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Showket A Dar
Department of Entomology Sher-e-Kashmir University of Agricultural Science and Technology, Shalimar, Srinagar, Jammu and Kashmir, India

GM Mir
Department of Entomology Sher-e-Kashmir University of Agricultural Science and Technology, Shalimar, Srinagar, Jammu and Kashmir, India

AR Wani
Department of Entomology Sher-e-Kashmir University of Agricultural Science and Technology, Shalimar, Srinagar, Jammu and Kashmir, India

Ajaz A Kandoo
Department of Entomology Sher-e-Kashmir University of Agricultural Science and Technology, Shalimar, Srinagar, Jammu and Kashmir, India

Mainaz Nissar
Department of Entomology Sher-e-Kashmir University of Agricultural Science and Technology, Shalimar, Srinagar, Jammu and Kashmir, India

Correspondence
Showket A Dar
Department of Entomology Sher-e-Kashmir University of Agricultural Science and Technology, Shalimar, Srinagar, Jammu and Kashmir, India

Insect pollinators of peach *Prunus persica* in landscapes of Temperate India

Showket A Dar, GM Mir, AR Wani, Ajaz A Kandoo and Mainaz Nissar

Abstract
The current studies were carried out in temperate conditions of Kashmir valley during 2013-2015. The patches of fruit crop selected were located in different types of landscape categories. Highest species richness of 46 was observed in landscapes of Budgam, belonging to 5 orders, 31 families and 20 genera of class Insecta. Of all these insects, genus *Lasioglossum* was most abundant flower visitor followed by comparatively less abundant genera *Xylocopa* spp. *Andrena* spp. *Megachile* spp. *Syrphus* spp. and *Musca* spp. The minimum value of Simpson diversity index, Shannon diversity indices and Simpson's dominance were 5.415, -6.056 and 0.8115, respectively in district Srinager. The species richness of pollinators varies from minimum of 32 (Srinager) to maximum of 46 (Budgam). The equitability of species varies from minimum of 0.718 in Srinager to maximum of 0.931 on in Pulwama. The Pielou's evenness, Nakamaru's richness, Menhinick's and Margalef's varies across the different landscapes. Species richness showed a corresponding and parallel increase with various indices estimated. The unequal distribution of abundance between species on three fruit crops allow the use of dominance index of Berger-parker to express the proportion of individuals accounted for by the most abundant species (*Lasioglossum marginatum*) in each site of investigation and it varies from minimum of 0.087 in Pulwama to maximum of 0.121 in Srinager. The family Halictidae were most abundant. The dissimilarity coefficient of species richness varies from 11.00 to 19.83. The order Hymenoptera was most abundant with rank (K) one and K-dominance of 0.602 followed by Diptera with rank value 2 and K-dominance value -1.259 and so on.

Keywords: *Lasioglossum*, diversity, landscape, Kashmir, temperate

1. Introduction
Diversity of insect pollinator community significantly affects the pollination of important agricultural crops (Albrecht *et al*. 2013). Insect pollination is one of the most important mechanisms in the maintenance and promotion of biodiversity, and in general, life on Earth. Many ecosystems, including agro ecosystems, depend on pollinator diversity to maintain overall biological diversity and benefit the society by increasing food security and improving the livelihoods (Khan and Khan, 2004) [26]. Since, insect pollination is a vital ecosystem service and the strong effect of insect pollinator diversity on the degree of pollination may be a result of complementary behaviour of the various functional groups, their richness and abundance. The stone fruit crops require only one viable pollen tube to produce a fruit and in most cases the pollen should arrive from another compatible blossom at the right time (McGregor 1976) [32], for that the insect pollinator diversity is important to bear a satisfactory commercial yield (Potts *et al.* 2005) [41] Generally, there are three types of diversity i.e. alpha (α), beta (β) and gamma (δ) diversity. However, there are different types of insect pollinators like bees, wasps, ants, flies, butterflies, moths and beetles. In Kashmir valley among the wild pollinators, the families *viz.* Helictidae, Empididae, Muscidae, Bibionidae, Pieridae, Sarcophagidae, Calliphoridae, Cathophgidae and Syrphidae were found abundant (Ganie *et al*. 2013) [14], indicating that pollinators other than honey bees are extremely valuable for fruit crop pollination. Further, the study in Kashmir (SKUAST-K) valley indicates that Halictid species *viz*, *Lasioglossum marginatum* (Shahida, 2015) [45] and *L. himalanyses* (Shahzada, 2015) were abundant pollinators on stone fruit crops. Abrol (2012) [2] showed that Hymenopteran bees are high in richness in horticultural ecosystems of Jammu (SKUAST-J). A total of 30 morpho-species from order Hymenoptera were observed belonged to families Apidae, Megachilidae, Andrenidae, Colletidae and Halictidae. The species composition amongst different non-*Apis* bees showed that families *viz*, Apidae, Megachilidae and Halictidae constitute 17, 9 and 2 different morpho-species, respectively.

