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Diversity and distribution of pollinators of temperate fruit crops of Shimla hills in Himachal Pradesh

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ABSTRACT: Present studies on diversity and distribution of various insect visitors to six temperate fruit crops was made by collecting the pollinators in different orchards located at Kandyali (2550 m), Ghumali (2070 m) and Dhamandri (1575 m) of Shimla hills (Himachal Pradesh), during March to May, 2004. Insect diversity studies showed that these temperate fruit crops were visited by 70 species of insects belonging to 6 orders and 27 families of class Insecta. Of these, 24 species belonged to Hymenoptera, 24 to Diptera, 16 to Lepidoptera, 3 to Coleoptera, 2 to Hemiptera and 1 to order Thysanoptera. Hymenopterans and dipterans constituted an important group of insect pollinators.

Keywords: Pollinators; Temperate fruit crops; Hymenoptera; Diptera; Lepidoptera; Shimla hills.

INTRODUCTION

Himachal Pradesh is predominantly a horticultural state of India, with diverse agro-climatic zones, ranging from subtropical to high altitude cold deserts, and has a vast potential for successful cultivation of a wide range of horticultural crops. Thus, a significant shift in the cropping pattern from traditional agriculture to high value horticultural crops is visible in the state. The commonly grown temperate fruit crops are apple, plum, peach, cherry, pear and apricot which occupy approximately 35 per cent of the total area of the hill state[1]. Most of the blossoms are self-incompatible in nature and need services of different insects for cross-pollination for increasing crop yield, improving seed and fruit quality and for the exploitation of heterosis in plants[2, 3 & 4]. The mountain farming systems like agriculture, horticulture and forest farming that offers specific advantages for developing sustainable agriculture is dependent on the pollinators. Pollination is an essential pre-requisite for fertilization and fruit/seed set. If there is no pollination, there will be no fertilization and no fruits or seeds will be formed[4]. India is the second most populous country in the world and to feed such a large population intensive cultivation methods are being practised which are based on high input investments. The area under the forest cover is shrinking fast to provide cultivable land and the nesting sites and shelter locations of various pollinators have been destroyed. Consequently, the diversity and distribution of flora and fauna is getting adversely affected. In view of immense significance of crop pollination, present studies were undertaken with an objective to study the diversity and distribution of different insect pollinators visiting temperate fruit crops in Shimla hills of Himachal Pradesh.

MATERIAL AND METHODS

Present investigations were made on different fruit crops in order to know diversity and distribution of different insect pollinators. Pollinator diversity studies were conducted on six temperate fruit crops viz. apple, pear, cherry, peach, plum and almond in Shimla hills of Himachal Pradesh in different orchards, each having 250-300 trees, from March to May 2004. These studies were conducted on apple (*Malus domestica* Borckh) and cherry (*Prunus avium* L.) crops located at Kandyali (latitude 77°27' N, longitude

30°15' E and altitude 2550 m a.m.s.l.) in Shimla hills. Apple orchard had trees belonging to Royal delicious, Red Gold, Golden delicious and Red delicious varieties, whereas, cherry orchard had trees belonging to Early Rivers, Bradbourne Black, Gaucher, Merchant, Napoleon Biggarreau, Roundel Heart and Stella varieties. Insect diversity studies were conducted on pear (*Pyrus communis* Linn.) and plum (*Prunus domestica* L.) crops located at Ghumali (latitude 31º6'N, longitude 77º1'E and altitude 2070 m a.m.s.l.). The pear orchard had trees belonging to Red Bartlett, Williams, Conference and Early China varieties. The plum orchard had trees of Santa Rosa and Starking Delicious varieties. Peach (*Prunus persica* Batsch) and almond (*Prunus amygdalus* Batsch) crops were studied in orchards located at Dhamandri (latitude 70º81'N, longitude 31º03'E and altitude 1575 m a.m.s.l.) in Shimla hills. The peach orchard had trees of varieties namely July Elberta, Alton, and J.H. Hale, whereas, almond orchard had trees mostly belonging to Non-Pareil. The study was made by selecting trees at random, on basis of their size, flowering stage and number of branches. The experimental branches selected were of nearly same size with respect to their spread, phase of flowering, numbers of flowers and height above the ground. The observations were started 2 to 3 days after the flowering commenced and recorded during 0900-1000 hrs, 1200-1300 hrs and 1500-1600 hrs under good climatic conditions[5]. All insect visitors of temperate food crops were collected, killed, stretched and preserved for identification.

Collection of Insect Pollinators: The methods followed for collection of different insect pollinator species were:

i. Hand Picking Method[6, 7 & 8]
ii. Sweeping Method[9]
iii. Beating Method[10]
iv. Aerial Netting Method[9 &7]
v. Aspirator Method[10]

Preservation of Insect Pollinators: Different methods were followed for the preservation of pollinators with respect to their insect orders. These have been summarized as follows:

i. Hymenoptera[6]
ii. Diptera[7]
ii. Lepidoptera[9]
iv. Coleoptera[11]
v. Hemiptera[8]
vi. Thysanoptera[10]

Identification was done with the earlier records of Socio-biology and Behavioural Ecology Research Laboratory, Department of Biosciences, Himachal Pradesh University, Shimla and High Altitude Zoological Field Station (HAZFS), Zoological Survey of India (ZSI), Solan (H.P.).

