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POLLINATOR DIVERSITY AND RELATIVE ABUNDANCE OF INSECT VISITORS ON APPLE CROP IN SHIMLA HILLS OF WESTERN HIMALAYA, INDIA

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ABSTRACT
Studies on diversity and relative abundance of various insect visitors to apple crop was made by collecting the flower visitors in different orchards located at Shilaroo (2409 m), Matiana (2514 m) and Narkanda (2648 m) of Shimla hills, during different seasons of the years from 2007-2009. Insect diversity studies showed that apple flowers were visited by 46 species of insects belonging to 5 orders and 17 families of class Insecta. Of these, 16 species belonged to Hymenoptera, 18 to Diptera, 8 to Lepidoptera, 3 to Coleoptera and 1 to order Thysanoptera. Analyses of data on relative abundance of different insect visitors revealed that Indian hive bee, *A. cerana* was the most abundant insect visitor to apple flowers in all the three experimental orchards i.e. Shilaroo (28%), Matiana (28.44%) and Narkanda (27.24%). Other important hymenopteans at Shilaroo, Matiana and Narkanda were European honey bee, *A. mellifera* (17.14%, 15.24% and 14.97%), *Bombus tunicatus* (1.74%, 1.82% and 1.19%) and *Vespa velutina* (0.69%, 0.68% and 0.59%). Besides, hymenopterans, dipterans also constituted an important group of insect pollinators.

KEY WORDS: Insect Pollinator, Relative Abundance, Apple Crop, Honeybee, Shimla Hills.

INTRODUCTION

Pollinators are essential for the reproduction of many wild flowers and crops: for one out of every three bites eaten, one can thank a bee, butterfly, bat, bird or other pollinator. Any loss in biodiversity is a matter of public concern, but losses of pollinating insects may be particularly troublesome because of the potential effects on plant reproduction and hence on food supply security. Many agricultural crops and natural plant populations are dependent on pollination and often on the services provided by wild, unmanaged, pollinator communities (Free, 1993; Kluser and Peduzzi, 2007).

Apple is the major fruit of the state accounting for 67 per cent of the total area under fruits and 88 per cent of total fruit production. But during the last few years, the production of apple per hectare has come down inspite of increased area under apple cultivation. So, there is a need for changed strategies and look for other possible inputs for increasing apple production in state (Verma and Jindal, 1997). A little is known about the role of different insect visitors in pollinating various horticultural crops in India especially Himachal Pradesh (Mattu and Verma, 1985; Mishra et al., 1976; Mattu et al., 1994; Verma, 1990, 1992; Verma and Partap, 1993; Kumar, 1995 & 1997; Minakshi, 2004; Mattu, 2008). Therefore, present investigation was conducted on the diversity and relative abundance of different insect species visiting apple crop in Shimla hills of Western Himalaya.

MATERIAL AND METHODS

Studies on diversity and relative abundance of various insect visitors to apple crop was made by collecting the flower visitors in different orchards located at Shilaroo (2409 m), Matiana (2514 m) and Narkanda (2648 m) of Shimla hills. Almost equal numbers of working hours were spent in each orchard. Moreover, these collections were made during different seasons of the years from 2007-2009. These apple orchards had more than 200 trees belonging to Royal delicious, Red Gold, Golden delicious and Red delicious varieties. Relative abundance of different insect visitors was determined in terms of their visits per 500 flowers/10 minutes (Verma and Chauhan, 1985). The observations were recorded during 0900-1000, 1200-1300 and 1500-1600 hours of a day and average counts at these hours gave abundance of an insect pollinator for the particular day (Southwood, 1978).

For collection of different insect species, following methods were used:

(i) Hand Picking Method (Jonathan, 1990; Joseph, 1990).
(ii) Sweeping Method (Arora, 1990).
(iii) Beating Method (Ghosh, 1990).
(iv) Aerial Netting Method (Arora, 1990; Joseph, 1990).
(v) Aspirator Method (Ghosh, 1990).

Different methods were followed for the preservation of insect pollinators belonging to different groups. These have been summarized as follows:

a) Hymenoptera (Jonathan, 1990).
b) Lepidoptera (Arora, 1990).
c) Coleoptera (Sengupta and Mukhopadhyaya, 1990).
d) Thysanoptera (Ghosh, 1990).
e) Diptera (Joseph, 1990).

