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A Systematic Survey of Alpha Diversity of Hymenopterans in Maize and Mustard Cash Crops of the Arid Region of Punjab, Pakistan

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ABSTRACT

Insects as pollinators are vital components for long-term sustainability and proper functioning of agroecosystems. Comprehensive investigations were undertaken to observe the alpha diversity and status of hymenoptera pollinators in relation to cash crop floristic composition in irrigated areas of District Bhakkar and Layyah. The current study revealed a total of 13 genera belonging to seven families with seven identified species from the agroecosystem of the studied areas. The values of Shannon Wiener (H'), Simpson's diversity index (1/D) and Menhinick's index, and abundance for different genera were recorded highest for the maize plantations of district Layyah as 1.05, 2.39, and 0.47, respectively. The Hymenoptera members were much more evenly distributed on maize flowers with the highest 1.30 and 0.65 values of Evenness index (J') in comparison to the other cash crops throughout the studied period. The studied sites of irrigated areas did not exhibit a declining trend of alpha diversity of pollinators in relation to different flowers. In addition, the descriptive analysis indicated that temporal variations in patterns of plant-pollinator interactions did not get affected by multiple environmental factors ($P > 0.05$). The genus *Apis* indicated a highest abundance (2929 and 4946) and relative abundance values of 0.9 and 1.0 from mustard crops of both districts. t-test, one-way-ANOVA, and Chi-square test did not reflect any significance at 0.05 probability level for various genera on different crops of experimental areas. Similarity indices (Sorensen, S_s and Jaccard, S_j) values for community analysis of different genera from the studied crops between both districts were recorded as 0.82 and 0.69, respectively. The present research serves as a baseline for conservation plans for future or sustainable agricultural crop management in the region. A total of 253,454 insects were collected, distributed among nine orders, 82 families and 241 species. No differences were observed in the insect community based on the richness, diversity and evenness indices. Predators and pollinators were more abundant in genetically modified maize. Parasitoids, detritivores, sap-sucking herbivores and chewing herbivores were more abundant in conventional maize with insecticide sprays. Significant differences were found for the species *Colopterus* sp., *Colaspis occidentalis* (L.) and *Nusalala tessellata* (Gerstaecker) which were most abundant in *Bt* maize, and *Dalbulus maidis* and *Condylostylus* sp. 2 in conventional maize.

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ARK performed the experiment and wrote the manuscript. AAK and MKM conceived, designed and performed insect identification. ZH, YA and TA edited manuscript. FS and AM performed data analysis.

Key words
Richness and evenness indices, Polistes, Apis, Andrena, Campsomeriella, Bowl traps

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INTRODUCTION

Native bees and other Hymenoptera pollinators are the most crucial pollinators in agro-ecosystems and are helpful in biodiversity protection and providing food to native wildlife (Thorp *et al*., 1992; Paini, 2004). The reproductive capacity of plants is dependent on pollinator diversity, visitation rate, pollinator foraging behaviour,

and amount of viable pollen (Muli *et al*., 2014; Rogers *et al*., 2014; Shenkute, 2009). Bees and other animals pollinate 1500 crop species of the world and are directly or indirectly important for 15-30% of world food production (Primack, 1978; Cunningham, 2000; Kremen *et al*., 2002). Bashir *et al*. (2021) recorded the abundance and richness of Hymenoptera community from Southern Punjab, Pakistan, which was composed of 68 different bee species within five families and 57 wasp species representing nine families. Among wasps *Delta dimidaitipenne*, *Vespa orientalis* and *Delta escurensesuriens* were most abundant, while *Apis florea*, *Apis dorsata* and *Halictus sp.* were most abundant overall. Kunjwal *et al*. (2014) and Roy *et al*. (2014) reported 23 species of hymenopteran pollinators from mustard flowers (*Brassica juncea*) which belonged to Xylocopidae (5), Apidae (5), Halictidae (4), Megachilidae (4), Anthophoridae (3) and Andrenidae (1), and *Apis mellifera* was the most abundant visitor overall. Devi *et al*. (2017) observed similar findings on mustard blooms and order Hymenoptera with 13 families formed higher percentage of insect visitors in which 12 species belonged to the family Apidae. Bosly (2021) revealed three hymenopteran superfamiles (Apoidea, Evaniodea, Vespoidea) from Saudi Arabia representing 15 species belonging to 10 genera under Apidae, Sphecidae, Crabronidae, Mutillidae, Vespidae and Evaniidae families.