RESULTS AND DISCUSSION

Diversity and distribution of different insect visitors on the bloom of different horticultural crops depends upon the geographical distribution, climatic conditions, availability of natural sites for nesting and hibernation and relationship between the plant and insect species[12]. The studies conducted on pollinator diversity mainly pertain to diversity, distribution and nomenclature of different insect species visiting temperate fruit crops in Shimla hills. The studies on different temperate crops viz., apple, pear, cherry, peach, plum and almond in Shimla hills revealed 70 species of insect visitors belonging to 6 orders and 27 families of class Insecta. Of these, 24 species belonged to Hymenoptera, 24 to Diptera, 16 to Lepidoptera, 3 to Coleoptera, 2 to Hemiptera and 1 to Thysanoptera (Table 1). The 24 species of order Hymenoptera belonged to 11 families. Out of these, 8 species belonged to family Vespidae; 3 each to Bombidae and Apidae; 2 each to Halictidae and Formicidae; and one each to Andrenidae, Xylocopidae, Ceretinidae, Tenthridinidae, Ichneumonidae and Scoliidae. The 24 species of order Diptera belonged to 7 families. Out of these, 14 belonged to family Syrphidae; 4 to Muscidae; 2 to Calliphoridae; and one each to Cordyluridae, Sepsidae, Asilidae and Dolichopodidae. The 16 species of order Lepidoptera belonged to 5 families. Out of these, 5 belonged to family Noctuidae; 4 each to Pieridae and Nymphalidae; 2 to Lycaenidae; and one to Zygaenidae. The 3 species of Coleoptera belonged to 2 families. Out of these, 2 belonged to family Coccinellidae; and one to Chrysomelidae. The 2 species of Hemiptera belonged to family Cixiidae. Only one species of Thysanoptera belonging to family Thripidae was recorded.

Table 1: Distribution of pollinator species visiting temperate fruit crops in different insect orders

S. No.	Order	Total no. of Families/Order	Total no. of Species/Order
1.	HYMENOPTERA	11	24
2.	DIPTERA	7	24
3.	LEPIDOPTERA	5	16
4.	COLEOPTERA	2	3
5.	HEMIPTERA	1	2
6.	THYSANOPTERA	1	1

Apple (*Malus domestica* Borckh): The studies showed that apple flowers were visited by 48 species of insects belonging to 5 orders and 18 families of class Insecta. Of these, 15 species belonged to Hymenoptera (7 families), 19 to Diptera (5 families), 10 to Lepidoptera (3 families), 3 to Coleoptera (2 families) and 1 to Thysanoptera (Table 2). Of 15 species of Hymenoptera, 5 belonged to family Vespidae i.e. *Vespa mandarina*, *V. velutina*, *V. flaviceps*, *Polistes maculipennis* and *Polistes* sp.; 3 to Bombidae i.e. *Bombus tunicatus*, *B. haemorrhoidalis*, and *Bombus* sp.; 2 each to Apidae i.e. *Apis cerana* and *A. mellifera*; and Halictidae i.e. *Halictus dasygaster* and *Halictus* sp.; and one each to Formicidae i.e. *Camponotus* sp.; Andrenidae i.e. *Andrena* sp.; and Xylocopidae i.e. *Xylocopa fenestrata*. Of 19 species of Diptera, 11 belonged to family Syrphidae viz. *Eristalis tenax*, *E. himalayaensis*, *E. cerealis*, *E. angustimarginalis*, *E. arvorum*, *Metasyrphus* sp., *Macrosyrphus* sp., *Episyrphus balteatus*, *Episyrphus* sp., *Scaeva* sp. and *Melanostoma* sp.; 4 to Muscidae i.e. *Musca domestica*, *Musca* sp., *Fannia domestica* and *Orthelia* sp.; 2 to Calliphoridae i.e. *Calliphora vicina* and *Lucilia* sp.; and one each to Cordyluridae i.e. *Scathophaga stereoraria*; and Dolichopodidae i.e. *Dolichopus* sp. Of 10 species of Lepidoptera, 4 belonged to family Noctuidae i.e. *Heliothis* sp., *Plusia* sp., *Agrotis flammatra* and *Agrotis* sp.; 3 each to Pieridae i.e. *Pieris canidia*, *Pieris* sp. and *Delias* sp.; and Nymphalidae i.e. *Pyrameis indica*, *Vanessa* sp. and *Neptis* sp. Of 3 species of Coleoptera, 2 belonged to family Coccinellidae i.e. *Coccinella septumpunctata* and *Coccinella* sp.; and one to Chrysomelidae i.e. *Altica* sp. Only one species of Thysanoptera i.e. *Thrips* sp. belonging to family Thripidae, was recorded (Table 2).

Table 2: Diversity of insect species visiting apple flowers with their taxonomic status

Order Hymenoptera	Order Diptera	Order Lepidoptera	Order Coleoptera	Order Thysanoptera
Family Vespidae	**Family Syrphidae**	**Family Noctuidae**	**Family Coccinellidae**	**Family Thripidae**
1.*Vespa mandarina*	16.*Eristalis tenax*	35.*Heliothis* sp.	45.*Coccinella*	48.*Thrips* sp.
2.*Vespa velutina*	17.*Eristalis himalayaensis*	36.*Plusia* sp.	*septumpunctata*	
3.*Vespa flaviceps*	18.*Eristalis cerealis*	37.*Agrotis flammatra*	46.*Coccinella* sp.	
4.*Polistes maculipennis*	19.*Eristalis angustimarginalis*	38.*Agrotis* sp.	**Family Chrysomelidae**	
5.*Polistes* sp.	20.*Eristalis arvorum*	**Family Pieridae**	47.*Altica* sp.	
Family Bombidae	21.*Metasyrphus* sp.	39.*Pieris canidia*		
6.*Bombus tunicatus*	22.*Macrosyrphus* sp.	40.*Pieris* sp.		
7.*B.haemorrhoidalis*	23.*Episyrphus balteatus*	41.*Delias* sp.		
8.*Bombus* sp.	24.*Episyrphus* sp.	**Family Nymphalidae**		
Family Apidae	25.*Scaeva* sp.	42.*Pyrameis indica*		
9.*Apis cerana*	26.*Melanostoma* sp.	43.*Vanessa* sp.		
10.*Apis mellifera*	**Family Muscidae**	44.*Neptis* sp.		
Family Halictidae	27.*Musca domestica*			
11.*Halictus dasygaster*	28.*Musca* sp.			
12.*Halictus* sp.	29.*Fannia domestica*			
Family Formicidae	30.*Orthelia* sp.			
13.*Camponotus* sp.	**Family Calliphoridae**			
Family Andrenidae	31.*Calliphora vicina*			
14.*Andrena* sp.	32.*Lucilia* sp.			
Family Xylocopidae	**Family Cordyluridae**			
15.*Xylocopa fenestrata*	33.*Scathophaga stereoraria*			
	Family Dolichopodidae			
	34.*Dolichopus* sp.			

