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ASSESSMENT OF RELATIVE ABUNDANCE AND DIVERSITY OF NATIVE INSECT POLLINATORS IN APPLE ORCHARDS OF KASHMIR HIMALAYA

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ABSTRACT

A study was made to assess the insect pollinator diversity and abundance in the apple orchards of Kashmir Himalaya. The selection of sites was in important focus so that an average data representative of the whole native insect pollinator diversity and distribution in apple orchards of Kashmir valley can be obtained. The findings of the study revealed that insect pollinators in the apple orchards were in general represented by three orders Hymenoptera, Lepidoptera and Diptera. At all the locations, the order Hymenoptera was found to represent three families Helictidae, Apidae and Tenthredinidae. A total of 21 species of insect pollinators belonging to 12 families and three orders Hymenoptera, Diptera and Lepidoptera registered their occurrence in different apple orchards of Kashmir valley. Overall, maximum abundance of 479 individuals, i.e. *Lasioglossoma himalayense* (412) and *Lasioglossoma nursie* (67) corresponding to a percent family contribution of 49.40% at all the studied apple orchards was registered by family Halictidae and least abundance was documented by the family Nymphalidae (4 individuals) contributed by a single species, *Vanessa cashmirensis* corresponding to a percent family contribution of 0.41%. Diptera was the most dominant order composing 11 species and as such accounting for 52.81% of total species found followed by Hymenoptera and Lepidoptera each of which registered 5 species corresponding to 23.81% of total species reported. The findings suggest to maintain a natural habitat that is suitable for *Lasioglossum* and other such dominant native insect pollinators to ensure successful survival of these important native insects in apple orchards which contribute significantly to fruit set especially to apple crop.
Keywords: Insect pollinator, Apple orchards, Kashmir, Himalaya

INTRODUCTION

Pollination is an ecosystem process that has evolved over millions of years to benefit both flowering plants and pollinators. Pollinators visit flowers for many reasons, including feeding, pollen collection, and warmth. When pollinators visit flowers, pollen rubs or drops onto their bodies. The pollen is then transferred to another flower or a different part of the same flower as the pollinator moves from one location to the next. This process is a vital stage in the life cycle of all flowering plants and is necessary to start seed and fruit production in flowers. Not only do pollinators provide essential services in nature, they are also necessary for healthy, productive agricultural ecosystems as they ensure the production of full-bodied fruit and fertile seed sets in many crops.

There is no doubt that insect pollination is a vital service for agricultural systems. Without insect pollinators, roughly a third of the world's crops would flower, only to fade and then lie barren. Pollinators ensure abundant fruits and vegetables. Pollinator diversity stabilizes pollination services through time. The more species in an area, the more likely there will be a species that can tolerate variable climatic conditions, like a cold and wet spring. Similarly when bee diversity is high, even if there is one species that is extirpated by disease, parasites, pesticides or habitat loss, other species continue to thrive and pollinate. While honey bees are important, they are certainly not the only crop pollinators (National Research Council). Native insect pollinators (species of insects that are native to a region) play an important, but underappreciated, role in crop pollination. Bees are an enormously diverse group. A number of recent studies in agricultural systems have suggested that native bees play an important role in crop pollination [*Kremen et al.* (2002) and Winfree *et al.* (2007)]. However, we are just beginning to understand the conditions under which native bees may play an important

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role. The most important wild pollinators of apple are ground-nesting bees. Ground-nesters excavate underground nests, comprised of tunnels and egg chambers where the young develop – a nesting strategy shared by 70% of bees worldwide. To avoid moisture-loving microbes that attack food and young, nests are built in well-drained soils. These nests are difficult to find because the entrance is normally a simple hole in the ground, just big enough for the bee to move in and out.

The apple is the most ubiquitous of temperate fruits and has been cultivated in Europe and Asia from antiquity. It was known to the Greeks and Romans and mentioned by Theophrastus in the third century B.C. Since then the apple has been distributed into almost all parts of the world. The genetic variability found in the apple has allowed adapted types to be selected for different environments, and selection continues for new types to extend apple culture into both colder and warmer regions.