Order Hymenoptera considered to be most diverse and important group of insects with over 100,000 species of which some are herbivores while others are parasitic or phytophagous. Hymenopteran pollinators distribution and diversity is reliant on food supplying and further environmental factors, and their role in ecosystem balance is significant (Bhardwaj *et al*., 2012; Hoen *et al*., 2008). Hymenopterans not only affect the abundance, distribution and foraging behavior of other pollinators but also the other *Hymenoptera* spp. (Shenkute, 2009; Aizen and Feinsinger, 1994; Markwell *et al*., 1993; Kato and Kawakita, 2004; Dupont *et al*., 2004; Thompson, 2006). Among thirty-five insect pollinators of canola belonging to twenty families under five orders, the hymenopterans formed the higher percentage with *A. mellifera* (87.7%) followed by *A. florea* (1.11%) and *A. dorsata* (0.98%) (Akhtar *et al*., 2018). Rajkumari *et al*. (2014) observed six families Sphecidae, Vespidae, Apidae, Halictidae, and Megachilidae in the agro-ecosystem of Assam, India, with the dominant Apidae family (8 species) followed by Vespidae (6 species). The variety and richness of pollinators in order Hymenoptera in maize crop fields were measured by using yellowish, white, and blue bee bowls and a total of 3617 insects representing 51 species were collected, in which hymenopterans were rich in number and it was noted that blue bee bowl was effective in pollinator's collection (Wheelock, 2014). Goswami and Khan (2014) studied that hymenopteran pollinators were abundant and diverse in mustard (*Brassica juncea*) field in Pantnagar, India, and hymenopterans belonged to 15 species and seven families (Apidae, Scollidae, Megachilidae, Xylocopidae, Anthophoridae, Halictidae and Sphecidae) among 19 insect visitor species. Insect pollinators particularly bees are highly attractive to *Brassica* spp. which are poorly wind pollinated (Irshad and Stephen, 2013), hence play an important role in more seed production or maintaining agro-ecosystem balance (Atmowidi and Buchoria, 2007; Bhowmik *et al*., 2014).

Maize is a wind-pollinated crop but insects play a major role in pollination and especially bees and other hymenopterans are able to pollinate maize plants. Bees collect pollen as a food source but cannot distinguish the quality of pollen as low and high quality or even toxicity of the pollen (Irshad and Stephen, 2013; Hocherl *et al*., 2012). Huber *et al*. (2022) examined species richness and Shannon-Wiener diversity of bees in pure and intercropped maize (*Zea mays* L.) in the agricultural landscape and found a significant increase in honeybees, bumble bees as well as other bee species richness, however solitary bees were not affected. Frizzas *et al*. (2018) collected a total of 253,454 insects from *Bt* maize (MON810), conventional and insecticide maize plants which were distributed among nine orders and 241 species belonged to 82 families. They observed a total of 70,904 insects on MON810 plant blooms which belonged to 193 species within 70 families with 2.24 H' and evenness index (J') of 0.43. The pollinator group indicated high relative percentage abundance of 102 (0.2%) with highest abundance of *Apis mellifera,* and second most species richness index (7) after conventional maize plants of 8. Gardiner *et al*. (2010) collected a total of 213 specimens with 42 identified species of pollinators especially bees *Megachila* sp., *Halictus* sp., and *Andrena* sp. 50 species of insect pollinators visited maize flowers and *Apis* bees, solitary bees, and bumble bees indicated high abundance and species richness index (Wheelock, 2014; Gill and O' Neal, 2015; Keller *et al*., 2005). This study focuses on the most important hymenopteran pollinator group including bees and wasps. This study also based on the wild native insects which play and important in overall pollination of flowers. This study majorly conducted to evaluate the pollinators difference in diversity and abundance between *B. rapa* and *Zea mays* crops in irrigated areas of District Bhakkar and Layyah. The diversity of Hymenoptera pollinators was measured in terms of diversity indices (Shannon-Wiener, Simpson's index and Menhinick index), their relative abundance, species accumulation curves, community analysis between different crops by Sorensen and Jaccard's similarity index

(S_S, S_J), Pielou evenness index (J') and Simpson E index. The present research serves as a baseline for conservation plans or sustainable agricultural crop management in the region.