Wild bees can be more effective and extremely diverse with more than 20,000 pollinator bee species (Hymenoptera: *Apidae*) described worldwide (Michener, 2007) [34]. In agro-ecosystems of Himalayan region, the pollinator's diversity of stone fruits comprise of *Osmia cornifrons* (Panzer), *Anthophora niveocincta* (Smith), *Anthophora himalayensis* (Rad), *Anthophora crocea* (Bangham), *Bombus tunicatus* (Smith), *Xylocopa dissimilis* (Lepel), *Xylocopa rufescens* (Smith), *Andrena harrietae* (Bangham) and *Andrena anonyma* (Cam) (Hossain *et al.* 2012); *Osmia rufa* (Penzer), *Eristalis tenax* (Linnaeus), *Episyrphus balteatus* (De Geer) and *Halictus* (Latreille) (Jauker *et al.* 2012) [24]; *Andrena* (Fabricius), *Amegilla* (Fabricius), *Ceratina* (Latreille); *Ceratina heiroglyphica* (Smith) (Abrol 2012) [2] and *Xylocopa violacea* (Dar *et al*. 2016) [9]. In the horticultural ecosystem of India the blossoms of cherry, were found to be visited by *Apis cerana* (Fabricius), *A. mellifera* (Linnaeus), *Helictid sp*., and *Syrphid sp*. (Holzschuh *et al*. 2013) [18]. Wild, unmanaged pollinators are effective, often critical contributors to pollination services in natural and managed crop systems (Garibaldi *et al*. 2013). Of these, native bees are most important pollinator group and their conservation has risen in tandem with honeybee decline (Menz *et al*. 2010; Winfree, 2010) [59]. Wild bees have complex habitat requirements and are the best indicators of overall species richness in agro-ecosystems (Duelli and Obrist, 1998) [11].

The shortage of bees, especially for fruit pollination became so severe that in 2005 the Honeybee Act of 1922 was altered to allow importation of bees from outside of North America (NRC 2007). Keeping these losses into consideration, researchers are looking for domestication and providing habitat, as an alternative ways of using wild bees in place of honey bees (James and Singer 2008) [23]. Bees are the main crop pollinators in the United States, and about 35% of world crop production depends on the pollinators (Klein *et al*. 2007) [27]. In Kashmir division of state Jammu and Kashmir (India), the stone fruit crops *viz*, Cherries (*Prunus avium*), plums (*P. domestica*), peaches (*P. persica*) and almond (*P. amygdales*) make up the common stone fruits produced commercially in valley. All varieties of sweet cherries and most plums, peach and almond varieties, are self- unfruitful (Patil *et al*. 1974), therefore depends on insects for cross pollination to produce a good quality and quantity commercial crop. Keeping in view the importance of insect pollinator's in stone fruit pollination no systematic work has been done in the Himalayan region till date. Therefore, the present study were designed to study the diversity of insect pollinator's of *P. persica* in landscapes of Kashmir valley during 2013-2014

2. Material and Methods

2.1 Study area and sites

Jammu and Kashmir State of India is located in North-eastern of India. Geographically it is stretched between 32º 17" to 37º 60" N latitude and 73º 26" to 80º 30" E longitudes. The mountain range in the Himalayas region varies in altitude between 5,550m on North-east dip down to about 2,770m on South. Generally, the Kashmir contains the upper stages of the forest vegetation and lower stages of agricultural and horticultural crops including apple, pear, peach, plum, apricot, almond and cherry. The research were conducted during March to May in three locations of each Budgam, Pulwama and Srinagar districts situated at the height of 1610, 1630 and 1550 meters respectively, from mean sea level (MSL). Overall 81 sites were taken into consideration, with average altitude of around 2350 meter above mean sea level. The various habitat types selected were having the patches dominated by peach *P. persica*.