The main aim of the study was based on the realization that the more species in an area, the more likely will be the occurrence of a species that can tolerate variable climatic conditions, like a cold and wet spring. Specifically, the present study was based upon the following objectives: (1) To estimate the relative abundance of different insect pollinators in apple orchards of Kashmir (2) To survey insect pollinator diversity in the apple orchards.

MATERIALS AND METHODS

Study Area and Study Sites

Kashmir has for long been considered the home of apples. Though apple is the major fruit grown in Kashmir, especially in Sopore in north and Shopian and Pulwama in the south, other fruits like cherry, peach, apricots and pears are also grown on a large scale. As a dominant crop of the valley "Apple" proudly represents the fruit industry of Kashmir, representing 98% of the total fruit production. Between 1974 – 75 and 2008-09, the area under apple has gone up from 46190 hectares to 1332810 hectares. A number of apple varieties are found indigenous to the state of which Ambri is "Par excellence".

Apple is the most important temperate fruit of the northwestern Himalayan region in India. It is predominantly grown in Jammu and Kashmir, Himachal Pradesh and hills of Uttar Pradesh, accounting for about 90% of the total production. Its cultivation has also been extended to Arunachal Pradesh, Sikkim, Nagaland, and Meghalaya in north-eastern region and Nilgiri hills in Tamil Nadu. The agro climatic conditions in these states are not as conducive as in north-western Himalayan region. Early and continuous rains from April onwards do not favour the production of quality fruits besides resulting in high incidence of diseases.

Anthropogenic changes in management practices in managing apple crop have resulted in substantial reductions in native pollinator diversity and abundance; the deficit in turn can lead to serious damage to entomophilous crops especially the apple crop.

The study was an attempt to assess the insect pollinator diversity and abundance in the apple orchards of Kashmir Himalaya. The selection of sites was in important focus so that an assessment of an average data representing the native insect pollinator fauna in apple orchards of Kashmir valley can be made.

Three different orchards located at different locations were selected to address the diversity and distribution of native insect fauna at distinct locations of the Valley. Apple orchards, viz. CITH (Badgam) apple orchard (33^{o}59'N, 74 ^{o}50'E, 1640m), Avengound (Pulwama) apple orchard (33^{o}49'N, 74 ^{o}50'E, 6040m) and Diaroo (Shopian) apple orchard (33^{o}47'N, 74 ^{o}50'E, 6150m) were the three locations selected for the pollinator studies during the period of investigation.

Sampling Methods

Apple orchards located at different locations were sampled using Active net collecting, and Passive bowl trapping in early spring during apple flowering. During the period of investigation, the collection of data regarding the assessment of populations of native pollinators in different apple orchards was based on the following variables; the number of insect species and the number of insects per species.

Active Netting

The first collection method i.e.; active netting was performed by the participants for thirty minutes two times each sampling day. The first was at 11am and the other at 3pm. Some pollinating insects have different foraging and behavioral schedules and that is why it was important that the netting be done at different times of the day (Winfree, 2007). After insect pollinators are netted they were euthanized to be identified later in a lab. A small amount of ethyl acetate was infused into plaster of Paris within a jar. Afterwards a crumpled paper towel was placed in the jar to keep the bees from touching the solution and the lids were fastened. When a bee was captured it was placed in the jar, quickly killing it due to the fumes produced by the ethyl acetate. It may then be removed and placed in a holding container until it can be identified.

Bowl Trapping

The next collection method that was used was bowl trapping. This is a standard collection method used in many studies that simply involves filling a bowl with a water and soap solution to collect insects (Winfree, 2007; National Research Council, 2007). The bowls that were used for this method were Solo brand, 6 oz., disposable bowls of fluorescent blue, yellow, and white (Winfree, 2007). In the course of study, the pollinators were sampled using two types of colored bowls, yellow and blue; the two colors being effective to attract insect fauna. There were 16 bowls, 8 of each color. Each bowl was placed 5m apart in a random position in each orchard i.e; each study site such that each end of the line touches a corner of the plot (National Research Council, 2007). The bowls were also placed in random order for color to reduce any sampling bias. The bowls were placed in each area in this manner from 9am to 5pm on the same days that the area is being sampled by netting. The samples were then collected at 5pm and the bowls removed.