MATERIALS AND METHODS

Collection of insects

Field surveys were performed in two seasons, autumn 2015 (from mid-September to mid-November) and spring 2016 (from mid-February to mid-April). During surveys, irrigated areas were supposed to be divided into two blocks, Block A representing Bhakkar and block B representing Layyah while each block was further divided into 8 hotspots (Ali Lak, Subhan Chowk, Basti Majoka, Jhok Shah Mohammad, Dajal, Khichi Khurd, Basti Nourang Khan, Basti Mulan Wali- District Bhakkar; Basti Umar Wali, Chughtai Nagar, Sheihn Wala, Sargani Nasheb, Basti Qazi Rajan Shah, Nasheb Dostoo Khoo, Basti Shadoo Khan, Mouza Sumra Nasheb- District Layyah). A field of minimum 0.5 acres of maize (*Zea mays*) and field mustard (*Brassica rapa*) crops was considered for the monitoring of hymenopteran pollinators in four hotspots randomly based on availability and suitability of crops. Each field was further separated into four repeats.

Collection methods

Bowls of bluish and yellowish colour were chosen to attract and collect hymenopteran insects. Each hotspot was divided into four replicates and bowl traps were placed properly in a cash crop field. Hardboard of 14 inches × 12 inches size with six bluish and yellowish bowls each with a white bowl in the centre was laid on the ground in a specific crop field and each bowl size was 3.5 inches diameter with 2.0 inches height. Hymenopterans were sampled by various methods. Active flier insects were collected by use of aerial nets. Aerial nets had 9 inches diameter circle and 15.5 inches handle with white small mesh size were used in collection of insects. A total of 253,454 insects were collected, distributed among nine orders, 82 families and 241 species. No differences were observed in the insect community based on the richness, diversity and evenness indices. Predators and pollinators were more abundant in genetically modified maize. Parasitoids, detritivores, sap-sucking herbivores and chewing herbivores were more abundant in conventional maize with insecticide sprays. Significant differences were found for the species *Colopterus* sp., *Colaspis occidentalis* (L.) and *Nusalala tessellata* (Gerstaecker) which were most abundant in *Bt* maize, and *Dalbulus maidis* and *Condylostylus* sp.2 in conventional maize. The data were collected fortnightly from studied crops of respective hotspot. Insects were killed in collection jar of 500 ml with chloroform without damaging their colour. Published taxonomic keys were used for the identification of Hymenoptera pollinators like Siddiqui *et al*. (2015), Saini and Rathor (2012), Gupta and Jonathan (2003), Michener (2000), Mason and Huber (1993) and Gupta (1992). An expert of family Vespidae at Arid University, Rawalpindi was also consulted.

Statistical analysis

The data collected from field experiments were computerized and statistically analyzed through SPSS 16.0® version. Descriptive statistics with standard errors (mean±S.E.) were used at $p = 0.05$ to evaluate different variables of bowl traps. t-test, Chi square test and One-way-ANOVA were used to estimate and analyze abundance of different Hymenoptera families and genera from cash crops in different meteorological months at $p = 0.05$ significance level. Two traits of pollinator assemblage collected by bowl traps were analyzed including abundance and diversity. Diversity was calculated by using the Shannon-Wiener index and the evenness index (Pielou's J index) that combines the two factors affecting diversity, i.e., dominance and species abundance, which itself is the complement of the Simpson index (1/D) and Simpson E index. Similarity indices (Sorensen, S_S and Jaccard, S_J) were applied for community analysis in the studied sites. Species accumulation curves were also drawn for sampling efforts for the collection of hymenoptera species from the studied crops.

RESULTS

Wild hymenopteran insect populations provide a substantial service to the productivity and seed set of many wild and domesticated crop species. During the current systematic survey on Hymenoptera insect fauna of irrigated areas of arid region of district Bhakkar and Layyah, a total of 8853 individuals of 13 genera under seven families and seven species were identified in the activity of pollination across the different studied crops. The maximum number of 11 genera belonged to seven families were recorded in mustard field of district Bhakkar. The genus *Apis* was found to be the most abundant pollinator group with 94.8% and 96.6% of total individuals observed on mustard flowers, followed by *Polistes* (57%) in maize plantations of district Layyah. Among families identified from studied areas, Apidae was the most dominant family visiting different flowers of the current arid region, followed by Vespidae (58%) on maize flowers of district Layyah (Tables I, II). During the present systematic survey on alpha diversity of Hymenoptera insect fauna, based on observations a highest number of seven species.

