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Mountain landscapes, foraging behaviour and visitation frequencies of insect pollinators on peach (*Prunus persia*)

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Abstract
The pollination services provided by wild insect fauna in peach depends on many factors, among them the diverse landscapes and habitat diversity is of immense importance contributing to foraging characteristics and hourly visitation frequencies. A considerable variation existed in visitation rate; total visits, percent visitation and total time spend on peach flowers by insect pollinators/visitors during our course of study in low maintained mountainous landscapes. Flower handling times consumed by species created a significant variation between total visitation and visitation rate. Most species prefer to collect pollen however the nectar is main reward from flowers, therefore time per flower sought by hymenopteran species were inherently shorter than lepidopteran and dipteran species. Among the members of genus *Lasioglossum* the total visits, visitation rate and per cent visitation were found highest by species *L. marginatum* and overall the order hymenoptera showed comparatively higher visitation rate, total visits and per cent visitation on peach flowers. From members of family Apidae species *Xylocopa valga* and *X. violacea* makes highest number of total visits followed by family Halictidae. During the two years of studies, almost 95% of the available peach flowers were visited by foraging wild bees varied significantly as per ANOVA; however, the statistical significance across two years of investigation varies too. The time spend by pollinators/visitors on peach flower bout varies among different species. Rank dominance curve (K-dominance curve) were determined with respect to species abundance and inferences were drawn species wise.

Keywords: Pollination, peach, visitation, pollen, nectar, Lasioglossum

Introduction
Insect pollination is one of the most important mechanisms in the maintenance and promotion of biodiversity, affecting significantly the sustenance of important agricultural crops (Albrecht *et al*. 2013) [2]. The maintenance of this vital service depends upon sound management practices mainly focusing on habitat diversification and management (Dar *et al*. 2017a, Dar *et al*. 2017b, Khan and Khan, 2004) [13, 16, 20]. Generally, orchardists need to protect semi-natural habitats in their landscapes to guarantee pollination and high yields in fruit crops. Conservation of semi-natural habitats, which provide nesting sites and additional food resources before and after stone fruit flowering, enhances gratis ecosystem services, and the pollination as well (Dar *et al*.2017c) [10]. 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) [22], for that the insect pollination is important to bear a satisfactory commercial yield. Apidae were regarded as the most important and dominant commercial pollinator (>90%), although other bee species like alkali bees (Nomia), mason bees (Osmia), leafcutter bees (Megachilidae) and bumble bees (Bombus) were also performing the pollination. Under Kashmir conditions, wild bee pollination for peaches was found important (Abrol *et al*. 1990) [1]. Yokozawa and Yasui (1957) [42] noted the insect visitors to the flowers of peaches at Italy and observed that Dipteran insects were most frequently visitors followed by Hymenopterawhile as; Lepidopteran and Coleopteran species were rarely observed to visit flowers in both years of study. Randhawa *et al*. (1963) [28] recorded that honey bees are most important pollinator of peaches, while as

Chansigaud (1972) [8] identified that 5-10% of wild bees (16 observed) visiting peach dominated (occurrences and longer flight periods at peak peach blossoming period) by genus Andrena especially by species *Andrenaarmata*, *A. carantonica* and *A. hoemorrhoa*. Serini (1985) [29] summarized the observations on the species composition of the pollinating insect of peach in different localities in Italy and found wild and domesticated bees being dominant; while as, Syrphids, Calliphorids, Nymphalids, Sphingids and Pierids were present in small numbers, especially if the orchards were surrounded by uncultivated areas having wild flowering plants. Chang *et al*. (2001) [7] reported that plums were mostly visited by *Apis cerana* and *A. mellifera*, respectively reaching to their peak pollination activity between 09.00 -11.00 h and 11.00-13.00 h coinciding with time period of maximum nectar and pollen reward by flowers. Allsopp *et al*. (2008) [3] reported that peach and plum pollination service is largely provided by wild pollinators and honeybees; however the Dikmen, (2007) [17] reviewed the economic value of using wild pollinator bees in organic farming and found Halictidae as one of the biggest groups throughout the pollinator bees widely distributed in all continents, with pollination efficiency contributed by their high abundance and large diversity. Knowing the significance of insect pollinators for stone fruit production (Dar *et al*. 2016) [14], especially peaches, current study was focused to determine the foraging behaviour and visitation frequency of insect on peach in unmanaged and scattered fruit trees growing in wild habitat with no inputs used for the soil culturing.

Material and Methods

Study area and sites

The research were conducted in three far flung locations from March and April in 2013 and 2014. The average altitude of three districts is around 2350 meter above mean sea level. The habitat types selected were having the patches dominated by tree species of plum plants. The research areas have total landholding of 1371, 2228 and 1398 Km^{2}respectively in Budgam, Srinagar and Pulwama.

Field survey and sampling

The experimental locations were visited three times during the study period. Data were recorded throughout the blooming period from April to June between 900h to 1700h 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) [27], to cover the distance of 200 m which is the flight range of the most wild bees.