2.2 Field Survey and Sampling

Each study site selected was visited three times during the study period. Data were recorded throughout the blooming period from April to June between 800h to 1200h on each week by transect walk using plot samplings and a minimum distance of 50m were left from the forest edge to avoid any edge effect. Plots were circular with a radius of 10m or 200m separated from each other (Owiunji *et al*. 2004) [40], to cover the distance of 200 m which is the flight range of the wild bees. Before the observations were recorded about the wild pollinators' activity in each selected plot, GPS point's altitude, temperature, and the weather status were recorded. During the 10 min observation time in each plot, all encountered flower-pollinator interactions were recorded (TIEE, 2004) [54]. The open flowers were monitored by moving slowly through plots to avoid disturbance of pollinators visiting flowers, so as to determine the total number of observed individuals of pollinators interacting with the plant species (stone fruits) when ≥ 10 per cent of the plants had started to bloom upto 80 per cent of the anthesis. Three trees of same age and same management practice, per three locations were selected growing at least 12 m x 12 m of spacing, otherwise about 200 m away from one another in similar environments.

2.3 Insect collection and identification

During the flowering season of peach fruits, canopy insects were collected at the stages coinciding with the most receptive period of the flowers using hand net. The collected insects were killed in the glass container containing the cotton saturated with ethyl acetate. All collected specimens were mounted and preserved following dry preservation method (Schauff 1986) [44]. All the samples were labelled and deposited in the laboratory of RTCPPPM-SKUAST-K, Srinager. The collected specimen were sorted into broad categories then identified by comparison with the preserved specimens. RTCPPPM, Srinager assist in identification of the pollinators. Further, the *Lasioglossum* specimens were identified by Dr. Alian Pauly from Belgium, Europe; Dr. Vickrim Singh Thakur from Patailla, Punjab and Syrphid flies were identified from Department of Zoological Survey of Bangalore, India.

2.4 Data analysis

Recordings were made from the onset of main blooming period with temperature ≥15 ºC, low rain and dry vegetation (Westpahl *et al*. 2008) [57]. Depending on the height of the tree, the use of a telescopic net and smaller ladder in the field were used to sample the foragers in all parts of the trees. The sample size (pollinators) within the each three plots of the one experimental location varies, therefore each plot were sampled independently. And the stratification were done homogenously before sampling. The plots of every experimental location (strata) were mutually exclusive. The strata are collectively exhaustive, and no population element were excluded. The Stratified Random Sampling were applied within each strata. Further each population per strata were its representative. And the arithmetic means of the population were done to determine the variability/exp. Location (strata). Various softwares like SPSS, R and excel were used to analysis the data, Poisson distribution, Multiple regression analysis, Chi square (χ^2) test and the T-test were also used. The various indices estimated were given below:

S. No	Index	Equation
1	Species evenness (E	$H' = C \{\log 10N\text{-}1/N\Sigma (\log 10 \text{ nr } \log 10)\}$
2	Pielou, s index (J)	$H/H_{max.}$
3	Species richness (Ma)	Ma = S-1, Log e N
4	Margalef's index, D_{ml}	S-1/In N
5	Menhinick's diversity index, D_{Mh}	$S/\sqrt{N}$
6	Simpson's dominance (D_1)	$1/\sum p^{2i}$
7	Simpson's diversity index (H)	$C = \Sigma \{ni (ni-1) / N (N-1)\}$ i =1 to S
8	Nakamura's index (M)	$RI = \Sigma R_i / S (M-I)$ r = i to S
9	The Berger–Parker index (BP)	$1/D^{\infty}$
10	Elucidean distance (d)	$D_{xy} = \sqrt{(x_1-y_1)^2 + (x_2-y_2)^2 + (x_3-y_3)^2}$

In order to study the proportion of each species within the local community, species diversity were computed based on Shannon-Wiener formula, where H is Shannon-Wiener (1963) [47] biodiversity index; Pi is the proportion of each species in the sample (relative abundance); log e Pi is the natural log of Pi; and S is the number of species in the pollinator's community. Species evenness (E)measure similarity among different species in ecosystem and it estimate the equitability component of diversity; Species richness (Ma)assess how the diversity of insect populations is distributed or organized among the particular species. Simpson's index (D_2) represents the probability that two randomly selected individuals collected in the community belong to the same species. It is accounted for both richness and proportion of each species (Simpson, 1949) [48]. Nakamura's index: "M" is the number of rank of abundance (0, 1, 2, 3…M-I) and "R" is the rank value of "i^{th}" species in the sample.The Berger-Parker index (BP) denotes the proportional abundance of most abundant species (*Lassioglossum marginatum*). Elucidean distance determines the difference between the species observed across the three experimental location during the study period.