The contents of the bowls were sieved to separate the insects which are then stored in 70% alcohol for later identification. Insect samples were sorted into key taxa in the laboratory and are identified. Once the sampling period is over and all the results have been recorded the data were analyzed.

Statistical Analysis of Collected Data

In order to assess the species diversity and relative abundance in apple orchards of Kashmir valley, standard statistical tests were used to analyze several measures of abundance and diversity from the collected data. First, we calculated the contribution (Number of individuals /Orchard/30 Minutes) of native insect pollinators at all orchards over the period of sampling. Second, we calculated the proportion of native insects collected at each site. Finally, we estimated the species diversity at each orchard using the Evenness, Richness, Simpson index and Shannon-Wiener (SW) index.

RESULTS

Diversity of insect pollinators in the apple orchards at different locations

The study revealed that the apple orchards were in general represented by three orders Hymenoptera, Lepidoptera and Diptera (table 1). At all the locations, the order Hymenoptera was found to represent three families Helictidae, Apidae and Tenthredinidae.

During the present study, a total of 21 species of insect pollinators belonging to 12 families and three orders Hymenoptera, Diptera and Lepidoptera registered their occurrence during apple flowering in Kashmir valley.

The findings of the study revealed that overall, maximum abundance of 479 individuals [*Lasioglossoma himalayense* (412) and *Lasioglossoma nursie* (67)] corresponding to a percent family contribution of 49.40% at all the studied apple orchards was registered by family Halictidae and least abundance was documented by the family Nymphalidae (4 individuals) contributed by a single species, *Vanessa cashmirensis* corresponding to a percent family contribution of 0.41%. The variation of abundance in percent family contribution among other groups (Table 3) followed the pattern: Empididae (28%), Muscidae (5.062%), Pieridae (4.96%), Bibionidae (3.51%), Sarcophagidae (2.48%), Syrphidae and Apidae (1.65% each), Calliphoridae (1.343%), Tenthredinidae (0.93% each), and Scathophagidae (0.52%).

As far as species composition of each of the order was concerned, Diptera was the most dominant order composing 11 species and as such accounting for 52.81% of total species found followed by Hymenoptera and Lepidoptera each of which registered 5 species corresponding to 23.81% of total species reported (Table 4).

Diversity indices for the apple orchards at different locations

To estimate the species diversity and relative abundance, four diversity indices viz. richness, evenness, Shannon-Weiner index, Simpson index were calculated (Table 5).

Richness
The sites, Avengound (Pulwama), Diaroo (Shopian) and the CITH orchards respectively registered 18, 19 and 18 species implying that apple orchards had almost same richness; the CITH orchard being somewhat being poor in diversity the species richness of which was less (i.e. 18).

Evenness
Evenness is a measure of the relative abundance of the different species making up the richness of an area. In other words, species evenness refers to how close in numbers each species in an environment are. The calculated values of evenness index for the three orchards CITH, Avengound and Diaroo were 0.52, 0.61 and 0.65 respectively implying that the species making up the community were more evenly distributed in Diaroo compared to the other studied orchards.

Shannon-Wiener Index
Shannon Weiner index values for the apple orchards CITH (Badgam), Avengound (Pulwama) and Diaroo (Shopian) under the study were respectively calculated to be 1.492, 1.804 and 1.871 impying that thus Diaroo (Shopian) apple orchard was more diverse site followed by Avengound (Pulwama) and CITH (Badgam) was comparatively of lesser diversity as per Shannon-Weiner index.

Simpson index
Simpson's Index is one of the simplest calculations that takes into account species evenness within a community. Simpson's Index (D) is dependent on the number of species and their relative dominance. The calculated Simpson index values for the three orchards at different locations were 0.62, 0.73 and 0.75 respectively.