Peach plant

Peach is an important stone fruit crop of temperate zone. High quality peaches are produced in higher hills of Kashmir region. However, in lower areas generally low quality peaches are grown, but with the introduction hybrid varieties and Italian varieties, even lower belts had shown a good yield performance. It is the third most important temperate fruit crop of India commercially grown in temperate regions, subtropical regions and parts of Tamil Nadu. Traditionally peaches are planted in low density (6 × 6 m, 7 × 7 m) resulting low yield per unit area. In Kashmir region the natural and land resources are dwindling very fast and there is urgent need to opt the judicious and intensive peach production technologies, adopting all horticultural packages of practices and sufficient pollination requirements.

Selection of trees

Tree selected for the observations were growing at least 12 m x 12 m of spacing, otherwise about 200 m away from one another in similar environments. Plants were grown in similar environmental conditions of abiotic factors (Dar *et al*. 2014, 2017f, 2018c) [36, 37, 35] to distinguish the Insect-plant interactions clearly. Hourly foraging behaviour was calculated by using formula as given below:

Total visits

$$\frac{\text{Number of visits}}{\text{Flower bout of one meter square length (m}^2\text{)}}$$

Visitation rate

$$\frac{\text{Total number of visits}}{\text{Insects/m}^2\text{/10 minutes}}$$

Visitation per cent

$$\frac{\text{Total Number of visits}}{\text{Bout of one meter square length (m}^2\text{)}} \times 100$$

Time periods

We recorded visitation between 900-1700 with 10 min of focal observations during each hour, totaling 100 min day^{-1}, and in 7 days totaling 700 min of week. Since flowering period is short, and other competitive flowering plants are in surroundings during the study periods that divert the bee, so we took intensely study to get as accurate informations possible.

Rank abundance values

Whittaker plot is drawn to display the relative species abundance, a component of biodiversity. The rank abundance curve visualizes the species richness and species evenness to overcome the shortcomings of biodiversity indices.

Insect collection

Insects collected from the each peach tree were sorted into broad categories then identified by comparison with the preserved specimens. RTCPPPM SKUAST-K, Srinagar 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 India (Kolkatta).

Data collection and Analysis

Recordings were made from the onset of the main blooming period with temperature ≥ 15ºC, low rain ad dry vegetation (Westpahl *et al*., 2008) [39]. 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. In order to study the proportion of each species within the local community, species diversity were recorded (will be discussed in next paper). ANOVA (one way), Chi square test (χ2-test), T-test, Kruskal Wallis test and Pearson's correlation were performed to the raw data.