3. Results

The present study was carried out in three Southern and three western area of the valley close to forest areas and the location selected for the experiment were mostly from krava with dry land type topography which is comparatively rich in diversity of insect pollinators; however, patches selected from the Srinagar are mostly located in plane areas. The diversity indexes of Shannon, Simpson as well as the evenness index of Pielou assess insect diversity within and between sites. The unequal distributions of abundance between species allow the use of the dominance index of Berger-parker. All these indices were commonly used in ecological community studies of insect pollinators of peach in current investigation. In total 971 insect specimens were collected from peach *P. persica* during the blooming period (>10 per cent blooming) of years 2013 and 2014 from Budgam (281specimens), Pulwama (292 specimens) and Srinagar (398 specimens) experimental locations, respectively. About 534 specimens collected, were from family Halictidae, the dominant species *Lasioglossum marginatum* constitutes 51.87 per cent (277 specimens) of total Halictids. Insect visitors from Dipteran order were recorded to constitute 26.05 per cent (253 specimens) of the total specimens. The diversity of insect pollinators/visitors of peach (*Prunus persica*) were given below (Table 1).

The taxonomic composition of insect species (Table1) encountered on peach (*Prunus persica*) trees in Budgam were found to fall in 46 different species under 5 orders, 20 families and 30 genera (Table 2). Among the five orders observed, Hymenoptera and Diptera shared maximum species 23 and 17, with ranks 1 and 2, respectively. Further, the orders Lepidoptera (4 species), Hemiptera (one species) and Odonata (one species) were represented by ranks 3, 4 and 5, respectively. About 86.95 per cent species (40 species) were found as active and frequent visitors of peach flowers. Of them, Hymenopteran species constituting about 50 per cent, and were significantly active foragers throughout the day, followed by Diptera and Lepidoptera constitutes nearly 36.95 and 8.69 per cent species, respectively. However, the Odonata constitute only 2.17 per cent of total species recorded.

The most dominant Hymenopteran flowers visitor families were *viz*., Halictidae and Andrenidae. While as, the dominant Dipteran families were Syrphidae. Lepidoptera, Hemiptera and Odonata were occasional flower visitor. However, similar trend in families dominance on peach flowers were observed in Pulwama and Srinagar during the both years of survey. While as, in district Srinagar, 35 species were identified, belong to 18 families, 24 genera and 5 orders only. The calculated values and comparison of calculated values of nine diversity indices of pollinator species collected from peach (*Prunus persica*) trees of three districts of Kashmir are given in Table (1). The calculated values of Simpson dominance, D1 index represent the t-test value of 0.047 across the two years of experiment, so were found significant at level of 5%. Simpson diversity index (D2) of peach pollinator species ranged from4.042 to 16.30 (SE= 1.90) and the significance were estimated by χ^2 test and the t-test <0.021 (Table 1). During the present investigations the species richness were lowest for Srinagar; however, species evenness of the pollinators across three experimental location ranges from minimum of 0.718 in Srinager to 0.954 in Budgam (SE= 0.033). Conducting the Multiple Regression Analysis of the data, the inference drawn were, r=0.99, R^2=0.97 and SE= 2.81. For the pooled data, the p-value and t-test estimated were 0.0045 and 0.023, respectively. The ranges of Shannon diversity index (H) were maximum in Srinager during both years of experiment and minimum in Budgam (Table 1). Pielou,s evenness index (J) or Shannon's equitability index measures the equitability of calculated species in the sample were highest for Budgam. Margalef's index (ml) is used to measure the richness of species distributed in three experimental locations and the calculated values were also reported maximum for Budgam. Menhinick's index (Mh) measures richness of pollinator species; while as, calculated value of Nakamura index (RI) ranged from 0 to 1. If the value tends to zero, the diversity will increase. The Berger-Parker index (Bp) equals the maximum p_i value i.e. inverse of true diversity of order infinity ($1/^{\infty}D$), and were observed maximum during 2013 (Table 1). During the current

investigations, the euclidean distances (Δd) are special because they conform to our physical concept of species distance (difference). It makes very good sense as a measure of difference between insect pollinator species on peach at three experimental locations under consideration. The Euclidean distances coefficients were recorded highest from district Budgam and lowest from Srinagar. However, the species distance were more in 2014 as compared to 2013 (Table 1).

