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Spider Diversity in Some Common Oilseed Crops in Central Punjab, Pakistan

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Abstract. Three commonly cultivated oilseed crops *viz*., soybean, sunflower and Indian mustard were sampled to compare density and diversity of spider at different developmental stages. This study was conducted at Ayub Agriculture Research Institute, Faisalabad, Pakistan. A total of 1210 spider individuals, 68 species and 5 families were sampled throughout the study period. The families showed different levels of association with the crops, like Lycosidae and Clubionidae were found commonly spread and highly abundant, whereas Philodromidae was only restricted to sunflower and locally rare. The *Evippa sohani*, *Pardosa fletcheri*, *Evippa shivajii* and *Pardosa oakleyi* were recorded most dominant and commonly spread spider species. Indian mustard constituted highest diversity of spider species followed by soybean and sunflower. Spider species diversity on the Indian mustard was significantly different from the sunflower. These predator species can play a major role to suppress devastating agricultural pests of oilseed crops, thereby enhance the crop yield.

Keywords: Araneae, agro-ecosystem, oil seed, ecology, agrochemicals, spider diversity

Introduction

The green revolution (1950-60) causes rapid loss of biodiversity by the adaption of monoculture system instead of polycluture (Abbas *et al*., 2014; Altieri, 1992). Almost 600 arthropod pest species seems to be affecting the yield of agricultural crops worldwide (Samways, 1997). In conventional agro-ecosystems, agrochemicals are heavily applied against insect pests that might be fatal to biocontrol agents, harmful to all levels of food chain, health risks of working with these chemicals, common people and further damage to environment quality (Pekar, 2005; Gamundi *et al*., 2001), whereas, biological pest control has several advantages over the chemical control as it is safe to handle, cost effective, provides long term management, self-perpetuating, no harms to the non-target organisms and environment friendly (Abbas *et al*., 2013; Abbas *et al*., 2012; Eisley and Hammond, 2007).

Over the last three decades, agriculture experiments have revealed that spiders species play a key role to suppress crop pest's populations. They are generalist terrestrial predators and potential bio-control agents compared to specialist predators (Wise, 1993). For instance, Fagan *et al*. (1998) documented that Lycosidae and Linyphidae spider families can suppress variety of pests e.g., aphids (Aphidae), thrips (Thysanoptera) and leafhoppers (Cicadellidae), while Symondson *et al*. (2002) and Lang *et al*. (1999) confirmed the biocontrol activity and working independently on Delphacidae and Cicadellidae in field experiment. The spider diversity in agricultural ecosystem is significantly important to determine the influence of these predators on pest populations (Maloney *et al*., 2003). Furthermore, the more diverse spider populations warrant the better crop growth, thereby higher crop yield. Spider diversity is closely associated with features of plant community, landscape structure, kind of habitat and stages of plant growth in an agro-ecosystem (Foelix, 2010; Susilo, 2007; Suana *et al*., 2004).

Spider diversity being an important bio-control agent in agricultural ecosystem has attracted attention of the ecologists worldwide (Liu *et al*., 2003; Rypstra *et al*., 1999). Despite of its economic and ecological importance in agro-ecosystem, in Pakistan, only fragmentary work is available (Parveen *et al*., 2007; Mushtaq *et al*., 2005; Khan *et al*., 2001; Mushtaq and Qadir, 1997), particularly on oil crops (Bukhari *et al*., 2012; Musthaq *et al*., 2003; Ghafoor, 2002). Hence, the present study was conducted to investigate the diversity and abundance of spider fauna in soybean, sunflower and Indian mustard.

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Furthermore, the diversity between studied habitats were compared, that were located in Ayub Agriculture Research Institute, Faisalabad, Pakistan.

Materials and Methods

The present study was conducted in Ayub Agriculture Research Institute, district Faisalabad (30° 31.5 N and 73° 74 E with an elevation of 184.4 m), that lies in northeast of Punjab Pakistan. In Faisalabad, May, June, and July are the hottest months of the year with mean maximum temperature reaching 39 °C and maximum daily temperature up to 49 °C. The monsoon rains mostly fall in July and August, which are the wettest months. December and January are the coldest months with a mean minimum temperature of 6 °C and occasionally passing below freezing (Mahmood-ul Hassan *et al*., 2010).