Table I. Occurrence (%) of Hymenopteran families and genera from different crops of district Bhakkar and Layyah.

Families/ Genera	Maize		Mustard	
	Bhakkar	Layyah	Bhakkar	Layyah
Families				
Sphecidae	6%	27%	1%	-
Vespidae	13%	58%	1%	1%
Scoliidae	1%	1%	1%	1%
Halictidae	3%	-	1%	-
Apidae	77%	13%	94%	96%
Andrenidae	-	1%	1%	1%
Megachilidae	-	-	1%	1%
Genera				
Sceliphron	6%	27%	0.8%	-
Polistes	13%	57%	0.8%	0.9%
Campsomierella	0.1%	-	0.8%	0.7%
Delta	-	1%	-	0.02
Vespa	-	-	-	0.02%
Andreana	-	2%	0.9%	1.2%
Nomia	2.8%	-	0.3%	-
Halictus	0.1%	-	0.2%	-
Lasioglossum	-	-	0.2%	-
Megachile	-	-	0.5%	0.2%
Osmia	-	-	0.2%	0.3%
Lithurgus	-	-	0.2%	0.2%
Apis	78%	13%	94.8%	96.6%

A*pis dorsata, Apis cerana, Apis florea, Sceliphron caementarium, Campsomeriella collaris, Polistes wattii, Delta dimidiatipenne* were categorized into four families Apidae, Vespidae, Sphecidae and Scoliidae. Genus *Apis* was categorized as very common with relative abundance value of 0.9 and 1.0 from mustard flowers, and 0.8 from maize flowers of district Bhakkar. Genus *Polistes* was common in maize plantations 0.6 relative abundance of district Layyah and *Sceliphron* with 0.6 value, while other genera were considered rare from different fields of experimental arid areas (Table I). The sampling efforts were consistent with collection of more individuals with more genera in the samples from the respective studied areas.

Tables II, III, IV express variations in the pattern of alpha diversity indices among different families and genera of insect fauna during the entire study period of irrigated areas. The values of Shannon-Wiener diversity index (H') and Simpson's reciprocal diversity index (1/D) were calculated as 1.05 and 2.39 for overall samplings of insect genera assemblage representing a rich diversity of insect pollinators in the maize fields of district Layyah, while Menhinick's index indicated more species per sample for maize (MI=0.47) as compared to district Bhakkar (MI=0.26). A rich alpha diversity was observed on mustard blooms of district Bhakkar (MI=0.20). The pollinators were more evenly distributed in maize plantations of both districts. A rich alpha diversity with Pielou's J index values of families and genera was observed in studied crops of irrigated areas during September and February of the studied months with slight variations. It may be due

Table II. Diversity indices showing different Hymenoptera families and genera of the maize and mustard fields from irrigated areas of District Bhakkar and Layyah during the autumn season (September, October, November) and spring season (February, March, April).

Index	September 2015					October 2015					November 2015				
	H'	J'	1/D	SEI	MI	H'	J'	1/D	SEI	MI	H'	J'	1/D	SEI	MI
Maize fields: Families															
Bhakkar	1.23	0.76	2.94	0.59	0.55	1.02	0.63	2.04	0.41	0.50	0.43	0.31	1.22	0.24	0.27
Layyah	1.1	0.80	2.7	0.68	0.72	0.85	0.61	2.08	0.52	0.61	0.48	0.35	1.28	0.32	0.62
Genera															
Bhakkar	1.23	0.69	2.94	0.42	0.76	1.05	0.59	2.04	0.34	0.60	0.42	0.31	1.23	0.31	0.22
Layyah	1.07	0.77	2.7	0.68	0.73	0.85	0.61	2.08	0.52	0.61	0.48	0.35	1.25	0.31	0.61
	February 2016					March 2016					April 2016				
Mustard fields: Families															
Bhakkar	0.4	0.21	1.18	0.17	0.25	0.41	0.23	1.18	0.20	0.28	0.21	0.12	1.07	0.18	0.14
Layyah	1.21	0.75	2.86	0.58	0.54	0.22	0.14	1.09	0.22	0.09	0.07	0.04	1.02	0.20	0.11
Genera															
Bhakkar	0.41	0.17	1.16	0.11	0.40	0.42	0.22	1.2	0.17	0.32	0.21	0.12	1.8	0.3	0.14
Layyah	1.33	0.68	2.86	0.41	0.75	0.22	0.10	1.09	0.14	0.15	0.07	0.04	1.02	0.15	0.15