RESULTS AND DISCUSSION

Insect diversity studies showed that apple flowers were visited by 46 species of insects belonging to 5 orders and 17 families of class Insecta. Of these, 16 species belonged to Hymenoptera, 18 to Diptera, 8 to Lepidoptera, 3 to Coleoptera and 1 to order Thysanoptera. It has been observed that Hymenoptera was represented by 6 families like Apidae, Vespidae, Halictidae, Andrenidae, Formicidae and Pteromalidae. Hymenopterans were represented by species like *Apis cerana, A. mellifera, Bombus tunicatus, B. haemorridalis, Vespa mandarina, V. velutina, V. flaviceps, Polistes maculipennis, Halictus dasygaster, Camponotus* sp etc. Of the dipterans, species like *Eristalis tenax, E. himalyansis, E. cerealis, E. angustimarginalis, E. arvorum, Metasyrphus corollae, Scaeva pyrastri, Musca domestica, Fannia domestica, Calliphora vicina* etc. spread over families Syrphidae, Cordiluridae, Calliphoridae and Dolichopodidae were recorded as pollinators of apple crop. Moreover, 8 species of lepidopterans were spread over families like Pieridae, Nymphalidae and Noctuidae. Order Coleoptera was represented by two families viz., Coccinellidae and Chrysomelidae. In addition, a single species of thrips belonging to order Thysanoptera was also recorded as pollinator of apple crop in Himachal Himalaya (Table 1; Fig. 1).

Different investigators have reported different number of pollinators on various temperate fruit crops. For example, Verma and Chauhan (1985) recorded 44 species of insect pollinators on apple bloom in Shimla hills, of which 16 belonged to Hymenoptera, 11 to Diptera, 9 to Lepidoptera, 7 to Coleoptera and 1 to Hemiptera, whereas, Kumar (1988) recorded 16 species of bees visiting apple bloom in Solan area of Himachal Pradesh. A similar survey by Hong *et al.* (1989) revealed a total of 88 species of pollinators on apple, pear and peach flowers in North Korea. Kumar (1997) observed that apple flowers were visited by 49 insect species. Pollinator diversity studies by Thakur (2005) showed that apple flowers were visited by 48 species of insects belonging to 5 orders and 18 families of class Insecta.

Analyses of data on relative abundance of different insect visitors revealed that Indian hive bee, *A. cerana* was the most abundant insect visitor to apple flowers in all the three experimental orchards i.e. Shilaroo (13.33±0.61, 28%), Matiana (12.5±0.62, 28.44%) and Narkanda (11.43±0.57, 27.24%). Other important hymenopteans at Shilaroo, Matiana and Narkanda were European honey bee, *A. mellifera* (8.16±0.28, 17.14%, 12.5±0.42, 15.24% and 6.28±0.42, 14.97%), *Bombus tunicatus* (0.83±0.03, 1.74%, 0.80±0.03, 1.82% and 0.72±0.02, 1.19%) and *Vespa velutina* (0.33±0.01, 0.69%, 0.30±0.01, 0.68% and 0.25±0.01, 0.59%). Among Dipterans, *Musca domestica* (6.36±0.16, 13.36%, 6.05±0.17, 13.76% and 5.88±0.06, 14%), *Eristalis angustimarginalis* (3.15±0.09, 6.69%, 3.06±0.09, 6.96% and 2.98±0.08, 7.10%) and *Syrphus* sp. (2.73±0.08, 5.73%, 2.68±0.06, 6.70% and 2.57±0.12, 6.12%) were the most important pollinators at Shilaroo, Matiana and Narkanda orchards respectively (Tables 2-4; Figs. 2-4).

Moreover, *Heliothis armigera* and *Pieris canidia* were important lepidopteran pollinators present at Shilaroo (1.73±0.07, 3.63% and 0.78±0.04, 1.63%), Matiana (1.27±0.16, 2.89% and 0.77±0.04, 1.75%) and Narkanda (1.22±0.22, 2.90% and 0.51±0.05, 1.21%) orchards, *Coccinella* sp. (0.5±0.02, 1.07%, 0.47±0.02, 1.06% and 0.44±0.01, 1.05%) was the only coleopteran and Thrips (0.80±0.03, 1.70%, 0.80±0.03, 1.82% and 0.75±0.03, 1.7%) belonging to order Thysanoptera were also seen visiting the apple flowers in Shilaroo, Matiana and Narkanda orchards (Tables 2-4; Figs. 2-4). Therefore, present results suggest that hymenopterans and dipterans were the most abundant insect pollinators of apple at Shilaroo (40.06%, 42.18%) and Matiana (47.74%, 44.07%) orchards, whereas, at Narkanda orchard dipterans (46.35%) were more in percentage than hymenopterans (46.07%) (Tables 2-4).