Result and Discussion

The chronic honey bee paralysis as well as well defined viral diseases (Ullah *et al*. 2020) [38] across the world had caused a severe symptom, bee mortality and finally the colony loss. Therefore the research and farmers in the world are shifting to reduce dependence on these commercial crop pollinators and have started to focus over wild bees and other flower visitors. The current investigation recorded a considerable variation in visitation rates, total visits; percent visitation and total time spend on peach flowers by insect pollinators/visitors (Table-1). The total visits, visitation rate and the per cent visitation of 4.24 visits/flower bout square meter length (m^2), 1.002 visits/insects/m^2/10min., and 16.08 visits/bout (m^2) ×100, were performed by *Lasioglossum marginatum*, with time spend on flower wereequal to 26±2.94 seconds. Flower handling times consumed by species created a significant variation between total visitation and visitation rate. The observation revealed that most of the Helictid bees and some Syrphid flies besides collecting nectar forages for pollens as well. In current study, among the members of genus Lasioglossum the total visits, visitation rate and per cent visitation were found highest by species *L. marginatum* and lowest were contributed by Sphecodes tantalus (Table-1).Overall the pollinators of order Hymenoptera comparatively showed higher visitation rate, total visits and per cent visitation on peach flowers during the both years of study. Among the members family Andrenidae the total visits, visitation rate and per cent visitation varies from minimum of 0.02 visits/flower bout m^2, 0.026 visits/insects/m2/10min. and 0.075 visits/bout (m2) ×100 by *Andrena barbilabris* to maximum of 0.075 visits/flower bout (m2), 0.854 visits/insects/m2/10min, and 2.881visits/bout (m2)×100 by *Andrena patella*, respectively. In family Apidae species *Xylocopa valga* and *X. violacea* makes highest number of total visitsof 2.89 and 3.10 visits/bout respectively, followed by family Halictidae. The visitation rate and percent visits performed by *X. valga* and X. *violaceae* were 0.874, 0.817 visits/insects/m^2/10min, and 7.299, 8.750 visits/bout (m2) ×100, respectively. Generally, the dipteran species for example, fruit flies are serious pest especially on stone fruit crops and vegetables (Mir *et al.* 2014; Mir *et al.* 2017) [24, 25]. Among Dipteran species visiting peach flowers *Sphaerophoria bengalensis* make comparatively more visits. *Empididae* sp. make lowest total visits and visitation rate, while as Tachinid flay perform 0.65 visits/ m^2. Overall the orders, Hemipteran, Lepidoptera and Odonate makes lowest foraging activities.During the both years of studies, almost 95% of the available peach flowers were visited by foraging wild bees. Analysis of variance (ANOVA) of % visitation rates showed high significance with CD=0.98, t-test≤0.043, Pearson's corr. = 0.92 and pvalue≤0.05%. However, for the year 2013 the statistical significance were 0.34 and p-value≤0.001. While as, for the year 2014, the statistical significance were 0.29 with p-value≤0.001. The time spend by pollinators/visitors varies for different species. Among the species of family Helictidae, the maximum time of 36±0.88s on peach flower bout were spend by *Lasioglossum polyctor*; while as, minimum of only 12±0.054 spend were spend by *Sphecodes tantalus*. For mean time spend on peach flowers the P-value≤ 0.05%, t-test=0.036, C.D=9.90 and Pearson's corr. is 0.98. For plant species that require insect interaction for pollination, insect visitation rates are important because the visitation rate affects the overall likelihood of effective pollination. For efficient pollination to be performed by any insect pollinator, the foraging behavioral elements like total visits, visitation rate, per cent visitation and time duration spend/flower is essential. For insects, the visitation rate is important to their overall success in terms of energy intake and expenditure. My observations of the interaction between peach flowers and pollinators/visitors indicated a wide range of Hymenopteran and Dipteran species as potential pollinators of this crop in Kashmir division. The difference in flower size, another position and pollen production between flower morphs might affect pollinator visitation patterns (Thomson, 2001) [33]. The time spent by insect pollinators on peach flowers, which is almost entirely accounted for by differences in flower handling time. Most Helictid bees and Dipteran flies gather some pollen; however, the nectar is main reward from flowers. This is in confirmative with the results of Gilbert (1985) [18] that flower visitor mainly foraging on pollen rather than nectar. An interaction between pollinator type and floral trait variation may be a potentially important feature of flower selection e.g. cherry (Dar *et al*. 2018a; Wilson and Thomson 1996) [9, 41]. This interaction is likely to be particularly important since different pollinators often show marked spatio-temporal variation in abundance (Herrera 1989) [19] and pollination effectiveness. Regardless of proboscis (tongh) length, Hymenopterans observed in present investigations have inherently shorter handling times than Dipterans. However, the decreasing handling time with increasing proboscis length were previously found in bumble bee foraging behavior. Among the members of genus Lasioglossum the visitation rate and time spent were found highest in *Lasioglossum polyactor* visiting peach flowers. Research showed that Lasioglossum sp. spent 302.7±13.2 seconds on staminate flowers during a single foraging bout; whileas, only 80s were send on single pistillate flowers (Oronje *et al.*, 2012) [26].

Hymenoptera showed higher visitation rate and spends comparatively less time on peach flowers during the both years of study, this was in accordance with Meerabai (2015) [23] and Dar *et al.* (2018b) [15] who showed that visitation rate and total visits are inversely correlated with time spend on each flower. In present investigation the number of visits and visitation rate were in correspondence with number of open flowers, and inversely related with time spend per flower. However, this is in partial agreement with the Thomson (2000) [34] who observed that number of pollinator visits and time spent is positively related to the number of open flowers in a patch; and species *Andrena falvus* made 61 visits in 35 hours of observation. *Xylocopa valga* spends least time of about 11.0±0.14 seconds on peach. The tachinid flay make about 1.20visits/bout; this is in close agreement with Spackman *et al.* (2001) [31] that fly visitation varies from 0-1.85 visits/open corolla/30min; while as, *Empididae* sp. make lowest visits/bout and similar to this is observed by Spackman *et al.* (2001) [31] that *Empididae* sp. make lowest 0-0.02 visits/open corolla/30min. In present study, we observed that possible reason for interspecific differences in flower visitation rates may be due to differences in time spent flying between consecutive flower visits ("flight time") and/or differences in time spent on each visited flower (handling time), weather parameters, species composition in area, population and density of honey bees and hives, nesting substrate and width of buffer zone area near to peach crop etc. The time spend/bout varies for different pollinator species with maximum mean time of 36±0.08seconds were spend on peach flower (bout length) by *L. polyctor*. The possible reason for this long duration may be that Lasioglossum sp. has a short tongue, and showed two types of foraging behavior; i.e., taking pollen with its mouth part from the stamen and then sucking nectar. Therefore, spends longer times on a single flower than did the honeybee. From family Helictidae minimum time on peach flowers were spend by *L. marginatum* however Sung *et al.* (2006) [32] recorded that time spend by *Lasioglossum* species is 7.9 seconds. Maximum time duration per flower were spend by ants (*Camponotus longs*) with 159±6.9, that is agreement with the results of Blancafort and Gomez (2005) [6] that ant species *Linepithem ahumile* and *Camponotus cruentatus* spends maximum time duration on flowers. Among the Hymenopteran pollinators visiting the flower bout, the minimum time were spend by *Xylocopa valga*. Sung *et al*. (2006) [32] in a field experiment recorded that *C. megacephala*, stayed for a long time of 12.3 ± 11.4s on a single flower and sucked nectar with their proboscis, while as Herrera (1989) [19] in an experiment found that flower handling time spent per flower varies among species of different orders. The possible reason for this may be that increase in proboscis length produces proportional decreases of log handling time in insect pollinators. Therefore, Herrera (1989) [19] observed that Lepidoptera texa did not differ in mean handling time spent on flowers.