Present diversity studies on the apple bloom are in accordance with the earlier studies of Verma and Chauhan (1985) who recorded 44 species of insect pollinators on crop in Shimla hills, of which 16 species belonged to Hymenoptera, 11 to Diptera, 9 to Lepidoptera, 7 to Coleoptera and 1 to Hemiptera[13]. Similarly, Kumar (1988) observed 16 species of bees visiting apple bloom in Solan area of Himachal Pradesh. Of the hymenopterans, Indian hive bee, *Apis cerana* was the most abundant insect visitor to this crop[14]. Verma and Chauhan (1985) also found *A. cerana* as the most predominant species an apple crop in Shimla hills[13]. Similarly, Mishra et al. (1976) have reported that honeybees constituted 70 per cent of total pollinators' population on three varieties of apple crop in Shimla hills[15]. Boyle–Makowski (1987) also observed honeybees as the important pollinators of apple flowers in Niagara peninsula[16]. Recently, Raj et al. (2012) reported that apple flowers were visited by 46 species of insects belonging to 5 orders and 17 families of class Insecta[17]. Of these, 16 species belonged to Hymenoptera, represented by 6 families like Apidae, Vespidae, Halictidae, Andrenidae, Formicidae and Pteromalidae. Diptera has 18 species belonging to families Syrphidae, Cordiluridae, Calliphoridae and Dolichopodidae. Similarly, 8 species belonged to Lepidoptera, represented by Pieridae, Nymphalidae and Noctuidae families. 3 species belonged to Coleoptera representing families Coccinellidae and Chrysomelidae. Only one species belonged to order Thysanoptera. Besides honeybees, other important hymenopteran visitors to apple bloom were *Vespa velutina, V. flaviceps, Camponotus* sp. and *Bombus tunicatus* (Table 2). Mishra et al. (1976) also found *Bombus* sp. in good number on apple flowers in Himachal Pradesh[15]. Similarly, Verma and Chauhan (1985) also recorded *Vespa* and *Bombus* species in good proportions on apple crop in Shimla hills[13].

Apple flowers were also visited by many dipteran species like *Eristalis tenax*, *Musca domestica* and *Fannia domestica*. Similar observations were also recorded by Mishra et al. (1976), Verma and Chauhan (1985) and Singh and Mishra (1986), who also found *Eristalis* sp. and syrphid flies as the frequent visitors to apple crop in Shimla hills[15,13,18]. Dashad (1989) observed three species each of *Apis, Halictus and Eristalis*; two each of *Bombus and Ceratina* and one each of *Xylocopa, Andrena, Episyrphus, Metasyrphus, Orthelia, Melanostoma and Musca* visiting apple flowers as the important visitors to apple crop in Solan hills[19]. Similarly, Hong et al. (1989) observed syrphid flies as the dominant visitors to apple, pear and peach flowers in North Korea[20].

Menke (1952) while studying relative abundance of insect pollinators on apple recorded on an average 13 honeybees in a time span of 15 minutes on one metre branch[21]. Whereas, Karmo and Vickery (1960) reported on average 23.3 pollinators on an apple tree in a span of 15 minutes, of which 16.5 were honeybees alone[22]. In Korea, a total of 496 species were found visiting the apple bloom and honeybees constituted 91 per cent of the total insect population[23].

Relative abundance studies on apple crop in Kullu valley of Himachal Pradesh by Kumar (1997) revealed that *A. cerana* was the most abundant insect visitor to this crop, followed by *A. mellifera*[24]. Among dipterans, *Syrphus* sp., *Fannia* sp. and *Eristalis tenax* were the most abundant dipteran pollinators. Lepidopterans like *Pieris canidia, Pyrameis indica* and coleopterans like *Coccinella* sp. formed a small proportion on this crop. He inferred that hymenopterans were the most abundant insect pollinators on apple bloom. Similar studies on relative abundance in Kullu valley revealed four types of pollinators visiting apple bloom[25]. Species of bumble bees and solitary bees like *Amegilla, Andrena, Anthophora, Ceratina, Halictus, Megachile, Nomia, Osmia, and Xylocopa* are important pollinators of apple flowers in the Hindu Kush Himalayan region, but the natural populations of these bees are declining[26].