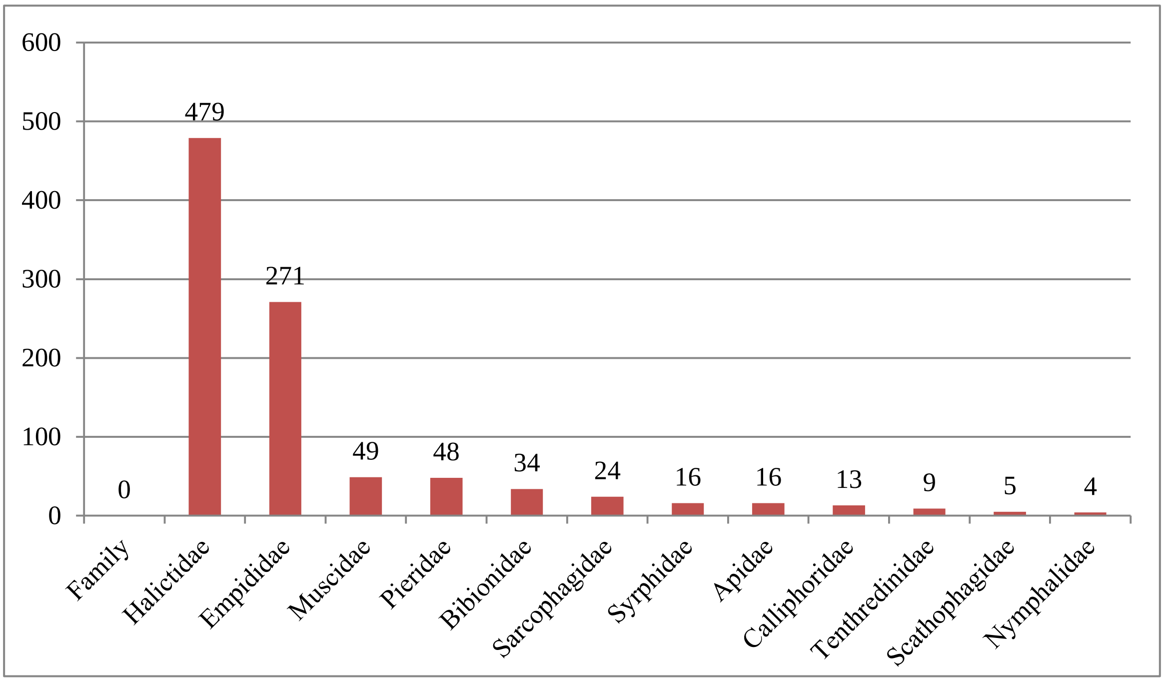

Fig. 1: Diagrammatic representation of collective contribution of different taxa collected at all sampled orchards.

Table 1: RELATIVE ABUNDANCE OF DIFFERENT INSECT POLLINATORS VISITING DIFFERENT APPLE ORCHARDS OF THE KASHMIR VALLEY

Order	Family	CITH (Badgam) (33°59'N,74 °50'E, 1640m)			Avengound (Pulwama) (33°49'N, 74 °50'E, 6040m)		Diaroo (Shopian) (33°47'N, 74 °50'E, 6150m)	
		Genus/ Species	Percent Population contribution	Percent Family contribution	Percent population contribution	Percent Family contribution	Percent Population contribution	Percent Family contribution
Hymenoptera	Halictidae	*Lasioglossum himalayense*	57.576	65.968	44.245	51.799	16.092	19.923
		Lasioglossum nursie	8.392		7.554		3.831	
	Apidae	*Euglossa* sp.	1.399	1.399	1.079	1.798	0	1.916
		Xylocopa sp.	0		0.719		1.916	
	Tenthredinidae	*Athalia* sp.	0.699	0.699	2.158	2.158	0	0
Lepidoptera	Pieridae	*Pieris brassicae*	3.497	5.129	3.237	4.696	2.299	4.981
		Pontia daplidice	0.233		0		0	
		Colias fieldi	1.166		1.079		2.299	
		Colias philodice	0.233		0.36		0.383	
	Nymphalidae	*Venessa cashmirensis*	0.699	0.699	0	0	0.383	0.383
Diptera	Syrphidae	*Echium* sp.	1.399	2.098	0.719	1.439	0.383	1.149
		Eristalis sp.	0.233		0.36		0.383	
		Syrphus sp.	0.466		0.36		0.383	
	Sarcophagidae	*Sarcophaga* sp.	1.865	1.865	2.158	2.158	3.831	3.831
	Calliphoridae	*Caliphora* sp.	0.233	0.233	1.079	1.079	3.448	3.448
	Muscidae	*Ophyra* sp.	0	0.699	1.079	2.518	6.513	14.942
		Musca domestica	0.699		1.439		8.429	
	Scathophagidae	*Scathophagia* sp.	0	0	1.079	1.079	0.766	0.766
	Bibionidae	*Bibio* sp.	1.632	2.331	4.317	5.396	2.682	3.448
		Plecia sp.	0.699		1.079		0.766	
	Empididae	*Unidentified* sp.	18.881	18.881	25.899	25.899	45.211	45.211