Table 1: Foraging characteristics of insect pollinators on peach flowers during 2 years on sloppy steeps of Kashmir Himalayas

S. No.	Insects pollinator species	Pollination efficiency			
		Time spent (in seconds)	Total visits (No. of visits/flower bout m^2)	Visitation rate (Total No. visits/abundance (insects/m^2/ 10min.)	Per cent visitation (Total No. visits/ bout (m^2)×100)
1	*Lasioglossum marginatum*	26±2.94	4.24	1.002	16.08
2	*L. regolatum*	25±0.65	2.00	0.800	9.100
3	*L himalayen*	25±2.98	3.40	0.863	12.89
4	*L. sublateraie*	25±0.45	2.00	0.704	7.584
5	*L leucozoni*	29±0.76	2.00	0.816	7.584
6	*L nursei*	24±1.66	3.00	0.750	11.37
7	*L. polyctor*	36±0.88	0.95	0.397	3.602
8	*Halictus constructus*	27±0.34	0.60	0.448	2.275
9	*Sphecodes tantalus*	12±0.45	0.23	0.220	0.872
10	*Andrena patella*	48±1.69	0.76	0.854	2.881
11	*Andrena flordula*	37±2.54	0.25	0.735	0.948
12	*Andrena cineraria*	38±2.45	0.28	0.636	1.061
13	*Andrena bicolor*	27±1.44	0.06	0.082	0.227
14	*Andrena barbilabris*	29±0.64	0.02	0.026	0.075
15	*Amegilla cingulata*	37±0.53	0.12	0.164	0.455
16	*Megachile rotundata*	30±0.19	0.48	0.432	1.820
17	*Anthedium consolatum*	16±0.32	0.33	0.458	1.251
18	*Xylocopa valga*	11±0.14	2.89	0.874	7.299
19	*Xylocopa violacea*	13.0±0.03	3.10	0.817	8.750
20	*Bombus sp.*	7.0±0.65	0.10	0.151	1.379
21	*Camponotus longus*	159±6.9	0.03	0.007	0.113
22	*Formica rufa*	125±3.0	0.04	0.001	0.151
23	*Vespa auraria*	98±0.43	0.01	0.010	0.037
24	*Erisyrphus balteatus*	50±1.94	0.29	0.580	1.099
25	*Eristalis tenax*	59±1.98	0.33	0.647	1.251
26	*Sphaerophoria bengalensis*	63±2.44	0.56	0.666	2.123
27	*Didea fasciata*	70±0.43	0.09	0.204	0.341
28	*Eristalis cerealis*	28±1.54	0.12	0.179	0.455
29	*Sarcophaga nodosa*	24±1.69	0.45	0.445	1.700
30	*Scathophaga stercoraria*	34±2.22	0.17	0.386	0.644
31	*Scathophaga inquinata*	30±1.65	0.12	0.315	0.455
32	*Chrysomya megacephala*	22±1.11	0.03	0.300	0.125
33	*Bibio johannis*	38±1.22	0.34	0.507	1.289
34	*Plecia* sp.	26±1.00	0.34	0.435	1.289
35	*Musca domestica*	75±1.32	0.12	0.705	0.455
36	*Musca* sp.	14±0.98	0.05	0.454	0.189
37	*Ophyra* sp.	10±0.24	0.07	0.411	0.265
38	Empididae sp.	15±0.23	0.06	0.098	0.246
39	*Tachinid fly*	18±1.43	0.65	0.537	2.460
40	*Neomyia cornicina*	15±1.34	0.23	0.230	0.870
41	*Pieries brassicae*	20±2.10	0.01	0.045	0.037
42	*Lycanadae* sp.	20±2.11	0.01	0.018	0.037
43	*Vanessa cashmeriensis*	21±1.90	0.02	0.090	0.075
44	*Ischnura verticalis*	85±2.01	0.00	0.002	0.003
45	*Pieridae* sp.	30±3.00	0.01	0.010	0.037
46	*Oncopeltus fasciatus*	93±7.00	0.00	0.002	0.007
Statistics (N=46)		CD= 9.90,t-test =0.036;P≤ 5%	CD=0.03, t-test=0.031; P≤ 5%	CD= 0.10, t. test<0.046; P≤ 5%	CD=0.98;t.test= 0.043; p.value ≤ 5%