Pear (*Pyrus communis* Linn.): Pear flowers were visited by 33 species of insects belonging to 4 orders and 16 families of class Insecta. Of these, 13 species belonged to Hymenoptera (6 families), 11 to Diptera (4 families), 6 to Lepidoptera (4 families) and 3 to Coleoptera (2 families) (Table 3). Of 13 species of Hymenoptera, 5 belonged to family Vespidae i.e. *Vespa flaviceps, V. magnifica, V. auraria, Polistes maculipennis* and *Polistes* sp.; 2 each to Bombidae i.e. *Bombus tunicatus* and *Bombus* sp.; Apidae i.e. *Apis cerana* and *A. mellifera*; and Halictidae i.e. *Halictus dasygaster* and *Halictus* sp.; one each to Formicidae i.e. *Camponotus* sp.; and Xylocopidae i.e. *Xylocopa fenestrata*. Of 11 species of Diptera, 6 belonged to family Syrphidae i.e. *Eristalis tenax, E. himalayaensis, E. cerealis, E. arvorum, Scaeva*

opimius and *Syrphus* sp.; 2 each to Muscidae i.e. *Musca domestica* and *Fannia domestica*; and Calliphoridae i.e. *Calliphora vicina* and *Lucilia* sp.; and one to Dolichopodidae i.e. *Dolichopus* sp. Of 6 species of Lepidoptera, 2 each belonged to family Pieridae i.e. *Pieris canidia* and *Pieris* sp.; and Nymphalidae i.e. *Pyrameis indica* and *Vanessa cance*; and one each to Noctuidae i.e. *Heliothis* sp.; and Zygaenidae i.e. *Zygaena* sp. Of 3 species of Coleoptera, 2 belonged to family Coccinellidae i.e. *Coccinella septumpunctata* and *Coccinella* sp.; and one to Chrysomelidae i.e. *Altica* sp. (Table 3).

Table 3: Diversity of insect species visiting pear flowers with their taxonomic status

Order Hymenoptera	Order Diptera	Order Lepidoptera	Order Coleoptera
Family Vespidae	**Family Syrphidae**	**Family Pieridae**	**Family Coccinellidae**
1.*Vespa flaviceps*	14.*Eristalis tenax*	25.*Pieris canidia*	31.*Coccinella septumpunctata*
2.*Vespa magnifica*	15.*Eristalis himalayaensis*	26.*Pieris* sp.	32.*Coccinella* sp.
3.*Vespa auraria*	16.*Eristalis cerealis*	**Family Nymphalidae**	**Family Chrysomelidae**
4.*Polistes maculipennis*	17.*Eristalis arvorum*	27.*Pyrameis indica*	33.*Altica* sp.
5.*Polistes* sp.	18.*Scaeva opimius.*	28.*Vanessa cance*	
Family Bombidae	19.*Syrphus* sp.	**Family Noctuidae**	
6.*Bombus tunicatus*	**Family Muscidae**	29.*Heliothis* sp.	
7.*Bombus* sp.	20.*Musca domestica*	**Family Zygaenidae**	
Family Apidae	21.*Fannia domestica*	30.*Zygaena* sp.	
8.*Apis cerana*	**Family Calliphoridae**		
9.*Apis mellifera*	22.*Calliphora vicina*		
Family Halictidae	23.*Lucilia* sp.		
10.*Halictus dasygaster*	**Family Dolichopodidae**		
11.*Halictus* sp.	24.*Dolichopus* sp.		
Family Formicidae			
12.*Camponotus* sp.			
Family Xylocopidae			
13.*Xylocopa fenestrata*			

Present results on pollinator diversity are in accordance with the earlier observations of Gautam et al. (1995) who also observed hymenopteran, dipteran and lepidopteran pollinators on pear crop in Kullu valley of Himachal Pradesh[27]. Earlier, Hong et al. (1989) recorded 88 species of insect pollinators on pear, peach and apple crops in North Korea[20]. In a similar study, Abrol (1993) observed various hymenopteran pollinators including honeybees, bumble bees and carpenter bees on pear crop in Jammu and Kashmir[28]. Among hymenopterans, *A. cerana* and *A. mellifera* were the most dominant insect visitors to pear crop. Similar results were also observed by Sharma et al. (2001) in Kullu Valley[25]. These results are also in conformity with the earlier observations of Lee et al. (1988) who also observed that majority of insect pollinators in pear orchard were honeybees[29]. Besides hymenopterans, pear crop was also visited by certain dipterans like *Syrphus* sp., *Eristalis* sp., *E. arvorum* and *Musca* sp. Only one lepidopteran species i.e. *Pieris canidia* was observed on this crop[30].

Cherry (*Prunus avium* L.): Cherry flowers were visited by 31 species of insects belonging to 5 orders and 13 families of class Insecta. Of these, 12 species belonged to Hymenoptera (5 families), 10 to Diptera (3 families), 6 to Lepidoptera (3 families), 2 to Hemiptera and 1 to Coleoptera (Table 4). Of 12 species of Hymenoptera, 5 belonged to family Vespidae i.e. *Vespa mandarina*, *V. velutina*, *V. flaviceps*, *Polistes maculipennis* and *Polistes* sp.; 2 each to Bombidae i.e. *Bombus tunicatus* and *Bombus* sp.; Apidae i.e. *Apis cerana* and *A. mellifera*; and Halictidae i.e. *Halictus dasygaster* and *Halictus* sp.; and one to Xylocopidae i.e. *Xylocopa fenestrata*. Of 10 species of Diptera, 6 belonged to family Syrphidae i.e. *Eristalis tenax*, *E. himalayaensis*, *E. arvorum*, *Macrosyrphus* sp., *Episyrphus* sp. and *Melanostoma* sp.; 3 to Muscidae i.e. *Musca domestica*, *Musca* sp. and *Fannia domestica*; and one to Calliphoridae i.e. *Lucilia*

sp. Of 6 species of Lepidoptera, 2 each belonged to family Noctuidae i.e. *Heliothis* sp. and *Plusia* sp.; Pieridae i.e. *Pieris canidia* and *Pieris* sp.; and Nymphalidae i.e. *Vanessa cance* and *Neptis* sp. Order Hemiptera comprised two species i.e. *Nysius* sp. and *Adolenda typicaic* belonging to Cixiidae. Order Coleoptera comprised one species i.e. *Coccinella septumpunctata* belonging to family Coccinellidae (Table 4).