Table 2: Collective contribution of different taxa from all the Apple orchards

Order	Family	Genus/ Species	Abundance	CITH	AVENGOUND	DIAROO
Hymenoptera	Halictidae	*Lasioglossum himalayense*	**412**	247	123	42
		Lasioglossum nursie	**67**	36	21	10
	Apidae	*Euglossa* sp.	**9**	6	3	0
		Xylocopa sp.	**7**	0	2	5
	Tenthredinidae	*Athalia* sp.	**9**	3	6	0
Lepidoptera	Pieridae	*Pieris brassicae*	**30**	15	9	6
		Pontia daplidice	**1**	1	0	0
		Colias fieldi	**14**	5	3	6
		Colias philodice	**3**	1	1	1
	Nymphalidae	*Venessa cashmirensis*	**4**	3	0	1
Diptera	Syrphidae	*Echium* sp.	**9**	6	2	1
		Eristalis sp.	**3**	1	1	1
		Syrphus sp.	**4**	2	1	1
	Sarcophagidae	*Sarcophaga* sp.	**24**	8	6	10
	Calliphoridae	*Caliphora* sp.	**13**	1	3	9
	Muscidae	*Ophyra* sp.	**20**	0	3	17
		Musca domestica	**29**	3	4	22
	Scathophagidae	*Scathophagia* sp.	**5**	0	3	2
	Bibionidae	*Bibio* sp.	**26**	7	12	7
		Plecia	**8**	3	3	2
	Empididae	*Unidentified* sp.	**271**	81	72	118
Total			**968**	**429**	**278**	**261**

Table 3: Species composition of various taxa collected from all apple orchards of Kashmir valley under the study

Order	No. of species	Percent Species contribution
Hymenoptera	5	23.81
Lepidoptera	5	23.81
Diptera	11	52.81

Table 4: Calculated values of diversity indices from different apple orchards of the Kashmir Valley

Diversity index	CITH (Badgam)	Avengound (Pulwama)	Diaroo (Shopian)
Shannon-Weiner index	1.49	1.80	1.87
Simpson index	0.62	0.73	0.75
Species richness	18	19	18
Evenness index	0.52	0.61	0.65

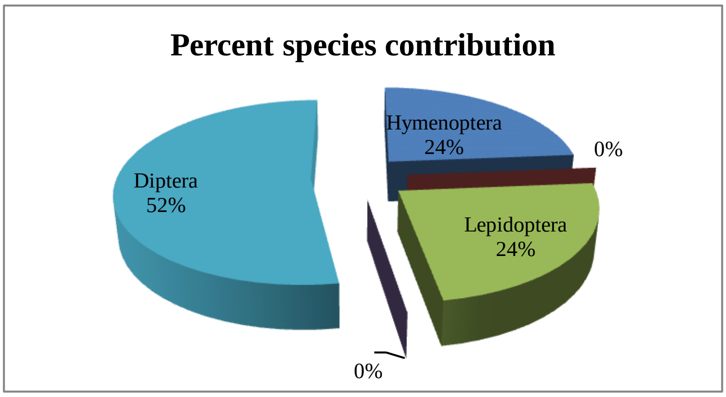

Fig. 2: Diagrammatic representation of percent species composition of various taxa from all apple orchards of Kashmir Valley.