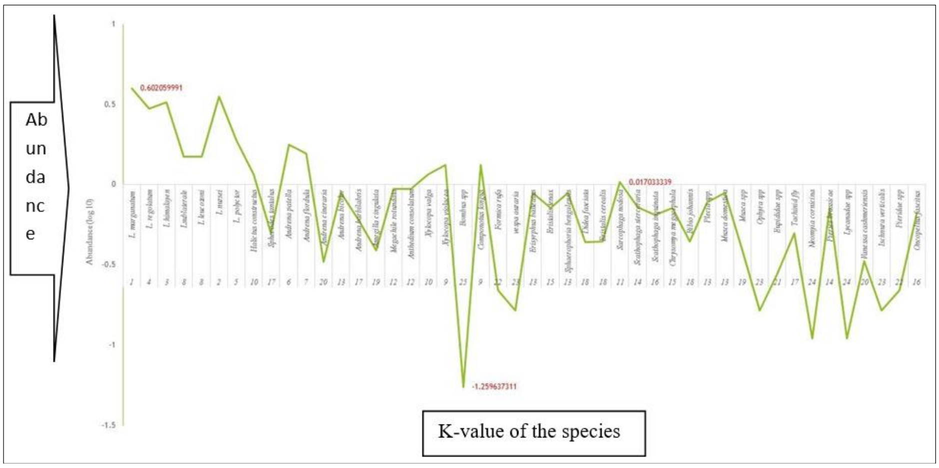

Fig 1: Rank abundance curve of insect pollinators of peach (*Prunus persica*) during 2013-2014

Rank abundance curve (ith rank (K) *vs* abundance in log@10) or whittaker plot (Whittaker, 1965) displayed the relative species abundance (Fig. 1), curve is 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 *Lasioglossum marginatum* were given rank 1, second most abundant (*L. himalanysis*) is 2 and so on.Whileas,ontheY-axis,usuallymeasuredonlogscale10,andisthemeasureof abundance (No. insect visitors/m^2/10min.) relative to the abundance of other species. The rank abundance curve visually depicts both species richness and species evenness. 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 almostsimilar.

K-dominance plot (Kth/S× 100 *vs* % species abundance) clearly demonstrates the diversity pattern in three stations. As the percentage contribution of abundance by each species is added, the curve extends horizontally [species number with respective ranks (K) is evident in the X-axis]. While as, the curve on Y-axis showed the percent abundance of each species. The curve at the highest peaks accommodate only a few species (*L.marginatum*, *L. himalayanse* and *L. nursi*), later it comes down quickly with small peaks representing the lower abundance per cent of other pollinators compared to the species of genus *Lasioglossum* (*L. marginatum*). As the percentage contribution of abundance by each species is added, the curve extends horizontally with species number evident in the X axis against the percent abundance of each species on Y-axis. The K-dominance plot represents rich diversity of pollinator species per experimental site.

The species Accumulation curve

The curve (Fig-2) represents a general characteristics of insect pollinator communities (insect samples) representing that number of species accumulates with increasing area sampled (No. species in three Ex. locations). The curve related to species–area relationship and species accumulation, and is concerned with accumulation rates of new pollinators (peach flower visitors) over the sampled area over three experimental sites and depending on species identity. Here we took 567 samples (X-Axis) collected from 3 experimental locations during two years of studies on peach, varying in abundance during season and in years of investigations. Total species determined were 46 (Y-axis), and increasing sampling is parallel to increasing number of species too. The curve showed an exact exact analytical expression for the expectance and variance of the species-accumulation curve in all random subsets of samples from a given area. The curve is influenced strongly by the distribution of species among the samples and the spatial relationship of the samples that are randomized in the experimental areas.The species richness in larger areas can be drawn taking account of the spatial relationships between samples collected divided by samples in single area. For new species and total, to be represented by the curve, an extrapolated curve is to be obtained from terminal point. Since our experiments were conducted in large heterogeneous areas, so the curve fits well. As, the curve is generally applicable for large heterogeneous areas varying in the slope and topography and in other parameters (e.g. wild buffer zones, barren lands, orchards, filed crops, etc).

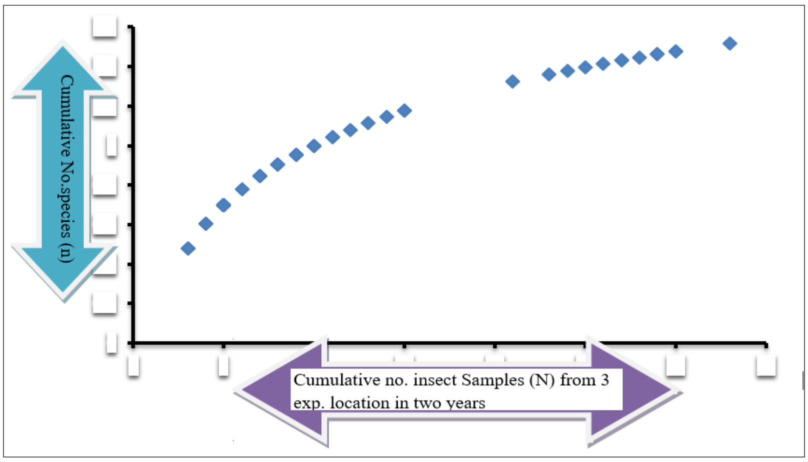

Fig 2: Species accumulation curve Cumulative number of insect samples (N) collected and species (n) drawn from each sample