Table 4: Diversity of insect species visiting cherry flowers with their taxonomic status

Order Hymenoptera	Order Diptera	Order Lepidoptera	Order Coleoptera	Order Hemiptera
Family Vespidae	**Family Syrphidae**	**Family Noctuidae**	**Family Coccinellidae**	**Family Cixiidae**
1.*Vespa mandarina*	13.*Eristalis tenax*	23.*Heliothis* sp.	29.*Coccinella septumpunctata*	30.*Nysius* sp.
2.*Vespa velutina*	14.*Eristalis*	24.*Plusia* sp.		31.*Adolenda typicaic*
3.*Vespa flaviceps*	*himalayaensis*	**Family Pieridae**		
4.*Polistes maculipennis*	15.*Eristalis arvorum*	25.*Pieris canidia*		
5.*Polistes* sp.	16.*Macrosyrphus* sp.	26.*Pieris* sp.		
Family Bombidae	17.*Episyrphus* sp.	**Family Nymphalidae**		
6.*Bombus tunicatus*	18.*Melanostoma* sp.	27.*Vanessa cance*		
7.*Bombus* sp.	**Family Muscidae**	28.*Neptis* sp.		
Family Apidae	19.*Musca domestica*			
8.*Apis cerana*	20.*Musca* sp.			
9.*Apis mellifera*	21.*Fannia domestica*			
Family Halictidae	**Family Calliphoridae**			
10.*Halictus dasygaster*	22.*Lucilia* sp.			
11.*Halictus* sp.				
Family Xylocopidae				
12.*Xylocopa fenestrata*				

Hendrickson (1916) was probably the first to reveal the importance of honeybees in the pollination of various prunes[31]. Later, some other investigators made preliminary observations about the role of honeybees and dipterans in the pollination of different *Prunus* species[32,28,4]. Present results on cherry pollinators corroborate the early findings of Bhalla et al. (1983) who observed 10 insect species on stone fruit crops in H.P. and most important among them were hymenopteran and dipteran pollinators[32]. Anesiewicz (1972) have also reported *Apis mellifera* as most common species on cherry and apple crops[33]. Recently, Sharma and Rana (2000) also found *A. cerana* as the most abundant pollinator on this crop in Kullu valley[34]. However, Abrol et al. (1989) reported *Xylocopa* sp., *Lasioglossum* sp. and *Halictus* sp. as the important pollinators of cherry, apple, peach and plum crops in Jammu and Kashmir[35].

Besides hymenopterous insects, cherry flowers were also visited by certain dipterans like *Musca domestica, Eristalis tenax* and *Episyrphus* sp. Abrol et al. (1989) also found dipterans in good proportions on cherry bloom in Jammu and Kashmir[35]. Mattu et al. (1994) found predominant presence of *Syrphus, Eristalis, Fannia, Musca and Dolichopus* species on cherry bloom[36]. Kumar (1997) made a detailed study on relative abundance of different insect visitors on cherry crop in Himachal Pradesh[24]. He observed that *A. cerana* and *A. mellifera* were the most abundant insect visitors to this crop, whereas, *Camponotus* sp. and chalcid flies were other important hymenopterans on this crop. *Musca domestica, Eristalis tenax* and *Syrphus* sp. were also observed by him on cherry flowers. He suggested that hymenopterans and dipterans played almost equal role in pollination of cherry flowers.

Peach (*Prunus persica* Batsch): Pollinator diversity studies on peach crop showed that peach flowers were visited by 40 species of insects belonging to 5 orders and 24 families of class Insecta. Of these, 15 species belonged to Hymenoptera (9 families), 12 to Diptera (7 families), 9 to Lepidoptera (5 families), 3 to Coleoptera (2 families) and 1 to Hemiptera (Table 5). Of 15 species of Hymenoptera, 4 belonged to family Vespidae i.e. *Vespa magnifica, V. auraria, Polistes maculipennis* and *Polistes* sp.; 2 each to Bombidae i.e. *Bombus tunicatus* and *Bombus* sp.; Apidae i.e. *Apis cerana* and *Apis mellifera*; and Halictidae i.e. *Halictus dasygaster* and *Halictus* sp.; one each to Formicidae i.e. *Holocomyrmex* sp.; Xylocopidae i.e. *Xylocopa fenestrata*; Ceretinidae i.e. *Ceratina hieroghyphica*; Tenthridinidae i.e. *Athalia* sp.; and Ichneumonidae i.e. *Fileantha* sp. Of 12 species of Diptera, 4 belonged to family Syrphidae i.e.

Eristalis tenax, E. cerealis, Scaeva opimius and *Syrphus* sp.; 2 each to Muscidae i.e. *Musca domestica* and *Fannia domestica*; and Calliphoridae i.e. *Calliphora vicina* and *Lucilia* sp.; and one each to Cordyluridae i.e. *Scathophaga stereoraria*; Sepsidae i.e. *Sepsis* sp.; Asilidae i.e. *Promachus* sp.; and Dolichopodidae i.e. *Dolichopus* sp. Of 9 species of Lepidoptera, 3 belonged to family Pieridae i.e. *Pieris canidia*, *Pieris* sp. and *Gonepteryx rhamni*; 2 each to Noctuidae i.e. *Heliothis* sp. and *Plusia* sp.; and Nymphalidae i.e. *Pyrameis indica* and *Vanessa cance*; and one each to Lycaenidae i.e. *Heliophorus* sp.; and to Zygaenidae i.e. *Zygaena* sp. Of 3 species of Coleoptera, 2 belonged to family Coccinellidae i.e. *Coccinella septumpunctata* and *Coccinella* sp.; and one to Chrysomelidae i.e. *Altica* sp. Order Hemiptera comprised of only one species i.e. *Nysius* sp. belonging to family Cixiidae (Table 5).