Fig. 3: *Lasioglossosum* sp.

Fig. 4: *Syrphus* sp.

Fig. 5: *Vanessa cashmirensis*

Fig. 6: *Ophyra* sp.

Fig. 7: *Plecia* sp.

Fig. 8: Insect pollinator collection box

Fig. 9: Identification of insect pollinator specimen under microscope in progress

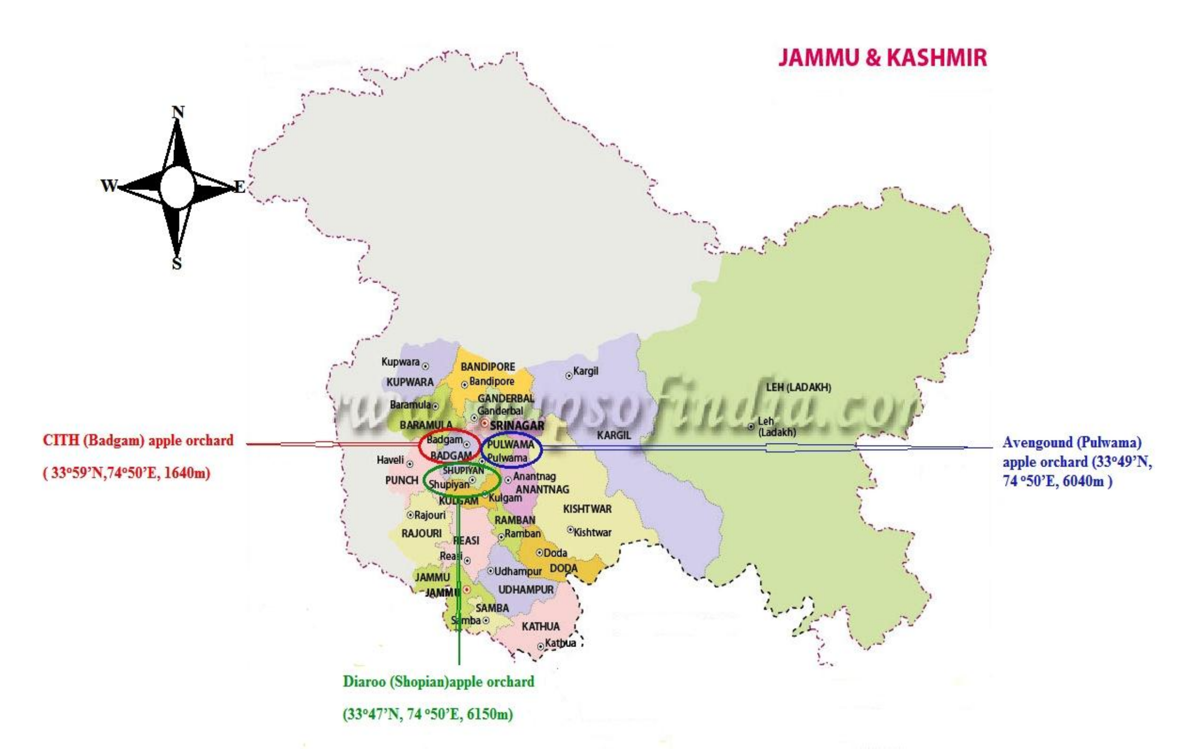

Fig. 10: Map of Jammu and Kashmir showing study sites

DISCUSSION

Diversity of different insect pollinators in the apple orchards at different locations

During the present study a total of 21 species of insect pollinators belonging to 13 families and 3 orders_ Hymenoptera, Diptera and Lepidoptera registered their occurrence at all the studied apple orchards of the Kashmir Valley.