Hourly abundance

The hourly abundance of insect pollinators of peach were found maximum in after noon (Table-2). Only opening and withering of peach flowers, predictably offer no reward to pollinators. Averaged over day time, the insect pollinator abundance (members of Helictid family, χ^2=0.044) start raising from early in the morning (900-1000 hrs) and become peak maximum in late afternoon (1300-1400 hrs). However, the abundance at dusk hours (1600-1700 hrs) were less compared to noon hours, but were significantly maximum then morning hours (900-1000 hrs). Almost a similar trend in the activity were observed for most of Dipteran pollinators. The insect pollinators/visitors on peach flower increased in course of the day; rising from a minimum around the morning hours (sunrise) to maximum atmidday (1200-1300, 1300-1400 hrs), then decreases in afternoon (1400-1500 hrs) and late afternoon (1500-1600 hrs); finally, exhibited sharp decline around sunset (1700 hrs) onwards. The abundance of *Lasioglossum* species remained comparatively good throughout the day. Whileas, the *Andrena* species start foraging at 1000-1100 hours, steadily reached maximum at 1400-1500 and then finished at 1600-1700 hours onwards. The members of order Lepidoptera were numerically abundant around 1300-1400 hours. The mean hourly abundance pattern of insect visitors of peach in Srinagar (N=35, df= 34, p-value≤0.005, F. critical= 1.49), Budgam (N=45, df= 44, p-value≤0.009, F. critical= 1.41) and Pulwama (N=32, df=31, p-value≤0.004, F. critical= 1.45) were almost similar, but only differing in the density of insect visitors/meter square flowering branch.

Table 2: Hourly abundance (No. insect pollinators /m2/10 minutes) of insect pollinators/visitors of peach (*Prunuspersica*) blossom