The species *L. marginatum* were most abundant as shown by curve (Fig 1) and Table (2). Further, the rank abundance curve visually depicts both species richness and species evenness. The curve is a two dimensional chart with relative abundance on the Y-axis and the abundance rank on the X-axis. On X-axis the most abundant species *L. marginatum* were given rank 1, second most abundant (*L. himalanyses*) is 2 and so on. While as, on the Y-axis, usually measured on log scale 10, and is the measure of abundance (No. insect visitors/m^2/10min.) relative to the abundance of other species. Rank abundance curve (i^{th} rank (K) *vs* abundance in log@10) or Whittaker plot displayed the relative species abundance (Fig. 1) and gives the relative role displayed by different pollinators. Figure 1 is the rank abundance curve in which species richness can also be viewed as the number of different species on the chart, i.e. how many species we ranked**.** Species evenness is reflected in the slope of the line that fits the graph (i.e. logarithmic series @10). A steep gradient indicates low evenness as the high-ranking species have much higher abundances than the low-ranking species. A shallow gradient indicates high evenness as the abundances of different species of order Diptera are almost similar. The curve at highest peaks accommodate only one species (*L. marginatum*); later it comes down quickly with small peaks representing the lower abundance of other pollinators. However, the plot represents the rich diversity of pollinator species. The curve showed the contrasting pattern of species richness and also highlights the difference in evenness among the species assemblage. When there are few species (Srinager), the relatively abundant species is clearly displayed in the plot. The curves displayed that in district Budgam, insect species diversity on peach were more, therefore the curve lie on the upper side. While, curve descending downwards because of the presence of a lower number of species (Magurran, 2005) [31]. As the curve lies above, and plots also simply proves the rich diversity across different experimental sites. Therefore, the K-dominance plot clearly demonstrates the mean diversity pattern of pollinators in Kashmir valley

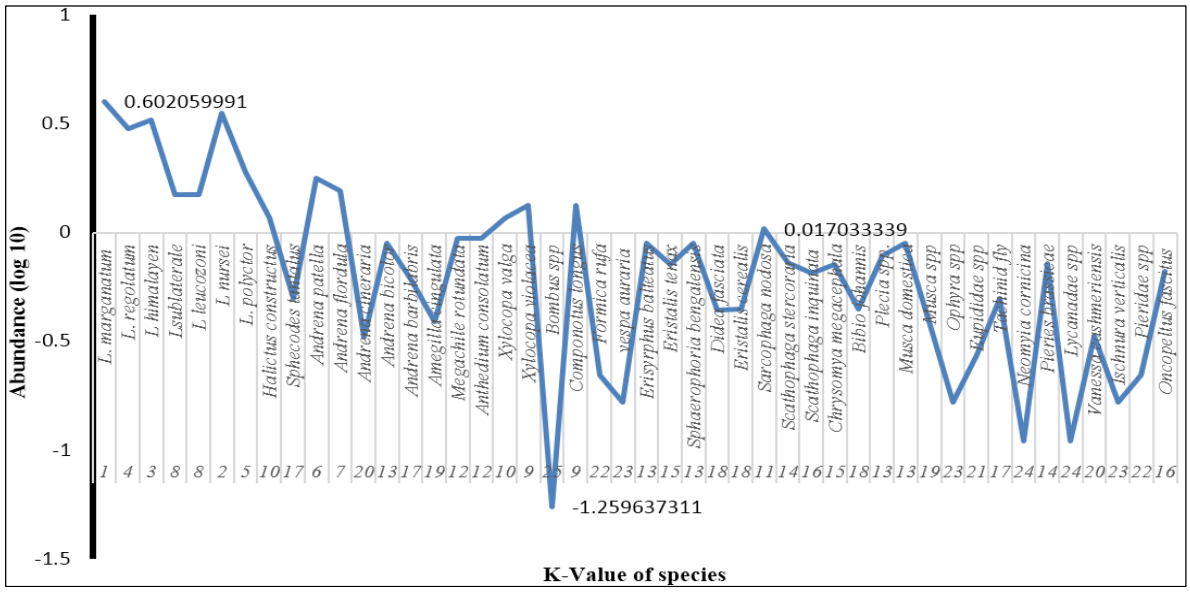

Fig 1: Rank abundance value (I^{th} rank (K) *vs* abundance in Log@10) of insect pollinators of peach (*Prunus persica*) during 2013-2014

Table 1: Diversity indices of insect pollinators/visitors of peach (*Prunus persica*) in Kashmir valley during 2013-14

