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Full Length Research Paper

The hymenopterous pollinators of Himalayan foot hills of Pakistan (distributional diversity)

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Studies were undertaken to explore the diversity of hymenopterans pollinators from a diverse agro-ecosystems of Himalayan foot hills comprising the orchards of pome and stone fruits at different altitudes from 2200 to 3000 m from sea level. Field experiments were conducted on seven commercial fruit orchards at five various localities. Out of the total 448 specimens, 60.94% were found in an ante-meridian (A.M.) phase and 39.06% specimens were found in post-meridian (P.M.) indicating their activity both diurnal and crepuscular. Rank abundance values revealed that 9 species in 5 genera belonged to four families of order Hymenoptera comprising the diversity of *Osmia cornifrons* Panzer, *Anthophora niveo-cincta* (Smith), *Anthophora himalayensis* Rad., *Anthophora crocea* Bangham, *Bombus tunicatus* (Smith), *Xylocopa dissimilis* Lepel., *Xylocopa rufescens* Smith, *Andrena harrietae* Bangham and *Andrena anonyma* Cam. The calculated values of all diversity indices showed that the lowest diversity was found in a monoculture fruit habitat with well weeded orchards, whereas the diversity of pollinators was found greater in multiple cultures with partially weeded orchards particularly during the successional stage of full bloom in both pomes and stone fruits. A significant difference in the pollinators' population was seen in the orchards with undisturbed surroundings. The natural ecosystem offers more opportunities of refuges for the insect pollinators compare to those orchards with clean cultivation.

Key words: Diversity, agro-ecosystem, fruit orchards, hymenopterans pollinators, monoculture.

INTRODUCTION

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. Pollination also benefits society by increasing food security and improving livelihoods (Khan and Khan, 2004). Pollinators are extremely diverse, with more than 16,000 pollinator bee species (Hymenoptera: Apidae) have been described worldwide (Michener, 2000; Kevan, 2003). The ecological relationship of the pollinators was recognized long before by Knutson et al. (1990) that cross pollination is the only means of maintaining the ecological diversity. Good pollination improves both fruit yield and size (Gautier-Hion and Maisels, 1994; Free, 1993).

It is estimated that bees accomplish more than eighty percent of the insect pollination. Yields of fruit, legumes and vegetable seeds often have been doubled or tripled by providing adequate number of bees for pollination (McGregor, 1976). The wild bees including bumble bees, leaf-cutting bees, alkali bees and carpenter bees are especially adopted for gathering pollens and nectars from flowers (Bohart, 1972). Pollinators other than honey bees are also extremely valuable although their value is difficult to estimate. Globally, the annual contribution of pollinators to the agricultural crop has been estimated at about US$54 billion (Buchmann and Nabhan 1996; Kenmore and Krell, 1998). In a recent survey from Pakistan, Jasra and Rafi (2008) concluded that 84% of the formers of northern area have no perception about the importance of pollination for their orchards and crops. The inadequacies have arisen from habitat fragmentation

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Table 1. Blooming months and availability of pollens on different flowering source of pome and stone fruits from High land of Pakistan.

Common name	Latin name	Blooming months	Pollen colour	Availability	Source for pollinator
Flowering quinc	*Chaenomeles japonica*	April to May	Yellow brown	Feral	Good
Walnut	*Juglans* spp.	April to May		Cultivated	Fair
Crab apple	*Malus* spp.	March to Jun	Light olive	Cultivated	Fair
Apple	*Malus domestica*	April to May	Yellow white	Cultivated	Good
Plum	*Prunus* spp.	April to May	Grey	Cultivated	Good
Almond	*Prunus amygdalus*	February	Light brown	Cultivated	Fair
Wild cherry	*Prunus avium*	April to May	yellow brown, light brown	Feral	Very good
Peach	*Prunus persica*	April to May	Reddish yellow	Cultivated	Good
Black cherry	*Prunus serotina*	April to May		Feral	Minor
Pear	*Pyrus communis*	April to May	Red yellow	Cultivated	Good
Callery pear		April to May	Yellow	Feral	Very good
Blackberry	*Rubus* spp.	May to Jun	Light grey	Feral	Minor
Apricot	*Prunus armeniaca*	April to May	Yellow	Cultivated	Very good

and destruction, pesticide use, and adverse effects of introduced species displacing natives (Ambrose and Kevan, 1990; Hingston and McQuillan, 1998; Kearns et al., 1998; Kevan, 1999, 2001; Kevan et al., 2002).