The findings of the study revealed that overall, maximum abundance of 479 individuals [*Lasioglossum himalayense* (412) and *Lasioglossum nursie* (67)] corresponding to a percent family contribution of 49.40% at all the studied apple orchards was registered by family Halictidae and least abundance was documented by the family Nymphalidae (4 individuals) contributed by a single species *Vanessa cashmirensis* corresponding to a percent family contribution of 0.41%. The variation of abundance in percent family contribution among other groups (Table 3) followed the pattern: Empididae (28%), Muscidae (5.062%), Pieridae (4.96%), Bibionidae (3.51%), Sarcophagidae (2.48%), Syrphidae and Apidae (1.65% each), Calliphoridae (1.343%), Tenthredinidae (0.93% each), and Scathophagidae (0.52% (Table 3). As far as species composition of each of the order was concerned, Diptera was the most dominant order composing 11 species and as such accounting for 52.81% of total species found followed by Hymenoptera and Lepidoptera each of which registered 5 species each corresponding to 23.81% of total species reported [Table (4)].

The same findings were also registered by different researchers undertaking similar types of problems. In the present study maximum abundance was shown by *the Lassioglossoma himalayense* and *Lasioglossum nursie* (Halictidae, Hymenoptera). The higher values of rank abundance of these species can be attributed to the fact that these species are supposed to have a greater adaptability to local environmental conditions. Similar findings were also registered by Park *et al.* (2012) who reported an impressive diversity of native bee species in the NY orchards and added that native bees were very abundant in the apple orchards and a number of native bees such as *Adrena, Osmia* and *Bombus* were reported to be effective vectors of apple pollen. Similar findings were also reported by Hussain *et al.* (2012), the result revelations of which confirmed that 9 species of insects in five genera belonged to order hymenoptera as per rank abundances. Our study results are also tune with those of Kumar (1995) who also reported the order hymenoptera as a dominant group among other groups of insect pollinators on almond bloom. The findings of our study are also supported by the study of Abrol *et al.* (2005); the findings of whom revealed the order hymenoptera a dominant group during the entire period of investigation. Order hymenoptera in the order of their respective dominance was represented by dominant species i.e. *A. dorsata* > *A. mellifera* > *A. cerana* > *A. florea*. Our study findings are also in accordance with the results of Saeed *et al.* (2012), the findings of whom confirmed that the pollinator community was composed of 15 insect species belonging to three orders and 10 families and confirmed that bees were the most abundant (435 individuals) flower visitors followed by butterflies (345 individuals) and flies (248 individuals) while moths and wasps were observed occasionally.

Also, for the calculation of abundance, richness and Evenness of species forming the community of the selected apple orchards, four diversity indices, viz. Shannon Weiner index, Simpson index, evenness index and Richness were used{Table(11)}. Shannon Weiner index for the apple orchards_CITH, Avengound (Pulwama) and Diaroo(Shopian) under the study were respectively calculated to be 1.4919, 1.80406 and 1.87105. Simpson index calculated from the data were 0.623205, 0.726565 and 0.7518 respectively. The sites respectively registered 18, 19 and 18 species implying no much difference in the distribution of species at the three locations. The meagre difference in diversity indices means that that the pollinator insect fauna were almost uniformly distributed along different locations of the Valley, as was also reported by Hussain *et al.* (2012) while studying the Hymenopterous pollinators of Himalayan foot hills of Pakistan.

SUMMARY AND CONCLUSION

There is no doubt that insect pollination is a vital service for agricultural systems. Without insect pollinators, roughly a third of the world's crops would flower, only to fade and then lie barren. Pollinators ensure abundant fruits and vegetables. Native insect pollinator diversity stabilizes pollination services through time. As declining populations of honey bees are reported, it is essential that we identify promising native insect pollinators to fill this crucial need for insect pollination.

Diversity and abundance of native insect pollinator in apple orchards at different locations

- The findings of the study revealed that overall, maximum abundance Halictidae (represented by *Lasioglossoma himalayense* and *Lasioglossoma nursie*) and least abundance was documented by the family Nymphalidae (contributed by a single species *Vanessa cashmirensis*).
- As far as species composition of each of the order was concerned, Diptera was the most dominant order composing 11 species and as such accounting for 52.81% of total species found followed by Hymenoptera and Lepidoptera each of which registered 5 species corresponding to 23.81% of total species reported.
- The sites, Avengound (Pulwama), Diaroo (Shopian) and the CITH orchards respectively registered 18, 19 and 18 species implying that apple orchards had almost same richness; the CITH orchard being somewhat being poor in diversity the

recorded species richness of which was less (i.e. 18).