Experimental sites	Ecological diversity indices										
	Species richness (Ma)	Equitability (evenness) (E)	Simpsons Dominance (D1)	Simpson diversity Index (D2)	Shannon Diversity Index (H)	Pielou,s evenness index (J)	Menhinick's index (Mh)	Margalef's index (ml)	Nakamaru's index (RI)	Berger-Parker dominance (BP)	Euclidean distance or dissimilarity coefficient (d) (%)
	2013										
Budgam	46	0.954	0.938	16.30	-3.988	1.041	6.133	25.74	0.599	0.089	11.00
Pulwama	37	0.801	0.888	8.983	-4.286	1.171	5.025	21.53	0.601	0.087	
Srinagar	35	0.718	0.752	4.042	-5.581	1.582	3.859	17.44	0.579	0.098	
SE±	1.12	0.033	0.052	1.90	0.74	0.191	0.493	1.32	0.076	0.018	
	2014										
Budgam	44	0.960	0.977	44.38	-2.751	0.727	7.710	28.45	0.512	0.092	19.36
Pulwama	33	0.931	0.958	24.04	-2.855	0.816	6.168	22.06	0.501	0.117	
Srinagar	29	0.901	0.909	11.02	-3.781	1.110	18.18	5.250	0.523	0.121	
SE±	2.01	0.021	0.043	2.21	0.45	1.22	0.354	1.09	0.054	0.010	15.18
	Pooled										
Budgam	45	0.957	0.962	26.42	-3.380	0.884	6.860	27.31	0.538	0.090	15.18
Pulwama	35	0.870	0.937	16.12	-3.456	0.920	5.981	23.31	0.533	0.099	
Srinagar	32	0.809	0.864	7.396	-4.589	1.291	4.825	19.23	0.545	0.108	

Table 2: Mean abundance of insect pollinators/visitors on Peach *P. persica* in Landscapes of Kashmir Valley

S.N	Insect Pollinator species	Mean abundance	Species (%)	Genus (%)	Family (%)	Order (%)	Rank
1	*Lasioglossum marginatum*	4.00	9.00	42.11	45.84 (Halictidae)	72.23 (Hymenoptera)	1
2	*L. regolatum*	3.00	6.75				
3	*L himalayense*	3.27	7.36				
4	*L sublaterale*	1.50	3.38				
5	*L leucozonium*	1.50	3.38				
6	*L nursei*	3.54	7.97				
7	*L. polyctor*	1.89	4.25				
8	*Halictus constructus*	1.16	2.61	2.61			
9	*Sphecodes tantalus*	0.50	1.12	1.12			
10	*Andrena patella*	1.78	4.01	11.64	11.64 (Andrena)		
11	*A. flordula*	1.56	3.51				
12	*A. cineraria*	0.33	0.74				
13	*A. bicolor*	0.89	2.00				
14	*A. barbilabris*	0.61	1.37				
15	*Amegilla cingulate*	0.39	0.87	0.87	0.87 (Anthophoridae)		
16	*Megachile rotundata*	0.95	2.14	2.14	4.25 (Megachilidae)		
17	*Anthedium consolatum*	0.94	2.11	2.11			
18	*Xylocopa valga*	1.17	2.63	5.65	5.76 (Apidae)		
19	*X. violacea*	1.34	3.02				
20	*Bombus* sp.	0.05	0.11	0.11			
21	*Componotus longus*	1.34	3.02	3.02	3.51 (Formicidae)		
22	*Formica rufa*	0.22	0.49	0.49			
23	*Vespa auraria*	0.16	0.36	0.36	0.36 (Vespidae)		
24	*Erisyrphus balteatus*	0.89	2.00	4.63	7.62 (Syrphidae)	22.01(Diptera)	2
25	*Eristalis tenax*	0.72	1.62				
26	*Eristalis cerealis*	0.45	1.01				
27	*Sphaerophoria bengalensis*	0.89	2.00	2.00			
28	*Didea fasciata*	0.44	0.99	0.99			
29	*Sarcophaga nodosa*	1.04	2.34	2.34	2.34(Sarcophagidae)		
30	*Scathophaga stercoraria*	0.73	1.64	3.10	3.10(Scathophagidae)		
31	*S. inquinata*	0.65	1.46				

4. Discussion

The diversity studies of insect pollinators visiting peach *P. persica* at peak blooming period in Kashmir division (J & K) revealed that among the 46 insect pollinators/visitors recorded, the order Hymenoptera were most abundant. A similar survey were done by Hong *et al*. (1989) [19] and Thapa (2006) [53] who reported a total of 88 and 50 species of pollinators on stone fruit crops. In the present investigation in all of the three experimental locations, the peach crop were dominantly pollinated by genera *Lasioglossum*, *Andrena* and *Syrphids*, which is in agreement with the findings of Williams (2002) [58] who observed that fruit crops were pollinated by Bombus spp. solitary bees, social wild bees, flies and thrips. Abrol (2012) [2] revealed a total of 13 species of insect pollinators from landscapes of Jammu and Kashmir, which is comparatively less than observed in present investigations. In present study, the species *Amegilla cingulate* of family Anthophoridae were found to pollinate stone fruit crops, which is in agreement with Freitas *et al*. (2000) [13] who reported that *Centris tarsata* (Family: Anthophoridae) acts as a major stone fruit pollinator. However, according to Botanical Survey in USA (2012), the fruit crops like peach, plum and cherry were observed chiefly pollinated by bees (*Apis* sp.), Bumble bees and Dipteran flies, which completely confirms the present results. In current study, the peak capture rates of flower-visiting insects within each fruit orchard largely corresponded with peak stage of the flowering period.