Table 5: Diversity of insect species visiting peach flowers with their taxonomic status

Order Hymenoptera	Order Diptera	Order Lepidoptera	Order Coleoptera	Order Hemiptera
Family Vespidae	**Family Syrphidae**	**Family Pieridae**	**Family Coccinellidae**	**Family Cixiidae**
1.*Vespa magnifica*	16.*Eristalis tenax*	28.*Pieris canidia*	37.*Coccinella septumpunctata*	40.*Nysius* sp.
2.*Vespa auraria*	17.*Eristalis cerealis*	29.*Pieris* sp.	38.*Coccinella* sp.	
3.*Polistes maculipennis*	18.*Scaeva opimius.*	30.*Gonepteryx rhamni*	**Family Chrysomelidae**	
4.*Polistes* sp.	19.*Syrphus* sp.	**Family Noctuidae**	39.*Altica* sp.	
Family Bombidae	**Family Muscidae**	31.*Heliothis* sp.		
5.*Bombus tunicatus*	20.*Musca domestica*	32.*Plusia* sp.		
6.*Bombus* sp.	21.*Fannia domestica*	**Family Nymphalidae**		
Family Apidae	**Family Calliphoridae**	33.*Pyrameis indica*		
7.*Apis cerana*	22.*Calliphora vicina*	34.*Vanessa cance*		
8.*Apis mellifera*	23.*Lucilia* sp.	**Family Lycaenidae**		
Family Halictidae	**Family Cordyluridae**	35.*Heliophorus* sp.		
9.*Halictus dasygaster*	24.*Scathophaga stereoraria*	**Family Zygaenidae**		
10.*Halictus* sp.	**Family Sepsidae**	36.*Zygaena* sp.		
Family Formicidae	25.*Sepsis* sp.			
11.*Holocomyrmex* sp.	**Family Asilidae**			
Family Xylocopidae	26.*Promachus* sp.			
12.*Xylocopa fenestrata*	**Family Dolichopodidae**			
Family Ceretinidae	27.*Dolichopus* sp.			
13.*Ceratina hieroglyphica*				
Family Tenthridinidae				
14.*Athalia* sp.				
Family Ichneumonidae				
15.*Fileantha* sp.				

Present pollinator diversity studies on peach crop are in accordance with the earlier findings of Kumar (1995) who reported 33 species of insect pollinators on peach flowers, which belonged to 4 orders and 18 families of class Insecta[37]. Of these, 12 species belonged to Hymenoptera, 12 to Diptera, 8 to Lepidoptera and 1 to Coleoptera. Data on relative abundance of different insect pollinators on peach crop indicated that *Apis cerana* and *A. mellifera* were the most abundant insect visitors. Among lepidopterans, only *Pieris canidia* was the important pollinator to this crop. Relative abundance studies revealed that hymenopterans and dipterans were almost equally predominant on this crop. These results corroborate the earlier observations of Rominsondo et al. (1972) and Langridge and Goodman (1979), who also found honeybees as the most frequent visitors on 'Dixired' and 'Golden Queen' cultivars of peach[38,39]. Besides hymenopterous insects, peach flowers were also visited by certain dipteran species. Among these, *Fannia domestica, Dolichopus* sp., *Eristalis tenax, Syrphus* sp., *Sepsis* sp. and *Lucilia* sp. were the most prominent. Similar observations were also recorded by Kumar (1995) on peach crop[37].

Choi and Kim (1988) also reported that honeybees constituted 70-80 per cent of total insect population on peach bloom in North Korea[23]. A similar survey conducted by Hong et al. (1989) in Korea regarding the insects visiting pear, peach and apple flowers revealed a total of 88 species of pollinators belonging to 5 orders and 40 families[20]. *Apis mellifera* was most abundant followed by syrphid flies. Abrol et al. (1989) also studied the pollinators of different temperate fruit crops such as apple, peach, plum and cherry in Jammu and Kashmir[35]. The important pollinators visiting these crops were *Xylocopa* sp., *Lasioglossum* sp., *Halictus* sp. and member of families Anthophoridae, Andrenidae, Halictidae and Callitidae. Whereas, *A. mellifera ligustica and Bombus terrestris* were frequent visitors in different almond orchards in Umbria[40].

Plum (*Prunus domestica* L.): Pollination studies on stone fruit crops showed that plum flowers were visited by 19 species of insects belonging to 4 orders and 11 families of class Insecta. Of these, 8 species belonged to Hymenoptera (4 families), 5 to Diptera (2 families), 5 to Lepidoptera (4 families), and 1 to Coleoptera (Table 6). Of 8 of Hymenoptera, 2 each belonged to family Vespidae i.e. *Vespa auraria* and *Vespa* sp.; Bombidae i.e. *Bombus tunicatus* and *Bombus* sp; Apidae i.e. *Apis cerana* and *Apis mellifera*; and Halictidae i.e. *Halictus dasygaster* and *Halictus* sp. Of 5 species of Diptera, 3 belonged to family Syrphidae i.e. *Eristalis* sp., *Metasyrphus* sp. and *Macrosyrphus* sp.; and 2 to Muscidae i.e. *Musca domestica* and *Musca* sp. Of 5 species of Lepidoptera, 2 belonged to family Pieridae i.e. *Pieris canidia* and *Pieris* sp.; and one each to Nymphalidae i.e. *Vanessa* sp.; Noctuidae i.e. *Plusia* sp.; and Lycaenidae i.e. *Heodes* sp. Order Coleoptera comprised of only one family Coccinellidae, with single species i.e. *Coccinella septumpunctata* (Table 6).