H', Shannon-Wiener index; J', Pielou's evenness index; 1/D, Simpson's reciprocal index; SEI, Simpson's evenness Iidex (Equitability); MI, Menhinick's diversity index.

Table III. T-test and One Way-ANOVA analysis of different families and genera of Hymenoptera from irrigated areas of District Bhakkar and Layyah.

	Independent samples t-test			Levene's homogeneity test		One way-ANOVA		
	T	df	Sig. (2-tailed)	df total	Sig.	F	df total	Sig. (2-tailed)
Families								
Maize	1.071	8	0.315	09	0.066	0.792	12	0.393
Mustard	-0.610	10	0.555	11	0.185	0.372	11	0.555
Genera								
Maize	0.896	9	0.393	10	0.112	0.803	10	0.393
Mustard	-0.503	18	0.644	19	0.292	0.253	19	0.621

Table IV. Community analysis of wasp and bee hymenopterans in different fields of Irrigated Areas of District Bhakkar and Layyah.

Genera	District Bhakkar						District Layyah					
	A.F.		A.D.		P.V.		A.F.		A.D.		P.V.	
	Maize	Mustard	Maize	Mustard	Maize	Mustard	Maize	Mustard	Maize	Mustard	Maize	Mustard
Sceliphron	100.0	50.0	687.5	612.5	6.87	12.25	66.6	-	1033.3	-	15.5	-
Polistes	100.0	50.0	812.5	737.5	8.12	14.75	100.0	62.5	1187.5	1100.0	11.87	17.6
Campsomierella	16.67	37.5	33.33	562.5	2.0	15.0	-	87.5	-	925.0	-	10.57
Delta	-	-	-	-	-	-	16.67	12.5	33.3	25.0	2.0	2.0
Vespa	-	-	-	-	-	-	-	12.5	-	25.0	-	2.0
Andreana	-	75.0	-	37.5	-	5.0	33.3	75.0	100.0	1200.0	3.0	6.0
Nomia	100.0	12.5	500.0	125.0	5.0	10.0	-	-	-	-	-	-
Halictus	16.67	12.5	33.33	62.5	2.0	5.0	-	-	-	-	-	-
Lasioglossum	-	12.5	-	62.5	-	5.0	-	-	-	-	-	-
Megachile	-	37.5	-	187.5	-	5.0	-	37.5	-	200.0	-	5.3
Osmia	-	25.0	-	187.5	-	7.5	-	50.0	-	260.0	-	5.2
Lithurgus	-	12.5	-	62.5	-	5.0	-	37.5	-	180.0	-	4.8
Apis	100.0	100.0	1512.5	1775.0	15.12	17.75	100.0	100.0	1662.5	2000	16.6	20.0

AF (Absolute frequency = No of samples containing a species/ total samples collected 100. (A.D) Absolute density = Numbers of individuals of a species in a sample/ Volume of the sample 100. (P.V) Prominence value = Absolute density/ Absolute frequency.

Table V. Showing descriptive analysis of abundance of different genera of Hymenoptera from irrigated areas of District Bhakkar and Layyah.

Genera/ Abundance	Independent samples t-test			Levene's homogeneity test		One way-ANOVA			Chi Square test		
	t	df	p	df total	p	F	df total	p	$\chi 2$	df	P
Bhakkar (3617) Layyah (5236)	-0.344	19	0.734*	20	0.464*	0.119	20	0.730*	95.33	90	0.330*

non-significant*, significant**

to the presence of large amounts of pollen and nectar in experimental crop fields. Descriptive statistics results (t-test, one-way-ANOVA) elucidated that the null hypothesis was retained at probability level of 0.05, as no