During the survey, a total of 971 insect specimens were collected from peach (*Prunus persica*) at the blooming period, and 534 specimens were from Halictidae family and the species *L. marginatum* constituted 51.87 per cent, accounting 277 specimens of total collection. This is in agreement with results of Jaganmohan *et al*. (2013) [22] who collected 1072 insect specimens and the order Hymenoptera were most dominant and constituted 61.47 per cent (659 specimens) of total population. Recently, in France, the family Halictidae were found dominant with largest diversity, constituting 59.0 (20.27%) different species of total 291 Hymenopteran species collected (Fortel *et al*. 2014) [12]. Insect visitors from Dipteran order were observed to constitute 26.05 per cent (253 specimens) of total 971 specimens collected during present investigation. Syrphid flies constitute majority of Dipteran pollinators of peach. So far, 46 species of hover flies have been reported as flower visitors and pollinators (Mitra, 2010) [35]. However, in present study only five Syrphid species were observed. Peach orchards of district Budgam contained the highest number of species compared to Pulwama and Srinagar, and the Dipteran flies constitute nearly 17 species which is in close agreement with the results of Datta and Chakraborty (1983) [10] who reported 25 fly species from fruit orchards of Jammu & Kashmir. On peach flowers, Diptera species were found to be second most abundant order constituting 13.47 per cent visitation done by 17 species and 135 specimens (22.00 per cent). Similarly, Thakur and Mattu (2014) [42] reported 19 Dipteran species visiting to the plum trees constituting 26.3 per cent of total species collected. Overall, it was found that the family Halictidae were found most prevalent of all the bee species. This is in close agreement with Mullinax (2015) [36] and Murao *et al*. (2015) [37] that the genus *Lasioglossum* (Helictid) is most dominant. During the current study the family Halictidae were found dominant in both abundance as well as in total population and constituted 8 species, which is in close agreement with Gular *et al*. (2015) [16] and Guler and Dikmen (2013) [17], who

carried out research on potential pollinators of sweet cherry and collected 1476 and 1200 bee specimens; the dominant family observed were Helictidae constituting 40 and 27 species, respectively.

The higher insect species richness and diversity could be as a result of higher diversity of plant species, restriction of human induced activities and fragmented areas. Insect species in heterogeneous areas were found abundant and diverse as well, because of their protection from the human induced activates, compared to urban areas. Due to diverse nature of plant species in different landscapes of Kashmir, insects are more attracted to these plants for foraging purpose which could result in their high richness and abundance. Since, the experimental locations of Budgam and Pulwama were more heterogeneous, therefore supported large diversity. It was supported by the fact that large patches provide usually higher heterogeneity and thereby support diverse communities of flower visitors (Lengyle *et al*. 2016) [30].

For the insect specimens collected from peach trees during the present investigation, values of Simpson dominance index (D1) were found high. Bashir *et al*. (2015) [5] estimated the pollinator species assemblage by using Simpson dominance index, ranging from 0.06 to 0.117; while as, the dominance of rang between 0.047 to 0.117 were observed by Anbalagan *et al*. (2015) [4]. In present investigation Dipteran species were second in diversity and dominance after Hymenoptera, which is in confirmation with the results of Belamkar and Jadesh (2012), that Dipteran pollinator had lowest dominance of 0.05 per cent.

Simpson diversity index (D2) of peach pollinator species observed in the current studies were in agreement with the results of Belamkar and Jadesh (2012) that Hymenoptera and Diptera had the diversity index of 3 and one, respectively. For various flower visiting bees, the diversity index varies from 1 to zero (Tepedino *et al*, 2011) [50]. Similarly, in case of bees, wasps and flies the D2 value reported were in range 0.873-0.873, 0.636-0.743 and 0.707-0.854, in spring and summer, respectively (Bashir *et al*. 2015) [5]. The maximum value occurs when all species are equally abundant with the greatest species richness. Further, pollinator diversity count data fit a Poisson distribution indicated by the goodness of fit test χ^2-test ≤ 0.002. The larger χ^2 and smaller p-value indicate more significance of results in the present study.