The natural ecosystem in Northren part of Pakistan is still preserved but the high land insect fauna from a very rich horticulture zone of Pakistan is still unexplored. The present study was designed to prepare an inventory of hymenopterans pollinator bees from fruit orchards of Skardu District, which is unique part of land on the earth due to its geographical importance.

MATERIALS AND METHODS

Field survey

Field surveys were undertaken in five locations of District Skardu, which is located in the north of Pakistan. The detailed survey of commercial fruit orchards in the five localities was conducted during early spring of 2009. These orchards and localities were City Park (37.5 acres), PCSIR Orchard (12.5 acres) and Agricultural Fruit Orchard Hamid Ghardh (7.5 acres) in Skardu City, Fruit Orchard of Shangrilla (Average of 35 acres) in Kachura, Agricultural fruit Orchard of Sermik (Average 10 acres) in Sermik, Agricultural Fruit Orchard Mehdiabad (Average10 acres) in Kharmang and Hashupi Fruit Orchard (11.5 acres) in Shighar. The clusters of orchard are located in a radius of 20 km radius. The occurrence and distribution of pollinators varies with the topographic change. The flowering period of major fruit plants of District Skardu is given in (Table 1).

At each location roving survey was taken up twice in 15 days. In roving survey, the occurrence of pollinators was assessed by taking observations on five randomly selected plants. The hymenopterans pollinators in orchard ecosystem were sampled by using two methods; 1) by sweep net (30 × 60 × 45 cm) and 2) using malaise trap. In sweep net practice, twenty-five sweeps were made diagonally across each canopy and samples were placed in separate plastic sachets. A total of 12 samples were taken from each orchard at different time. The collection obtained from malaise trap was taken out after every 72 h from the previous collection. But the time of their activity in the field and their proportion in different localities was only possible to determine through sweep net collection in different times of the day. A maximum number of pollinator's activity was also observed during the full bloom and fruit setting.

In order to study the proportion of each species within the local community, species diversity was computed based on Shannon-Wiener formula, also called the Shannon's index or Shannon-Wiener index (Humphries et al., 1996), where H is the Shannon-Wiener (1963) 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 pollinators community.

Species evenness (J)

With a view to understanding the measure of how similar the abundance of different species, species evenness was calculated to estimate the equitability component of diversity (Pielou, 1969);

$$H' = C \{\log 10N - 1/N \sum (\log 10\ nr\ \log 10)\}$$

Where, H is the Shannon-Wiener Richness index and S is the number of species in the community.

Species richness (Ma)

In order to assess how the diversity of the population is distributed or organized among the particular species, this index was calculated (Pielou, 1975) by;

$$Ma = \frac{S-1}{\log e\ N}$$

Where, S is the total number of species collected and N is the total number of individuals in all the species

Simpson's diversity index

This accounts for both richness and proportion (per cent) of each species in the local community. The index has been defined in three different ways (Simpson, 1949);

Simpson's index (D): This denotes the probability that two randomly selected individuals in the community belong to the same species. The form of the Simpson's index used was:

$$C = \sum_{i=1}^{S} \{ni\ (ni-1) / N\ (N-1)\}$$

Table 2. Specific, generic and family wise detail of the specimens collected from different commercial fruit orchards of district Skardu.

Family	Genus	Species	Number of species
Apidae	*Bombus*	*tunicatus*	1
Anthophrodae	*Anthophora*	*niveo-cincta* *himalayensis* *crocea*	3
Anthophrodae	*Xylocaopa*	*Dissimilis* *Dissimilis* *rufescens*	3
Andrenidae	*Andrina*	*harriete*	1
Megachilidae	*Osmia*	*anonyma* *cornifrons*	2

Where, “ni” is the number of individuals in the” ith” species and “N” is the total number of individual in the sample.
The form of the Nakamura’s index used was:

$$RI = \sum_{r=i}^{S} Ri \,/\, S\,(M - l)$$

Where, “S” is the number of investigated species of insects; “M” is the number of rank of abundance (0, 1, 2, 3… M - l) and “R” is the rank value of “ith” species in the sample.