Significant differences were observed between different insect fauna on respective crops (Tables II and III). Total of 3617 insect samples were collected in district Bhakkar while 5236 individuals were observed in district Layyah, and statistics results were not significant for abundance of insect fauna in the studied areas (Table IV). Ten genera (with 8 bee species) were observed in yellowish and bluish bowls. Yellowish bowls accounted a total abundance of 31 while bluish bowls showed abundance of 59 pollinators from both districts. *Andrena* 15/samples and *Osmia* 13/samples were attracted towards bluish bowls while yellowish bowls indicated a maximum abundance of 9 *Megachila* per samples in different fields from irrigated areas. Only two species of wasps were attracted towards bowl traps, and *Camposomeriella* with abundance value of 9 was recorded in bluish bowls. No positive relationship

between different bowl traps was observed ($p > 0.05$) (data not shown) among wasp community (Fig. 1).

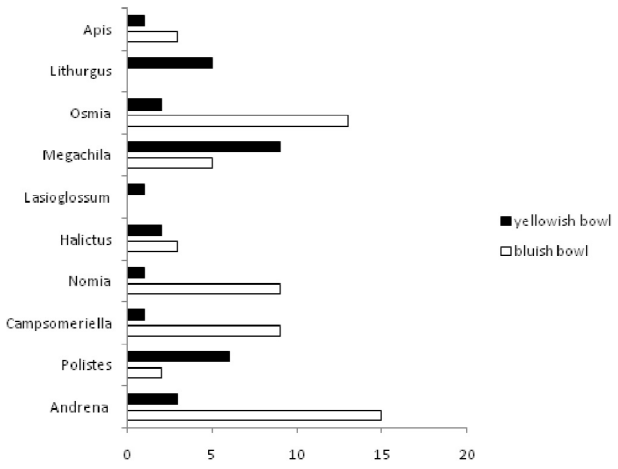

Fig. 1. Abundance of hymenoptera in different bowl traps from irrigated areas of District Bhakkar and Layyah.

Campsomierella had maximum prominent value from mustard fields, while genus *Apis* was more prominent among bee community in mustard fields of studied areas (Table V). Similarity indices (Sorensen, S_s and Jaccard, S_j) values for community analysis of various genera from the studied crops between district Bhakkar and Layyah were 0.82 and 0.69 respectively, while between the two districts, similarity indices values of 0.55 and 0.38 (maize), and 0.63 and 0.46 (mustard) were also observed (data not shown).

DISCUSSION

Hymenoptera is one of the most valuable and diverse group of insects indicating agricultural, ecological and economic importance and the most beneficial to human beings. It keeps functioning and balancing of most of the planetary ecosystem. Hymenopteran pollinators visit different crops; however, their frequency, density and relative abundance vary with respect to different factors relating to depth of corolla (Gilbert, 1980), flower texture (Free, 1970), and in addition to floral abundance and rewards (Rao and Suryanaryan, 1990; Rao, 1991). The study conducted in the irrigated areas of District Bhakkar and Layyah showed that a diverse variety of Hymenoptera pollinators was present in crops of maize and mustard. These results were similar to those Bhardwaj *et al*. (2012) and Howell (2001) who reported that bee pollinators were found to be the most visiting cash crop flowers. In terms of overall percentage occurrence of hymenopteran families, family Apidae (77%) was the most visiting maize flowers in District Bhakkar, while in District Layyah, the most studied family was Vespidae (58%). In District Bhakkar, the most prevalent genus was *Apis* (78%). A study of Malerbo-Souza (2011) revealed that percentage occurrence of *Apis* sp. was 97.13% while genus *Nomia* with 2.8% and *Halictus* with 0.1% collected from study areas, respectively. In solitary bees, *Lipotrichus* (family Halictidae) was abundant in maize crops and *Lasioglossum* (family Halictidae) was 65% (Wheelock *et al*., 2016). From studied corn fields, Gardiner *et al*. (2010) collected a total of 213 specimens with 42 identified species of pollinators particularly bees including *Halictus* sp., *Andrena* sp., *Lasioglossum* sp. and *Megachila* sp. fifty species of insect pollinators visited maize flowers including Apis bees, solitary bees, bumble bees (Wheelock, 2014; Gill and O'Neal, 2015; Keller *et al*., 2005; Krupke *et al*., 2012).