Species	Hourly abundance							
	900-1000	1000-1100	1100-1200	1200-1300	1300-1400	1400-1500	1500-1600	1600-1700
Lasioglossum marginatum	1.75± 0.19	3.75± 0.54	4.96± 0.23	5.60± 0.40	6.75± 0.21	5.96± 0.51	4.98± 0.61	3.8± 0.200
L. regolatum	0.33± 0.02	1.65± 0.06	2.66± 0.02	3.44± 0.23	4.30± 0.23	3.80± 0.10	2.96± 0.11	1.66± 0.20
L himalayense	1.07± 0.11	2.65± 0.17	3.33± 0.32	4.11± 0.60	4.66± 0.34	3.95± 0.23	3.65± 0.23	2.0± 0.400
L sublaterale	0.67± 0.03	2.65± 0.07	3.90± 0.09	4.60± 0.30	4.97± 0.45	4.10± 0.40	3.88± 0.55	2.70± 0.25
L leucozonium	0.33± 0.06	2.75± 0.08	3.35± 0.09	4.60± 0.80	4.87± 0.54	4.56± 0.50	3.77± 0.76	2.40± 0.26
L nursei	1.60± 0.16	2.95± 0.06	4.33± 0.12	4.96± 0.45	5.84± 0.34	4.60± 0.60	4.33± 0.65	2.90± 0.12
L. polyctor	0.67± 0.04	1.85± 0.05	2.96± 0.09	3.66± 0.45	3.96± 0.23	4.33± 0.78	2.82± 0.22	2.09± 0.21
Halictus constructus	0.45± 0.04	2.00± 0.06	2.33± 0.05	2.96± 0.66	3.86± 0.11	4.60± 0.90	3.33± 0.40	2.16± 0.12
Sphecodes tantalus	0.00± 0.00	1.22± 0.07	1.56± 0.06	1.86± 0.71	2.40± 0.22	2.87± 0.80	2.30± 0.50	0.65± 0.13
Andrena patella	0.33± 0.11	2.50± 0.08	3.00± 0.07	3.33± 0.05	3.56± 0.34	3.96± 0.60	3.25± 0.60	2.30± 0.14
A. flordula	0.00± 0.00	0.54± 0.09	1.90± 0.08	2.7± 0.450	2.98± 0.56	3.60± 0.54	2.70± 0.70	1.60± 0.15
A. cineraria	0.00± 0.00	0.00± 0.00	0.33± 0.09	0.67± 0.60	1.11± 0.56	0.56± 0.26	0.00± 0.00	0.00± 0.20
A. bicolor	0.00± 0.00	0.33± 0.05	1.01± 0.04	2.0± 0.070	2.33± 0.76	2.2± 0.780	1.56± 0.12	0.33± 0.23
A. barbilabris	0.00± 0.00	0.10± 0.06	1.00± 0.05	1.00± 0.87	2.00± 0.54	1.11± 0.30	0.70± 0.22	0.33± 0.34
Amegilla cingulata	0.00± 0.00	0.33± 0.06	0.95± 0.06	1.64± 0.06	1.76± 0.32	1.69± 0.45	1.40± 0.33	0.25± 0.45
Megachile rotundata	0.00± 0.00	0.37± 0.11	1.07± 0.07	1.66± 0.05	1.95± 0.34	2.00± 0.60	1.60± 0.54	0.22± 0.54
Anthedium consolatum	0.00±0000	0.33± 0.34	0.46± 0.08	0.78± 0.04	1.11± 0.45	1.67± 0.78	1.00± 0.11	0.00± 0.00
Xylocopa valga	0.67± 0.02	1.11± 0.32	1.65±0.14	1.90± 0.34	2.00± 0.06	2.33± 0.10	1.48± 0.20	0.33± 0.12
X. violacea	0.33± 0.04	0.67± 0.12	1.06±0.02	1.33± 0.50	1.80± 0.70	1.67± 0.23	1.00± 0.21	0.25± 0.15
Bombus sp.	0.00± 0.00	0.00± 0.00	0.22± 0.05	0.47± 0.24	0.89± 0.01	1.22± 0.40	0.00± 0.00	0.00± 0.00
Camponotus longus	1.33± 0.06	1.67± 0.01	2.33± 0.06	2.48± 0.30	3.00± 0.02	1.00± 0.50	0.67± 0.24	0.00± 0.00
Formica rufa	0.22± 0.20	0.25± 0.01	0.31± 0.07	0.40± 0.43	0.5± 0.022	0.22± 0.60	0.11± 0.02	0.00± 0.00
Vespa auraria	0.00± 0.00	0.0± 0.000	0.00± 0.00	0.33± 0.10	0.46± 0.34	0.76± 0.37	0.21± 0.03	0.0± 0.000
Erisyrphus balteatus	0.33± 0.09	0.67± 0.23	0.89± 0.07	1.16± 0.60	1.36± 0.54	1.67± 0.60	0.67± 0.04	0.35± 0.18
Eristalis tenax	0.33± 0.05	0.56± 0.53	0.96± 0.11	1.20± 0.10	1.11± 055	1.73± 0.40	0.78± 0.05	0.46± 0.17
Sphaerophoria bengalensis	0.22± 0.05	0.56± 0.44	0.89± 0.23	1.05± 0.20	2.00±0.060	2.67± 0.01	2.11± 0.06	0.33± 0.12
Didea fasciata	0.10± 0.01	0.33± 0.43	0.45± 0.34	0.56± 0.38	0.67± 0.07	1.00± 0.02	0.34± 0.07	0.11± 0.13
Eristalis cerealis	0.36± 0.12	0.47± 0.32	0.60± 0.45	0.68± 0.40	0.78± 0.08	1.00± 0.03	1.22± 0.08	0.36± 0.14
Sarcophaga nodosa	0.11± 0.05	0.24± 0.13	0.34± 0.67	0.44± 0.36	0.67± 0.09	0.70± 0.10	0.78± 0.09	0.11± 0.43
Scathophaga stercoraria	0.33± 0.22	0.56± 0.42	0.77± 0.78	0.89± 0.25	1.00± 0070	1.33± 0.20	1.56± 0.01	0.67± 0.12
S. inquinata	0.22± 0.34	0.33± 0.17	0.46± 0.09	0.76± 0.30	1.10± 0.06	1.67± 0.10	1.89± 0.02	0.67± 0.23
Chrysomya megacephala	0.26± 0.43	0.53± 0.17	0.76± 0.01	1.33± 0.43	1.46± 0.05	1.67± 0.23	1.89± 0.03	0.11± 0.04
Bibio johannis	0.10± 0.02	0.67± 0.29	0.76± 0.12	1.22± 0.50	1.46± 0.04	1.67± 0.34	2.00± 0.05	0.11± 0.06
Plecia sp.	0.26± 0.21	0.67± 0.03	0.86± 0.23	1.00± 0.62	1.33± 0.56	1.66± 0.45	2.22± 0.06	0.89± 0.76
Musca domestica	0.10± 0.06	0.33± 0.04	0.46± 0.04	0.56± 0.70	0.67± 0.06	1.00± 0.65	0.33± 0.06	0.11± 0.06
Musca sp.	0.09± 0.04	0.10± 0.05	0.22± 0.05	0.33± 0.85	0.47± 0.07	0.56± 0.34	0.10± 0.02	0.02± 0.01
Ophyra sp.	0.00± 0.00	0.00± 0.06	0.23± 0.32	0.33± 0.70	0.45± 0.08	0.50± 0.50	0.12± 0.04	0.11± 0.10
Empididae sp.	0.13± 0.05	0.35± 0.07	0.46± 0.33	0.48± 0.63	0.64± 0.09	0.31± 0.07	0.14± 0.01	0.10± 0.10
Tachinid fly	0.22± 0.11	0.32± 0.08	0.47± 0.34	0.68± 0.50	0.35± 0.09	0.20± 0.08	0.18± 0.02	0.12± 0.10
Neomyia cornicina	0.00± 0.00	0.0± 0.000	0.50± 0.54	0.68± 0.41	0.78± 0.08	0.91± 0.11	0.55± 0.03	0.09± 0.00
Pieries brassicae	0.00± 0.00	0.33± 0.02	0.67± 0.56	0.74± 0.48	0.13± 0.07	0.0± 0.000	0.0± 0.000	0.0± 0.00
Lycanadae sp.	0.00± 0.00	0.0± 0.000	0.22± 0.67	0.34± 0.51	0.37± 0.07	0.40± 0.21	0.0± 0.000	0.0± 0.00
Vanessa cashmeriensis	0.00± 0.00	0.0± 0.000	0.23± 0.10	0.46± 0.60	0.68± 0.01	0.40± 0.04	0. 0± 0.00	0.0± 0.00
Ischnura verticalis	0.00± 0.00	0.0± 0.000	0.33± 0.20	0.65± 0.71	0.70± 0.05	0.13± 0.06	0.10± 0.07	0.0± 0.00
Pieridae sp.	0.00± 0.00	0.22± 0.06	0.32± 0.30	0.67± 0.10	0.78± 0.05	0.0± 0.000	0.0± 0.00	0.0± 0.00
Oncopeltus fasciatus	0.00± 0.00	0.0± 0.000	0.33± 0.02	0.65± 0.03	1.11± 0.06	1.33± 0.07	0.67± 0.01	0.0± 0.00
Statistics	N=46, T-test= 0.001; p.value<0.05%. Study commencing from 2nd week of March to 4th week of April							