For the insect specimens collected, the species richness Ma were highest for district Budgam and lowest for Srinagar, the possible reason could be that pollinator species richness was positively affected by landscape configuration, large habitat area and high habitat quality (i.e. steep slopes). As the landscape composition only affected the species richness which increased with increasing percentage of semi-natural habitat in the experimental sites. Raj and Mattu (2014) [42] observed the pollinator diversity and recorded the species richness of 40, 19 and 31 on peach, plum and cherry, respectively. However, Bhalla *et al*. (1983) [7] observed species richness of 10, Kumar (1988) [28] 33, Thakur (1988) [52] 15 and Rana (1989) [43] 20 on plum fruit crops and the most important species among them were from orders Hymenopteran and Dipteran. Abrol *et al*. (1987) [1] reported *Apis cerana* as the frequent visitor on almond flowers at Srinagar (J & K). The evenness of the pollinator species across three experimental location ranges from minimum of 0.109 to 1.00. Differences in species richness across the three locations could be due to combination of large high-quality patches and heterogeneous landscapes, which maintains high bee species richness and communities with diverse trait composition. During the current study, bee species richness recorded on peach were 43.47; however, the mean bee species richness recorded were 67% of estimated species richness of the orchard patches and 83% of total study region (Hopfenmuller *et al*. 2014) [20]. The species evenness were observed statistically significant across the two years of study with t-test valued 0.027. Stirling and Wilsey (2001) [49] observed that evenness of species varies from 0.58 to 0.99, which is partly in agreement with our findings that species evenness of the insect pollinators varies from 0.109 (Pulwama) to 1.00 (Budgam). Whileas, Belamkar and Jadesh (2014) [6] and Kyerematen *et al*. (2014) [29] recorded the insect pollinator species evenness of 0.928 and 0.977, respectively.

The high pollinator diversity at location Budgam may be attributed to the fact that during blooming period of the years 2013-2014, there were ample food resources for the pollinators and the rainfall was not too heavy; since heavy rainfall tends to sweep most pollinators away and destroy many of their food resources. Further, the high dominance of Halictidae (sweat bees) may have accounted for the low evenness recorded during the blooming season.

The calculated Shannon diversity index (H) of peach pollinators were maximum in Srinager, Belamkar and Jadesh (2014) [6], observed that Shannon diversity index (H) ranges from minimum 1.009 for Hymenopteran pollinators to 2.226 for Coleopteran visitors. However, for Dipteran flower visitors the calculated H value recorded were 1.00.Kyerematen *et al*. (2014) [29] studied the species composition and observed the highest Shannon diversity index (H) of 3.927, which is in close agreement with the present results. The equitability of peach pollinator species ranged from minimum during 2014 to maximum (Srinagar) in 2013; similarly, Anbalagan *et al*. (2015) [4] observed that Hymenopteran pollinator equitability ranged from 0.813 to 0.907 in different seasons of the year.

The difference in species number were estimated by Euclidean distances (Δd) and it make very good sense as a measure of difference between insect pollinator species on peach across three experimental locations in two study years. The species distance were more in 2014 as compared to 2013. For example, Wragg and Johnson (2011) [60] used the euclidean distances to differentiate the distance of perception by bees towards different floral traits attracting the different pollinator species. We used the Euclidean distance to quantify the difference in species number across the three locations for peach. Similarly, Ollerton *et al*. (2009) [39] calculated euclidean distances among the 3-dimentional coordinates and compared the distance matrix with distance relationships in original trait space, pollination syndromes. Vereecken *et al*. (2010) [55] used the euclidean distance in floral odour between samples which attracts pollinator community on a highly specific basis through the emission of odour blends that mimic the female sex pheromone of the specific pollinator species. The Whittaker plot rank abundance curve visually represents both species richness and species evenness, and the plot demonstrates the mean diversity pattern in landscapes of Kashmir valley.

5. Summery and Conclusion

The ecological management of agro-ecosystems depends on interpreting the various biological properties of natural environment surrounding the ecosystem, and the knowledge of local insect communities and the way insect deal with environment have ubiquitous benefits for biodiversity conservation. The work presented here bring with the aims to

insight into. "Pollinator Species diversity indices of insect pollinators of peach *Prunus persica* in temperate region". The insect specimens collected during the blooming period were observed to show variable diversity indices with respect to landscapes of the study locations. The taxonomic composition of insect species encountered on peach trees were found to fall in 46 different and the order Hymenoptera were recorded dominant. The majority of insect pollinators are either neutral or beneficial to humans. Budgam, with its vast territory, diverse climate and ecosystems, is richest in insect diversity. However, as a result of the economic and population growth and development in Srinager, the pollinator diversity is now faced with habitat degradation, species extinction, and a decline in foraging plants. These problems are due to expansion of urbanization, industrialization, pollution, mining and tourism, which in turn are responsible for varied ranges of diversity indices across three experimental locations.

6. Conflict of interest

There is no conflict of interest among the authors

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