Eleven genera belonging to 7 different families were recorded from the *Brassica* flowers in the present study. The above-mentioned results are in consistent with those of Singh *et al*. (2004) and Thapa (2006), and they observed that the bees visiting brown mustard belonged to *Apis* sp., *A. mellifera, A. dorsata* and *A. florea.* Genus *Apis* was frequent visiting mustard flowers while *Polistes* was insignificant in mustard crops (Bhati and Srivastava, 2014). In mustard fields of Saudia Arabia, Osmia, *Andrena*, *Halictus* and other bee species along with wasps as significant pollinators were also observed (Ahmad, 2005). A total of 859 floral visitors were collected from *Brassica* among which honey bees mostly visited mustard crops (Poveda *et al*., 2004). *Apis* sp. as prominent agents of mustard flowers were observed to increase in quality and quantity of *Brassica* seeds in Pakistan (Parveen *et al*., 2000).

Shannon-Wiener diversity index showed that maize crops had rich diversity of Hymenoptera families with H'=1.05 value in district Layyah, and had rich diversity of Hymenoptera genera of H'=2.33 and 1.05 in district Bhakkar and Layyah, respectively. Howell (2001) estimated diversity on maize crops as H'=2.73. There was a decreasing pattern of J' value observed in mustard crops in winter season (Anbalagan *et al*., 2015). Detailed studies indicated that various colored bowls attracted bees and wasps from different cash crops of District Bhakkar and Layyah. From different field crops of District Bhakkar, *Polistes* had the maximum abundance of 6 and *Megachila* 9 in yellowish bowls. Kapkoti *et al*. (2016) showed that yellowish bowls elucidated a bee density of 5.90 while wasp density was observed to be 2.30. It was studied that bees were more attracted towards bowls than wasps, while density of *Apis mellifera* was low in bowl traps (Grundel *et al*., 2011; Goncalves and Oliveira, 2013). In the maize crops of district Bhakkar and Layyah, the most prevalent

genera were *Polistes* (AD=1187.5%) and *Sceliphron* (AD= 1033.33%), respectively while the least observed genus was *Campsomeriella* and *Delta* (AD=33.33%) among the wasp community. Among the plant bee community, the most prevalent genus was *Apis* (AD=1512.5%) and (AD=1662.5%) in the respective districts while the least observed genus was *Halictus* (AD=33.33%). Hoen *et al*. (2008) and Sabugosa-Madeira *et al*. (2007) noticed that the density of *Apis* bees was high on maize flowers as compared to non-Apis bees. In the mustard crops of district Bhakkar and Layyah, the most studied genera among the wasp community the most observed genus was *Polistes* (AD= 1100.0%/ sample) followed by *Campsomeriella* which showed absolute density of 925.0%/ sample. Among the plant bee community, the most prevalent genus was *Apis* (AD=1512.5%/ sample) and (AD=2000.0%/ sample) in the respective districts while the least observed genera were *Lasioglossum, Nomia, Halictus* and *Lithurgus*. Honey bees were predominant with 58% among bee community while *Megachila sp.* were 14.4%, *Nomia* sp. 14.3%, *Andrena* sp. 2.0% and *Xylocopa* sp. 0.1% (Chaudhary, 2001).

CONCLUSION

Hymenoptera insects are crucial in improving field crop productivity. These pollinators are diverse and abundantly found in irrigated areas of District Bhakkar and Layyah. Thirteen genera of Hymenoptera pollinators from seven different families were recorded from the flowers of different crops of studied arid areas. Seven species were also observed and identified from selected crops in both districts. The present findings indicated Apidae was highly abundant Hymenoptera family in different crops. Non-*Apis* bees were also observed to visit flowers of selected crops but in a less significant number than *Apis* bees while genus *Polistes* (Family Vespidae) was noted as second most occurred genera on all selected crops. Hymenoptera pollinators were more attracted towards bluish bowl traps in maize and mustard fields. Shannon (H') and Simpson (1/D) diversity indices and J' values revealed that high diversity of Hymenoptera families and genera was seen on maize crops of respective districts. This research would possibly be a base to understand and document the alpha diversity of Hymenoptera pollinators in these agricultural-based districts and this data base can contribute to the development of policies to protect these valuable pollinators.

DECLARATIONS

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Statement of conflict of interest

The authors have declared no conflict of interest.

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