The higher population of *A. cerana* in experimental apple orchards may be due to its being native species and thus having better adaptability to local environmental conditions. These results are in conformity with the earlier observations of Mishra *et al.* (1976) who reported that honeybees constituted 70% of total pollinator population on apple crop in Shimla hills and *Bombus* sp. in good number also visited apple flowers. Similarly, Verma and Chauhan (1985), Dashad (1989), Kakkar and Bhatia (1990) and Kumar (1997) have accounted the hymenopterans and dipterans as the most predominant insect species on apple crop in Shimla hills. Recently, Minakshi (2004) and Thakur (2005) reported *Bombus* sp. *Vespa* sp. *Polistes* sp. *Halictus* sp., *Xylocopa fenestrata* and *Camponotus* sp. in good proportion on different mountain fruit crops in Himachal Pradesh.

Present studies on insect diversity and relative abundance on apple bloom showed that Hymenopterans were most abundant insect pollinators on apple bloom. These results corroborate the findings of Kumar (1995) who also found hymenopterans (78.89%) as the most important insect pollinators on almond bloom, whereas, hymenopterans (44.50%) and dipterans (49.37%) were almost equally abundant on peach bloom in Shimla and Solan hills respectively.

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TABLE 1: Insect species visiting apple flowers with their taxonomic status

Order HYMENOPTERA	Order DIPTERA	Order LEPIDOPTERA	Order COLEOPTERA	Order THYSANOPTERA
Family Apidae	Family Syrphidae	Family Pieridae	Family Coccinellidae	46. *Thrips* sp.
1. *Apis cerana*	17. *Eristalis tenax*	35. *Pieris canidia*	43. *Coccinella septumpunctata*	
2. *Apis mellifera*	18. *Eristalis himalyansis*	36. *Pieris* sp.	44. *Coccinella* sp. (i)	
3. *Bombus tunicatus*	19. *Eristalis cerealis*	Family Nymphalidae	Family Chrysomelidae	
4. *Bombus haemorridalis*	20. *Eristalis angustimarginalis*	37. *Pyrameis indica*	45. *Altica* sp.	
5. *Bombus* sp. (i)	21. *Eristalis arvorum*	38. *Vanessa cashmirensis*		
Family Vespidae	22. *Metasyrphus corollae*	39. *Neptis* sp.		
6. *Vespa mandarina*	23. *Macrosyrphus* sp.	Family Noctuidae		
7. *Vespa velutina*	24. *Episyrphus* sp.	40. *Heliothis* sp.		
8. *Vespa flaviceps*	25. *Scaeva pyrastri*	41. *Agrotis flammatra*		
9. *Polistes maculipennis*	26. *Melanostoma*	42. *Agrotis ipsilon*		
10. *Polistes* sp.	Family Cordiluridae			
Family Halictidae	27. *Musca domestica*			
11. *Halictus dasygaster*	28. *Musca* sp.			
12. *Halictus* sp. (i)	29. *Fannia domestica*			
Family Andrenidae	30. *Orthelia* sp.			
13. *Andrena* sp.	31. *Scathophaga stereoraria*			
Family Anthophoridae	Family Calliphoridae			
14. *Xylocopa* sp.	32. *Calliphora vicina*			
Family Formicidae	33. *Lucilia* sp.			
15. *Camponotus* sp.	Family Dolichopodidae			
Family Pteromalidae	34. *Dolichopus* sp.			
16. *Chalcid* sp.				

TABLE 2: Relative abundance of different insect pollinators visiting apple bloom at Shilaroo orchard No. of insects/500 flowers/10 minutes)

Family	Genus/Species	Mean ± S.E.	Percentage Population	Family Percentage	Order Percentage
HYMENOPTERA					
Apidae	*Apis cerana*	13.33* ± 0.61	28.00		
	Apis mellifera	8.16 ± 0.28	17.14	49.97	49.06
	Bombus tunicatus	0.83 ± 0.03	1.74		
	Bombus haemorrhidalis	0.52 ± 0.03	1.09		
Formicidae	*Camponotus* sp.	0.19 ± 0.01	0.40	0.40	
Vespidae	*Vespa velutina*	0.33 ± 0.01	0.69	0.69	
DIPTERA					
Cordyluridae	*Musca domestica*	6.36 ± 0.16	13.36	13.36	
Syrphidae	*Eristalis anqustimarginalis*	3.15 ± 0.09	6.69		
	Syrphus sp.	2.73 ± 0.08	5.73		42.18
	Eristalis tenax	2.72 ± 0.04	5.71	22.22	
	Eristalis himalyansis	1.98 ± 0.05	4.16		
Calliphoridae	*Calliphora* sp,	0.71 ± 0.05	1.49	2.48	
	Lucilia sp,	0.47 ± 0.01	0.99		
Dolichopodidae	*Dolichopus* sp.	1.96 ± 0.04	4.12	4.12	
LEPIDOPTERA					
Noctuidae	*Heliothis armigera*	1.73 ± 0.07	3.63	3.63	
Pieridae	*Pieris canidia*	0.78 ± 0.04	1.63	1.63	6.00
Nymphalidae	*Pyrameis indica*	0.35 ± 0.04	0.73	0.73	
COLEOPTERA					
Coccinellidae	*Coccinella* sp.	0.51 ± 0.02	1.07	1.07	1.07
THYSANOPTERA	*Thrips*	0.80 ± 0.03	1.70	1.70	1.70

