-	0.48
	Sarcophagidae							
85.	*Sarcophaga* sp.	+	+	-	-	-	-	0.40
	Tipulidae							
86.	*Tipula* sp.	-	-	-	-	+	-	0.80
	Coleoptera							
	Scarabaeidae							
87.	*Cetonia bensoni* (Westwood)	-	+	-	-	-	-	1.04
	Coccinellidae							
88.	*Coccinella septempunctata* (L.)	+	+	+	-	+	-	0.40
89.	*Coccinella transversalis* (F.)	-	-	-	+	-	-	0.24
	Chrysomelidae							
90.	*Altica cyanea* (Weber)	+	-	-	-	-	-	0.72
	Meloidae							
91.	*Mylabris cichorii* L.	+	+	-	-	+	-	0.40
92.	*Mylabris pustulata* (Thunberg)	-	-	+	-	-	-	0.16
	Total	51	40	28	25	30	19	

(Abbreviations used: + = species present; - = species absent; * = insect species also act as pest)

with 19 species (20.65 %), *Apis cerana* F. was the most abundant (5.62 %). *Philoliche longirostris, Componotus compressus, Hybomitra* species, and *Mylabris pustulata* were found to be the least abundant. Families of insect pollinators are as given in Fig. 2. Across the four major temperate fruit growing belts studied, maximum number of species were observed from the Dhanachuli region (81 species) followed by others. Data in Table 2 reveals that apple flowers were visited by 935 individuals, 51 species under 20 families of four orders. Of these, Lepidoptera was the most dominant order with 26 species. The flowers of apple, peach, plum, and pear were visited by 51 species (20 families), 40 species (17 families), 30 species (14 families), and 11 species (12 families) of insect pollinators, respectively. Likewise, apricot and kiwi flowers were visited by 25 species (9 families) and 19 species (8 families); peach flowers by 534 individuals under 40 species and 17 families, with

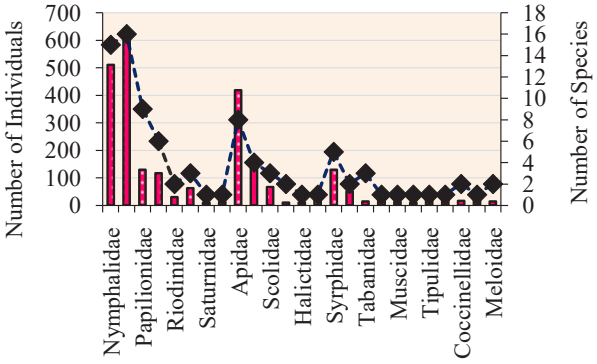

Fig. 2. Species/ individuals of families of insect pollinators

Lepidoptera being the most dominant, and with the family, Pieridae represented by 8 species. Plum flowers were visited by 278 individuals under 30 species and 14 families and of these, Lepidoptera was the most dominant; and pear was visited by 304 individuals under 28 species and 11 families, with Lepidoptera being the most dominant. Apricot flowers were visited by 360 individuals under 25 species and 9 families with Lepidoptera again being the most dominant order with 15 species. Kiwi flowers were visited by 168 individuals under 19 species and 8 families, and Lepidoptera was the most dominant.

Table 3 provides details of richness of insect pollinators across fruit crops as calculated with Margalef's index- maximum value was in apple (7.309), followed by peach (6.193), plum (5.153), pear (4.723), apricot (4.316) and kiwi (3.513) respectively. The calculated values of the evenness were 0.847, 0.766.765, 0.750, 0.746, and 0.720 for apricot, apple, kiwi, plum, pear, and peach, respectively. Shannon-Weiner index were found to be- for apple (3.665), peach (3.361), plum (3.114), apricot (3.053), pear (3.040), and kiwi (2.677). Thus, maximum diversity was recorded in apple, peach, and pear crops. The single linkage Bray- Curtis cluster analysis of species richness showed the % of similarity of insect pollinators (Fig. 3)- showing two major clusters, first cluster being kiwi, plum, apricot, and pear, while the second cluster being of apple and peach. Thus, the 92 species of insect pollinators fall under 25 families with maximum species belonging to the orders

Table 2. Relative number of individuals/ species of pollinators of fruit crops

Orders	Apple	Peach	Pear	Apricot	Plum	Kiwi	No. of individuals/ species
Lepidoptera	527/26	308/22	173/13	166/15	179/16	135/14	1488/53
Hymenoptera	309/12	145/10	78/8	66/6	50/5	26/3	674/19
Diptera	73/10	59/5	45/5	22/3	46/7	7/2	252/14
Coleoptera	26/3	31/3	8/2	6/1	32/2	--	74/6
Total (Indv./Sp.)	935/51	543/40	304/28	260/25	278/30	168/19	2488/92