- Shannon Weiner index values for the apple orchards CITH (Badgam), Avengoun (Pulwama) and Diaroo (Shopian) under the study were respectively calculated to be 1.492, 1.804 and 1.871 impying that Diaroo (Shopian) apple orchard was more diverse site followed by Avengound (Pulwama) and CITH (Badgam) was comparatively of lesser diversity as per Shannon-Weiner index.
- The calculated Simpson index values for the three orchards at different locations were 0.62, 0.73 and 0.75 respectively showing the same trend of diversity change as was also gesticulated by Shannon-Weiner index.

The studies reported a numerically abundant and diverse group of native pollinators present in apple orchards in the Valley of Kashmir; however, the most numerous native pollinators in apple orchards were reported from the family Halictidae, and the genus *Lasioglossum*, which were reported in high numbers. The findings of the study suggest maintaining a natural habitat that is suitable for *Lasiogloossum* and other native pollinators that will ensure a successful survival of these important native insects in apple orchards that will consequently contribute to significant fruit set. Specifically, there needs a well-defined conservation strategy to avoid the danger or threat the native pollinators face while encountering different environmental stresses.

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REFERENCES

Abrol, D. P., Sharma, D. and Monobrullah, M. (2005). Abundance and diversity of different insect pollinators visiting peach and plum flowers and their impact on fruit production. *J. res.*, 4 (1), 38-45.

Cane, J. H., R. L. Minckley and L. J. Kervin (2000). Sampling Bees (Hymenoptera: Apiformes) for Pollinator Community Studies: Pitfalls of Pan-Trapping. *J. Kan. Entom. Soc.*, 73:225-231.

Hussain, Rahim, K. M., A. Ghffar, Alia, H., and Jamil. (2012). The hymenopterous pollinators of Himalayan foot hills of Pakistan (distributional diversity). *Afri. j.biotech.*. 11(28), 7263-7269.

Kremen, C. *et al.* (2002). Crop pollination from native bees at risk from agricultural intensification. *Proc. Natl. Acad. Sci. U. S. A.* 99, 16812–16816.

Kumar, L. (1997). Foraging ecology and behaviour of *Apis cerana* F. and *Apis mellifera* L. in pollinating apple and cherry flowers. *Ph.D Thesis, Himachal Pradesh University, Shimla, India.*

National Research Council (U.S.).Committee on the Status of Pollinators in North America, and National Academies Press (2007). *Status of pollinators in North America*. Washington, D.C.: National Academies Press.

Osborne, J.L., Martin, A.P., Shortall, C.R., Todd, A.D., Goulson, D., Knight, M., Hale, R.J. & Sanderson, R.A. (2008). Quantifying and comparing bumblebee nest densities in gardens and countryside habitats. *J. of Appl. Ecol.*, 45, 784–793.

Park, M., *et al.* 2012. Wild Pollinators of Eastern Apple Orchards and How to Conserve Them. Cornell University, Penn State University, and The Xerces Society.

Saeed S., Malik S. A., Dad K., Sajjad A. and Ali M. (2012). In Search of the Best Native Pollinators for Bitter Gourd (*Momordica charantia* L.) Pollination in Multan, Pakistan. *Pak. J. Zool.,* vol. 44(6), pp. 1633-1641.

Westphal, C., R. Bommarco, Carre, E. Lamborn, N. Morison, T. Petanidou, S. G. Potts, S. P. M. Roberts, H. Szentgyorgyi, T. Tscheulin, B. E. Vaissiere, M. Woyciechowski, J. C. Biesmeijer, W. E. Kunin, J. Settele, and I. Steffan Dewenter. (2008). Measuring bee diversity in different European habitats and biogeographical regions. *Ecolo.Monogr.* 78: 653-671.

Winfree, R., N.M. Williams, J. Dushoff, and C. Kremen. 2007. Native bees provide insurance against ongoing honey bee losses. *Ecol. Letters*. 10:1105-1113.