Rank abundance values

In a biodiversity study, there are mainly four categories to be worked out; abundance, richness, evenness and dominance. For studying the species dominance of pollinators during the flowering period, rank abundance values were needed to be solved. This was done by taking the sum of individual species found throughout the crop period and ranks were given based on the dominance of hymenopterans species.

RESULTS AND DISCUSSION

Occurrence of hymenopterous bee pollinators in orchard ecosystems

Field surveys for collection of the bees were carried out during March 2010. The specimens were identified up to species level. A total of nine species belonging to five genera that fall in four families, were identified. The abundance, richness and evenness (equitability) of pollinators found in each sampled commercial fruit orchard and total abundance of each species and total abundance of species collected from all sampled commercial fruit orchards are in accordance with Jasara et al. (2000) and Jasara and Rafi (2008). Abundance, richness and evenness (equitability) of the hymenopterous pollinator bees was found at peak during the successional flowering time in the orchards of both pome and stone fruits in various localities. Previously, Verma and Pertap (1993) also highlighted the impact of mountain pollinators during spring from Himalayan region.

Ante-meridian (before noon) collection surveys

During ante-meridian (A.M.) collection, a total of two hundred and seventy three (273) specimens were collected from all sampled commercial fruit orchards of district Skardu, which is the 60.94% of the total collected specimens in both ante-meridian (A.M.) and post-meridian (P.M.). It showed that hymenopterous pollinator bees prefer to visit flowers during ante-meridian (A.M.) phase as compared to post-meridian (P.M.) phase of the day time. There was no significant difference in abundance, richness and evenness (equitability) of the hymenopterous pollinator bees found in all commercial fruit orchards of district Skardu at post-meridian taxa collected at post-meridian. These results were in accordance with that of Louadi and Doumandji (1998). The diversity density of bee pollinators perhaps decreased in mono culture more rapidly.

Post-meridian (after noon) collection surveys

During post-meridian (P.M.) collection, a total of one hundred and seventy three specimens (175) were collected from all sampled commercial fruit orchards; that is the 39.06% of the total specimens collected in both ante-meridian (A.M.) and post-meridian (P.M.). This indicated that hymenopterous pollinator bees less preferred to visit flowers during post-meridian (P.M.) phase as compared to ante-meridian (A.M.) phase of the day time. Abundance, richness and evenness

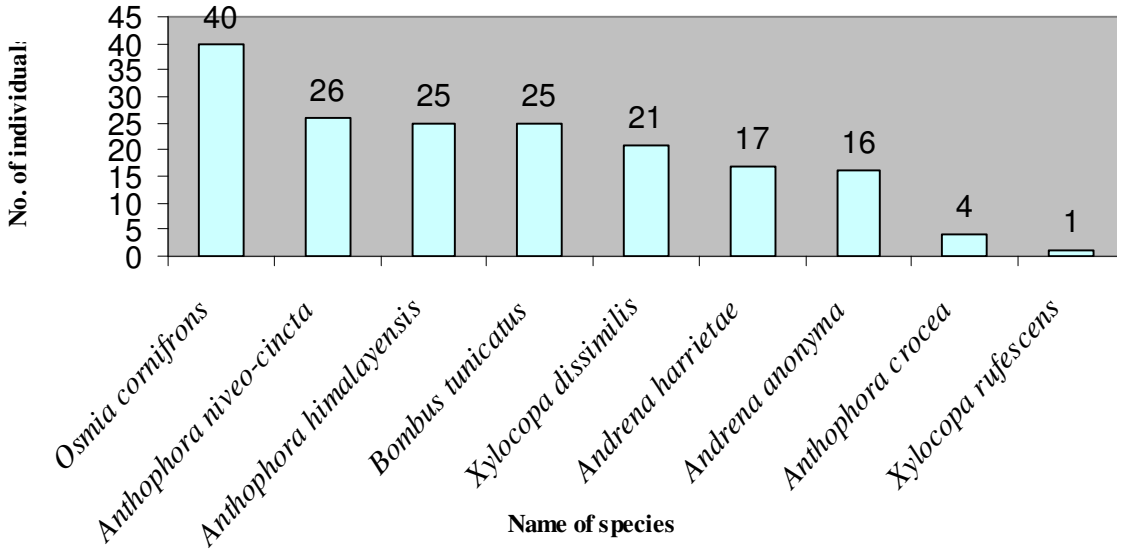

Figure 1. Diagrammatic representation of the specimens collected from all sampled commercial fruit orchards of district Skardu during post-meridian (P.M.).