* Each value is an overall average for an insect species

S.E. = Standard error about the mean

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TABLE 3: Relative abundance of different insect pollinators visiting apple bloom at Matiana orchard. No. of insects/500 flowers/10 minutes

Family	Genus/Species	Mean ± S.E.	Percentage Population	Family Percentage	Order Percentage
HYMENOPTERA					
Apidae	*Apis cerana*	12.5* ± 0.62	28.44		
	Apis mellifera	6.7 ± 0.42	15.24	46.69	47.74
	Bombus tunicatus	0.80 ± 0.03	1.82		
	Bombus haemorrhidalis	0.52 ± 0.02	1.18		
Formicidae	*Camponotus* sp.	0.16 ± 0.01	0.36	0.36	
Vespidae	*Vespa velutina*	0.30 ± 0.01	0.68	0.68	
DIPTERA					
Cordyluridae	*Musca domestica*	6.05 ± 0.17	13.76	13.76	
Syrphidae	*Eristalis anqustimarginalis*	3.06 ± 0.09	6.96		
	Syrphus sp.	2.68 ± 0.06	6.70		44.07
	Eristalis tenax	2.58 ± 0.05	5.87	23.21	
	Eristalis himalyansis	1.88 ± 0.05	4.28		
Calliphoridae	*Calliphora* sp,	0.69 ± 0.04	1.57	2.48	
	Lucilia sp,	0.40 ± 0.01	0.91		
Dolichopodidae	*Dolichopus* sp.	2.03 ± 0.15	4.62	4.62	
LEPIDOPTERA					
Noctuidae	*Heliothis armigera*	1.27 ± 0.16	2.89	2.89	
Pieridae	*Pieris canidia*	0.77 ± 0.04	1.75	1.75	5.30
Nymphalidae	*Pyrameis indica*	0.29 ± 0.02	0.66	0.66	
COLEOPTERA					
Coccinellidae	*Coccinella* sp.	0.47 ± 0.02	1.06	1.06	1.06
THYSANOPTERA	*Thrips*	0.80 ± 0.03	1.82	1.82	1.82

* Each value is an overall average for an insect species
S.E. = Standard error about the mean

TABLE 4: Relative abundance of different insect pollinators visiting apple bloom at Narkanda orchard. No. of insects/500 flowers/10 minutes

Family	Genus/Species	Mean ± S.E.	Percentage Population	Family Percentage	Order Percentage
HYMENOPTERA					
Apidae	*Apis cerana*	11.43* ± 0.57	27.24		
	Apis mellifera	6.28 ± 0.42	14.97	45.11	46.07
	Bombus tunicatus	0.72 ± 0.02	1.72		
	Bombus haemorrhidalis	0.50 ± 0.02	1.19		
Formicidae	*Camponotus* sp.	0.15 ± 0.01	0.36	0.36	
Vespidae	*Vespa velutina*	0.25 ± 0.01	0.59	0.59	
DIPTERA					
Cordyluridae	*Musca domestica*	5.88 ± 0.06	14.00	14.0	
Syrphidae	*Eristalis anqustimarginalis*	2.98 ± 0.08	7.10		
	Syrphus sp.	2.57 ± 0.12	6.12		46.35
	Eristalis tenax	2.30 ± 0.09	5.48	22.88	
	Eristalis himalyansis	1.75 ± 0.07	4.27		
Calliphoridae	*Calliphora* sp,	1.77 ± 0.07	4.21	5.27	
	Lucilia sp,	0.44 ± 0.01	1.05		
Dolichopodidae	*Dolichopus* sp.	1.76 ± 0.07	4.19	4.19	
LEPIDOPTERA					
Noctuidae	*Heliothis armigera*	1.22 ± 0.22	2.90	2.90	
Pieridae	*Pieris canidia*	0.51 ± 0.05	1.21	1.21	4.74
Nymphalidae	*Pyrameis indica*	0.26 ± 0.02	0.62	0.62	
COLEOPTERA					
Coccinellidae	*Coccinella* sp.	0.44 ± 0.01	1.05	1.05	1.05
THYSANOPTERA	*Thrips*	0.75 ± 0.03	1.78	1.78	1.78

* Each value is an overall average for an insect species

S.E. = Standard error about the mean

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