Table 6: Diversity of insect species visiting plum flowers with their taxonomic status

Order Hymenoptera	Order Diptera	Order Lepidoptera	Order Coleoptera
Family Vespidae	**Family Syrphidae**	**Family Pieridae**	**Family Coccinellidae**
1.*Vespa auraria*	9.*Eristalis* sp.	14.*Pieris canidia*	19.*Coccinella septumpunctata*
2.*Vespa* sp.	10.*Metasyrphus* sp.	15.*Pieris* sp.	
Family Bombidae	11.*Macrosyrphus* sp.	**Family Noctuidae**	
3.*Bombus tunicatus*	**Family Muscidae**	16.*Plusia* sp.	
4.*Bombus* sp.	12.*Musca domestica*	**Family Nymphalidae**	
Family Apidae	13.*Musca* sp.	17.*Vanessa* sp.	
5.*Apis cerana*		**Family Lycaenidae**	
6.*Apis mellifera*		18.*Heodes* sp.	
Family Halictidae			
7.*Halictus dasygaster*			
8.*Halictus* sp.			

Different investigators have observed different number of pollinators on plum bloom in various eco-geographic zones. For example, Thakur (1988) observed 15 species of insect visitors on plum flowers in Himachal Pradesh[41]. Similarly, Rana (1989) recorded 20 species of insects visiting plum bloom under mid-hill conditions of Solan area[42]. Studies on the comparative abundance of insect pollinators on plum bloom indicated that *Apis mellifera* was most abundant species followed by *A. cerana*, whereas, other hymenopterans excluding the honeybees, lepidopterans and dipterans were least in abundance. Earlier, many studies have shown that honeybees from a high percentage of the insects visiting *Prunus* and *Pyrus* flowers[21,43,44,45,46,47,15,48]. But many other insect pollinators also visit these flowers. Notable amongst them are bumble bees (*Bombus* spp.) and solitary bees belonging to the families Andrenidae and Megachilidae[49,50,51,25]. Mann and Singh (1983) also found *Apis dorsata, A. mellifera* and *A. florea* in good proportion on the plum crop at Ludhiana[52]. Some dipteran flies, especially syrphids, also visited the plum

flowers, but their number was negligible. Langridge and Goodman (1979) noted that the honeybees constituted 99.4 per cent of total anthophilous population on canning peach in Australia[39]. Similarly, Bhalla et al. (1983) showed that honeybees were predominant among ten insect species visiting peach, plum and almond blossom at Solan, Himachal Pradesh[32]. Peach bloom attracted a maximum number of honeybees. Kumar et al. (1985) studied the pollination requirements of fifteen peach cultivars at Solan[53]. *A. cerana* was the most frequent visitor, but their number varied with cultivars and time of the day. Singh and Mishra (1986) studied the abundance of different insect pollinators of temperate fruit crops under different agro-climatic conditions of Himachal Pradesh[18]. They reported that irrespective of fruit species and location, *A. cerana* was most abundant insect visitor followed by *Musca* sp. and *Eristalis* sp. whereas, according to Rana et al. (1995), the insect pollinators of plum bloom at Solan comprised 20 special belonging to 4 orders and 10 families[54]. Comparative abundance studies showed that *A. mellifera and A. cerana* were dominant insect pollinators than lepidopterans, dipterans and other hymenopterans excluding honeybees.

1.1 Almond (*Prunus amygdalus* Batsch)

Almond flowers were visited by 30 species of insects belonging to 4 orders and 17 families of class Insecta. Of these, 10 species belonged to Hymenoptera (6 families), 12 to Diptera (6 families), 5 to Lepidoptera (3 families) and 3 to Coleoptera (2 families) (Table 7). Of 10 species of Hymenoptera, 3 belonged to family Apidae i.e. *Apis cerana*, *A. mellifera* and *A. dorsata*; 2 each to Vespidae i.e. *Vespa flaviceps* and *Polistes maculipennis*; and Bombidae i.e. *Bombus tunicatus* and *Bombus* sp.; and one each to Halictidae i.e. *Halictus dasygaster*; Formicidae i.e. *Camponotus* sp.; and Scoliidae i.e. *Elis thoracica*. Of 12 species of Diptera, 5 belonged to family Syrphidae i.e. *Eristalis tenax*, *E. himalayaensis*, *E. cerealis*, *Scaeva opimius and Syrphus* sp.; 2 each to Muscidae i.e. *Musca domestica* and *Fannia domestica*; and to Calliphoridae i.e. *Calliphora vicina* and *Lucilia* sp.; and one each to Cordyluridae i.e. *Scathophaga stereoraria*; Asilidae i.e. *Promachus* sp.; and Dolichopodidae i.e. *Dolichopus* sp. Of 5 species of Lepidoptera, 2 each belonged to family Pieridae i.e. *Pieris canidia* and *Gonepteryx rhamni*; and Nymphalidae i.e. *Pyrameis indica* and *Vanessa cance*; and one belonged to Noctuidae i.e. Sphinx moth. Of 3 species of Coleoptera, two belonged to family Coccinellidae i.e. *Coccinella septumpunctata* and *Coccinella* sp.; and one belonged to Chrysomelidae i.e. *Altica* sp. (Table 7).