(equitability) of the Hymenopterous pollinator bees found in all commercial fruit orchards of district Skardu at post-meridian (P.M.) are diagrammatically represented in Figure 1. Table 3 shows the collective rank list along with the list of taxa collected at post-meridian from different commercial fruit orchards of district Skardu. This ancient and co-evolved process arose at about, or before, the age of the dinosaurs and has allowed the marvelous radiation of flowering plants and pollinating insects that now comprise part of the green biofilm of the terrestrial surface, robed in the world's largest membrane, the atmosphere (Thomas, 1993). These results are also in accordance with McGregor (1976) who estimated that bees accomplish more than 80% of the insect pollination. Yields of fruit, legumes and vegetable seeds often have been doubled or tripled by providing adequate number of bees for pollination. Shannon's diversity index in perturbed situations are usually higher (Pileou, 1975).

During the present study, four (4) diversity indices namely; Shannon-Wiener's diversity index along with its equitability component, Margalef's index, Simpson's index and Nakamura and Toshima's index were used for the calculation of abundance, richness and evenness (equitability). The calculated values and comparison of calculated values of four diversity indices for each sampled commercial fruit orchards of district Skardu are given in Table 4. Moreover, the pollinators' guild (Table 5) indicated a significant difference of 14.38 and 8.64 from clean and bushy fields, reflecting the effect of cropping pattern on the availability of the pollinators. This pattern is followed by the each spp. of hymenopterous pollinators available during the full bloom.

The calculated values of this index in different commercial fruit orchards of District Skardu ranged from 2.262 (Agricultural Fruit Orchard Mehdiabad) to 2.945 (PCSIR Fruit Orchard Skardu). The remaining commercial fruit orchards yielded values in between the above-mentioned figures (2.262 to 2.945). The calculated values showed that there is no big difference (0.921) and (0.988) in the richness and evenness of Shannon-Wiener's diversity index, which meant that the hymenopterous pollinator bees are well distributed in all commercial fruit orchards of district Skardu. However, the maximum diversity value was calculated from the PCSIR Fruit Orchard Skardu (2.945) and minimum diversity value was calculated from the Agricultural Fruit Orchard Mehdiabad (2.262).

Shannon's equitability (J')

Shannon's equitability index measures the evenness (equitability) of the calculated species in the sample or sampling area (Shannon, 1963). The calculated values of the Shannon's equitability index 'J' in sampled commercial fruit orchards of District Skardu ranged from 0.875 (Agricultural Fruit Orchard Mehdiabad) to 0.988 (Agricultural Fruit Orchard Hamid Ghardh). Out of the seven commercial orchards, the similarity and differences in calculated values were not significantly different in pollinators' number as well in the fruit yields. This uniform distribution indicated the equitability of the hymenopterous pollinators (Table 2). The evenness and richness of the pollinators are coinciding in values from two diversity indexes (Shannon-Wiener's diversity index) and (Shannon's equitability index 'J') which support normal distribution of the pollinators' species indicating less diverse pattern in the study area of monoculture.

Table 3. The collective rank list along with the list of taxa collected from different commercial fruit orchards of district Skardu.

Rank	Name of Taxa	Abundance	City Park orchard	Hamid Gardh orchard	PCSIR Fruit Orchard	Shangrila orchard Kachura	Fruit Orchard Sermik	Agriculture Fruit Orchard Mehdiabad	Fruit Orchard Hushupi, Shigar
1	*Osmia cornifrons*	87	25	13	12	11	12	0	14
2	*Anthophora niveo-cincta*	84	18	11	9	12	11	13	10
3	*Anthophora himalayensis*	69	14	11	9	8	6	10	11
4	*Bombus tunicatus*	58	8	9	10	9	5	8	9
5	*Xylocopa dissimilis*	57	9	15	9	5	6	7	6
6	*Andrena harrietae*	44	8	8	7	6	5	6	4
7	*Andrena anonyma*	37	9	8	5	6	4	3	2
8	*Anthophora crocea*	7	7	0	0	0	0	0	0
9	*Xylocopa rufescens*	5	0	0	5	0	0	0	0
No of individuals		∑N=448	N=98	N=75	N=66	N=57	N=49	N=47	N=56
No of species			8	7	8	7	7	6	7

Table 4. Calculated values of diversity Indices from different commercial fruit orchards of District Skardu, N.Areas.