Table 3. Diversity indices of insect pollinators of fruit crops

Diversity indices	Apple	Peach	Pear	Apricot	Plum	Kiwi	Total
Taxa_S	51	40	28	25	30	19	92
Individuals	935	543	304	260	278	168	2488
Dominance_D	0.031	0.043	0.057	0.052	0.053	0.094	0.021
Simpson_1-D	0.969	0.956	0.942	0.947	0.946	0.905	0.978
Shannon_H	3.665	3.361	3.040	3.053	3.114	2.677	4.153
Evenness_e^H/S	0.766	0.720	0.746	0.847	0.750	0.765	0.691
Margalef's	7.309	6.193	4.723	4.316	5.153	3.513	11.64

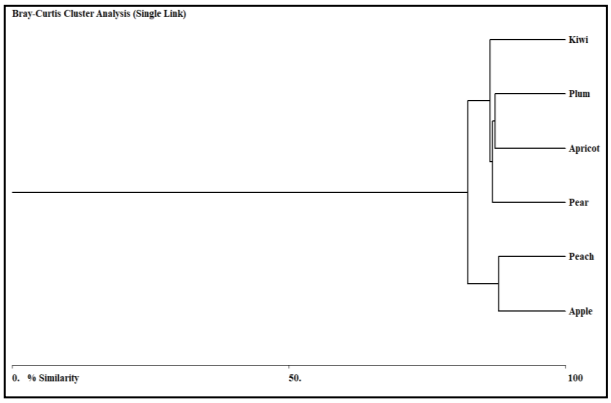

Fig. 3. Bray-Curtis Cluster Analysis of pollinators in fruit crops

Lepidoptera, Hymenoptera, Diptera and Coleoptera. Relative abundance reveals that *Apis cerana*, *Pieris brassicae*, *Aglis caschmirensis*, *Pieris canidia*, *Vanessa cardui*, *Apis melifera*, *Vanessa indica*, *Issoria lathonia, Syrphus fulvifacies,* and *Eristalis tenax* were the most abundant. Maximum diversity was observed in apple, followed by peach, pear, plum, apricot and kiwi.

In North Korea, 88 species of insect pollinators were found on the flowers of apple, pear, and peach (Hong et al., 1989). Joshi and Joshi (2010b) in the orchards of apple, peach, pear, and citrus in the Mukteshwar area of district Nainital reported 122 species under 31 families. Lepidoptera was the most dominant order followed by Hymenoptera, Coleoptera, Diptera, Odonata, Hemiptera, and Heteroptera. Sharma and Mitra (2012) on insect pollinators of temperate fruit crops in Himachal Pradesh revealed Hymenoptera as the most dominant. Maximum number of insect pollinators were observed from *Malus* sp. Raj and Mattu (2014) with apple, pear, peach, plum, almond, and cherry in Himachal Himalaya, revealed the presence of 70 insect pollinators under 27 families and six orders. Mattu and Bhagat (2015) in twenty orchards showed that apple flowers were visited by 44 species of insect pollinators corresponding to six orders and 18 families. *Apis cerana* was found the most abundant. Mattu and Nirala (2016) with apple crop in Shimla hills revealed 41 species of insect pollinators with Hymenoptera as the most dominant. *Apis cerana*, *Pieris brassicae*, *Aglis caschmirensis*, *Pieris canidia*, *Vanessa cardui*, *Apis melifera* were realtively more abundant and these results are in conformity with those of others (Mishra et al., 1976; Verma and Chauhan, 1985; Verma, 1990; Mattu and Mattu, 2010; Joshi and Joshi, 2010a; Raj et al., 2012; Sharma et al., 2013; Mattu and Bhagat, 2016). Likewise, McGregor (1976) and Free (1993) observed that honey bees were the important and dominant pollinators in the United States and Europe. The dominance of bees, syrphids, butterflies, and beetles in apple crops in the Himalayan region had been reported (Raj et al., 2012; Mattu, 2014). *Apis cerana* enhances apple production in the Nainital district of Uttarakhand (Sharma et al., 2012). Unfortunately, the bees that pollinate the wild plants are seldom paid any scientific attention (Bhattacharyya and Chakraborty, 2014). Sathe and Gophane (2015) from Kolhapur region, India, observed 30 pollinating insects belonging to the order Lepidoptera, Hymenoptera, Diptera, Coleoptera, and Thysanoptera; *Apis dorsata* was the most abundant. Dar et al. (2017) observed 45 pollinators from Srinagar, Budgam, and Pulwama region of Kashmir valley, India. Kapkoti et al. (2016) studied the variations in the abundance and diversity of insects in different apple orchards of Kumaun, Western Himalaya, India, and reported the important insect groups like bees, wasps, hoverflies, and dragonflies. Arya et al. (2018) conducted a systematic survey of anthophilous insect fauna and reported a total of 53 species of insects under 18 families in Binsar Wildlife Sanctuary, Western Himalaya, India.

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