In present investigation, flies were the important pollinator groups of peach; while as the wild bees were found as the most common pollinator, followed by bumble bees, honeybees and Syrphid flies (Bailey, 1944) [4]. Results showed that various flies and bees shear pollination of peach however, the difference in % contribution across the three sites were significantly different. Similarly, depending on the region, time of day and flowering phenology (Dar *et al*. 2017d) [11], flies were the exclusive pollinators, and share pollination services with bees (Ssymank *et al.* 2008). In Srinagar, Dipteran species viz. *Erisyrphus balteatus*, *Eristalis tenax*, *Sphaerophoria bengalensis* and *Didea fasciata* of family Syrphidae recorded the maximum abundance; with species *Eristalis cerealis* being most abundant in Pulwama, possibly due to rural gradient. Bates *et al*. (2011) [5] observed that hoverfly population abundance change across the Urban-rural gradient.The results showed that species of family Syrphidae were potential pollinators of peach which is in agreement with the Shezad (2011) [30] and Kuhn *et al*. (2006) [21] who showed that species *viz*., *Eristalis tenax, Eristalinu sarvorum, Episyrphus balteatus, Eupeode scorollae* and *Ischiodons cutellaris* were the important pollinators of fruit crops and others (apple, mango and lichi). In current investigation the abundance of insect pollinators on peach were maximum in Srinagar followed by Pulwama and Budgam.

Conclusion

Generally, the role of honey bees have been prominently studied as a potential pollinator of peach and other stone fruits but with the aid of other bee fauna present in a particular landscape will definitely help in better fruit set, yield and quality. The pollination of stone fruits is highly dependent on foraging characteristics of insect pollinators; previously we observe that bagged flowers producing only 0-3% of the fruits compared to open flowers. It is false notion that 2/3rd of all flower visitors were honey bees, but in real the fruit set is related to wild insect visitation, presumably due to their higher pollination efficiency, diversity and overall abundance. It is confirmed fact that bee visitation increases with proportion of high-diversity habitats (Dar *et al*. 2017c) [10] in the surrounding landscape (1 km radius), as buffer zone adjacent to orchards (20% recommended). An increase of high-diversity bee habitats in the landscape from 20% to 50% enhanced fruit set by 150% (3 times), which was experimentally shown to be due to pollen limitation. Visitation and fruit set is independent of ground flower cover due to vegetation or the bee densities on ground transects. Our results show that pollination services by wild insects in peach depends on many factors, and among them the diverse landscapes and habitat diversity (Dar *et al*. 2017e) [12], is of immense importance contributing to foraging characteristics and hourly visitation frequencies. So, in order to guarantee high foraging and yield, the farmers need to protect semi-natural habitats in their landscapes, conservation of semi-natural habitats (providing nesting sites) and additional food resources before and after peach flowering enhances gratis ecosystem services, and thereby, the farmer's yield. Wild pollinator visitation to peach flowers is positively related to yield; however honey bee visitation is not much related to peach yield in mountainous landscapes of Kashmir due to their less abundance.

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