Table 7: Diversity of insect species visiting almond flowers with their taxonomic status

Order Hymenoptera	Order Diptera	Order Lepidoptera	Order Coleoptera
Family Apidae	**Family Syrphidae**	**Family Pieridae**	**Family Coccinellidae**
1.*Apis cerana*	11.*Eristalis tenax*	23.*Pieris canidia*	28.*Coccinella septumpunctata*
2.*Apis mellifera*	12.*Eristalis himalayaensis*	24.*Gonepteryx rhamni*	29.*Coccinella* sp.
3.*Apis dorsata*	13.*Eristalis cerealis*	**Family Nymphalidae**	**Family Chrysomelidae**
Family Vespidae	14.*Scaeva opimius.*	25.*Pyrameis indica*	30.*Altica* sp.
4.*Vespa flaviceps*	15.*Syrphus* sp.	26.*Vanessa* sp.	
5.*Polistes maculipennis*	**Family Muscidae**	**Family Noctuidae**	
Family Bombidae	16.*Musca domestica*	27.Sphinx moth	
6.*Bombus tunicatus*	17.*Fannia domestica*		
7.*Bombus* sp.	**Family Calliphoridae**		
Family Halictidae	18.*Calliphora vicina*		
8.*Halictus dasygaster*	19.*Lucilia* sp.		
Family Formicidae	**Family Cordyluridae**		
9.*Camponotus* sp.	20.*Scathophaga stereoraria*		
Family Scoliidae	**Family Asilidae**		
10.*Elis thoracica*	21.*Promachus* sp.		
	Family Dolichopodidae		
	22.*Dolichopus* sp.		

Kumar (1995) also reported species of insect pollinators on almond bloom in Shimla hills, which belonged to 5 orders and 17 families of class Insecta[37]. Of these, 9 species belonged to Hymenoptera, 12 to Diptera, 5 to Lepidoptera, 3 to Coleoptera and 1 to Thysanoptera. Data on relative abundance of different insect pollinators on almond crop indicated that *Apis cerana* was the most abundant species followed by *A. mellifera* and *Halictus dasygaster*. These results are in conformity with the earlier observations of Thakur (1988), who recorded 15 species of insect visitors on almond bloom at Nauni (Solan) and found *A. cerana* as the frequent visitor on early, as well as the late flowering cultivars of almond[41]. However, Kumar (1988) and Kumar et al. (1989) also recorded 16 wild bees on the temperate fruit bloom in Solan, and *A. dorsata* was the predominant constituting 93 to 98 per cent of wild bees[14,55]. Abrol et al. (1987) also observed *A. cerana indica* as the most frequent visitor on almond flowers at Jammu[56]. Other important visitors on this crop were *Xylocopa* sp., butterflies, mosquitoes and *Musca* sp. Ricciardelli and Quaranta (1992) observed *A. mellifera ligustica* and *Bombus terrestris* as the dominant pollinators of different almond cultivars in Umbria[40]. Besides hymenopterous insects, almond flowers were also visited by many dipteran species. Among them, *Eristalis tenax, Syrphus* sp. and *Scaeva opimius* were most prominent. Similar observations were also made by Abrol et al. (1987) and Kumar (1995) in Jammu and Kashmir and Himachal Pradesh respectively[56 & 37].

Among dipterans, *Scaeva* sp., *Syrphus* sp. and *Eristalis tenax* were the important crop pollinators. Some lepidopterans like *Pyrameis indica*, *Pieris canidia* and *Gonepteryx rhamni* were also observed on this crop. These studies indicated that hymenopterans were the most abundant insect pollinators on almond bloom. On almond, Abrol et al. (1990) observed mosquitoes and *Musca* in a low number in Jammu and Kashmir, whereas, Singh (1988) has recorded 4 species of *Eristalis*, one species each of *Episyrphus*, *Metasyrphus, Scaeva* and *Orthelia* as insect pollinators of almond in Himachal Pradesh[57 & 58].

Above results suggests that hymenopterans and dipterans were the most important insect pollinators of temperate fruit crops. These findings were in correlation to earlier workers as, among insects, hymenopterans embrace a vast multitude of pollinating agents and include most efficient pollinators of horticultural crops, like honeybees and bumble bees. Besides hymenopterans, various dipterans and some lepidopteran also act as pollinators of various temperate fruit crops[59, 32, 13, 35, 28 & 4]. Waite (1898) probably was the first to recommend the use of honeybees for the pollination of apple and pear crops[60]. Kinman (1938) warned that the temperate fruit crop failures would be expected if sufficient number of bees were not present in the orchards[61]. Flies (Diptera) are also reckoned as primitive pollinators, as important dipteran pollinators belong to genera *Eristalis, Episyrphus, Syrphus, Musca, Rhingia, Calliphora, Lucilia, Sarcophaga, Bibio, Dilophus and Bombylius*[13,18,19,4,24]. In those areas, where bees do not exist, flies have taken over the pollination of flowers, e.g. as reported from New Zealand where pollinating Hymenoptera were absent, flies acted as important pollinators[62]. Besides hymenopterans and dipterans, coleopterans are one of the oldest groups of insects and beetles are considered as the most primitive pollinators[63-64]. Strawberry and pear blossoms have been reported to be visited by some coleopterans[65-66]. Kumar (1997) and Sharma (2000) reported *Coccinella* sp. pollinating apple, cherry and balsam flowers in Shimla hills of Himachal Pradesh[24 & 67]. Insects form an important group of biotic pollen dispersal agents of different agricultural and horticultural crops.

CONCLUSION

Present studies on insect diversity and distribution on six temperate fruit crops viz., apple, pear, cherry, peach, plum and almond in Shimla hills, showed that various insect groups, which were of major significance in pollination of horticultural crops belonged to orders Hymenoptera, Diptera, Lepidoptera, Coleoptera, Hemiptera and Thysanoptera. Of these, order Hymenoptera and Diptera dominated with 24 species each and order Lepidoptera was also significant with having 16 species. Order Diptera dominated apple and almond crops, having 19 and 12 species respectively, similarly, Hymenoptera dominated pear, cherry, peach and plum fruit crops with 13, 12, 15 and 8 species respectively. The main objective of the study was to record the diversity of the prime pollinators of major temperate fruit crops of Shimla hills, which subsequently can lead to generate knowledge on their biology, nesting behaviour and relative

abundance, and hence to formulate an intricate management strategy. Pollinator database and conservation mechanism is also needed, thereby, useful to collate, computerize and disseminate all the available information on pollinator diversity in the country.

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