S/N	Name Orchard	Shannon-Wiener's index (H´)	Shannon-Wiener's index (H´)	Margalef's index (D)	Simpson's index (C)	Nakamura's index (RI)
1	City park	2.764	0.921	1.527	0.965	0.642
2	Agril. Fruit Orchard	2.774	0.988	1.389	0.959	0.666
3	PCSIR Fruit Orchard	2.945	0.982	1.671	0.999	0.642
4	Orchard of Shangrila Kachura	2.945	0.982	1.671	0.999	0.642
5	Agril. Fruit Orchard Sermick	2.698	0.958	1.542	0.999	0.666
6	Agril. Fruit Orchard Mehdiabad	2.262	0.875	1.298	0.999	0.700
7	Agril. Fruit Orchard Hashupi, Shighar	2.617	2.932	1.490	0.999	0.666

Table 5. Pollinators guild in a clean cultivated and a bush surrounding orchards.

S/N	Pollinators fauna	Orchard with bushy surrounding	Orchard with clean cultivation
01	*Osmia cornifrons*	14.38 ± 0.14	8.64 ± 0.08
02	*Anthophora niveo-cincta*	9.34 ± 0.19	7.20 ± 0.19
03	*Anthophora himalayensis*	5.26 ± 0.06	4.21 ± 0.14
04	*Bombus tunicatus*	4.37 ± 0.18	3.84 ± 0.010
05	*Xylocopa dissimilis*	7.30 ± 0.15	4.34 ± 0.14
06	*Andrena harrietae*	3.34 ± 0.010	3.24 ± 0.19
07	*Andrena anonyma*	2.23 ± 0.16	3.13 ± 0.18
08	*Anthophora crocea*	4.12 ± 0.17	2.24 ± 0.14
09	*Xylocopa rufescens*	3.38 ± 0.26	4.22± 0.25

Margalef's index

Margalef's index is used to measure the richness of the species distributed in the sample or sampling area **(**Margalef, 1969). This index is used frequently in the biological data. The calculated values of the Margalef's index in the seven commercial fruit of district Skardu ranged from 1.298 (Agricultural Fruit Orchard Mehdiabad) to 1.671 (PCSIR Fruit Orchard Skardu). The remaining sampled commercial fruit orchards yielded the values in between these two (Table 4). The yielded values of this index from all the sampled commercial fruit orchards indicated that there was no any big difference in the richness of hymenopterous pollinator bees in these orchards of district Skardu.

Simpson's index

The calculated values of the Simpson's index from sampled commercial fruit of district Skardu was calculated as: 0.965 (City park Skardu), 0.959 (Agricultural Fruit Orchard Hamid Ghardh Skardu) and the remaining sampled commercial fruit orchards as 0.999 (Table 4). The yielded values of this index indicated that the abundance of City Park Skardu and Agricultural Fruit Orchard Hamid Ghardh Skardu were slightly higher than remaining all sampled commercial fruit orchards of district Skardu.

Nakamura's index (RI)

Nakamura and Toshima's index measures the richness of the species. The calculated value of Nakamura (RI) index ranged from 0 to 1. If the value tends to zero, the diversity will increase (Nakamura and Toshima, 1995). The calculated values of the Nakamura's index (RI) from sampled commercial fruit orchards of district Skardu were calculated as: City park Skardu PCSIR Fruit Orchard Skardu (0.642) and the remaining sampled commercial fruit orchard as 0.666. The yielded values of this index indicated that the diversity of City Park Skardu and PCSIR Fruit Orchard Skardu was slightly higher then remaining all sampled commercial fruit orchard of district Skardu (Table 4).

Conclusion

The calculated values of all the indices from the entire sampled commercial fruit orchards showed that despite the big difference in the total number of individuals (abundance) there was no big difference in the richness and evenness of Hymenopterous pollinator bees in district Skardu.

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