Soybean, sunflower and Indian mustard were sampled every 15 days interval and spider fauna was collected from different developmental stages of the studied crops. A total of 10 visits were made throughout the sampling period (January to May, 2014). An area of at least 4 hectares of these crops culture was selected randomly. Pitfall traps are commonly used in ecological studies. This is an absolute sampling technique to capture both nocturnal and diurnal active fauna. For this purpose, a glass jar comprised of 13 cm height and 6 cm in diameter was filled with 150 mL of 70% of ethyl alcohol. Two to five drops of 5% detergent was also added. A total 30 pitfall traps were installed, in diagonal pattern started from the margin of the fields. The traps were buried in soil with open end flushing with soil surface, whereas, shaking method was used to collect foliage spiders. For this purpose, branches of one plant at a time were shaken with an average 10 jerks for three times. A total of 50 plants were shaken from each site. Spider existed over a plant of sampling crops fall over white cloth, which were preserved in the polythene bags and were brought to Araneae Laboratory, Department of Zoology and Fisheries, University of Agriculture Faisalabad, Pakistan.

The collected specimens were washed with xylene and preserved into glass vials having a mixture of 1:1 ethyl alcohol and glycerin. All the spiders were identified up to the species level by using spider identification keys (Khalid, 2004; Barrion and Litsinger, 1995; Tikader, 1981).

Data was analyzed statistically to determine species diversity, species richness and evenness by using PAST statistical software. Microsoft Excel was used to construct different graphs according to analyzed data.

Results and Discussion

A total of 1210 specimens belonging to five families, 14 genera and 68 species were identified from oil producing crops. Soybean was found more abundant with 512 individuals followed by Indian mustard (n=422) and sunflower (n=276).

Overall abundance of spiders. On average 51.2 (±9.58 s.e) spider individuals were collected per trapping session (including pitfall and shaking methods) from the soybean and was found highly abundant, while Indian mustard 42.2 (±10.79 s.e) stood second in abundance followed by sunflower 27.25 (±6.14 s.e). Only first two trapping sessions were recorded without spider individuals from these crops except Indian mustard. The abundance of spiders were varied in pitfall and shaking methods and further two sessions were without spiders in both sampling methods from soybean and sunflower, while one pitfall sessions from Indian mustard. Moreover, Indian mustard, sunflower and soybean habitats varied with the number of spider individuals (Fig. 1-2).

The abundance of spider is influenced by habitat structure, kind of vegetation and their complexity (Susilo, 2007; Suana *et al*., 2004). This indicates that spider species are host specific and reside on the specific kind of vegetations (Foelix, 1982). In the present study, abundance of spider individuals varied among studied crops that might be due to variable habitat complexity,

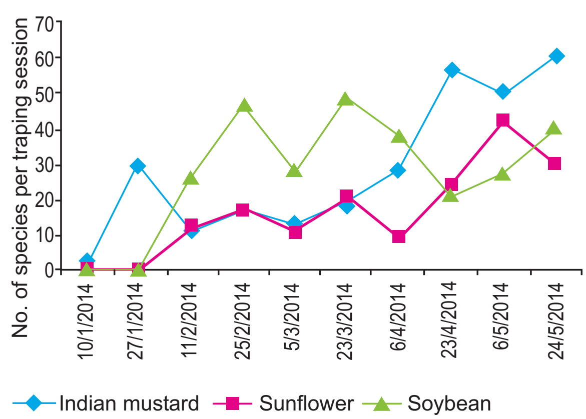

Fig 1. The dynamics of spider individuals of Indian mustard, sunflower and soybean in Shaking method.

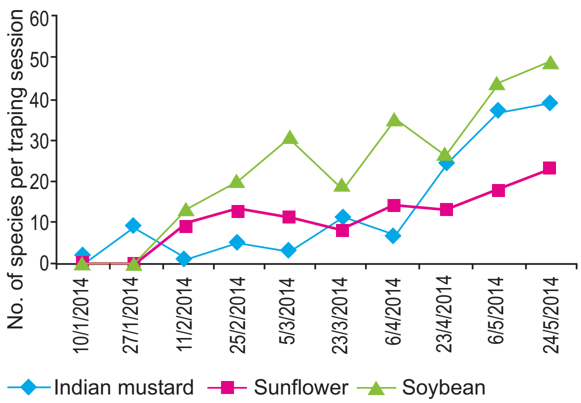

Fig 2. The dynamics of spider individuals of Indian mustard, sunflower and soybean in Pitfall method.

availability of food resources as well as association of spider individuals to certain crops. Similarly, Abbas *et al*. (2013) documented similar trends among the macroinvertebrates including spiders. They documented higher abundance of spiders on sugarcane weeds compared to wheat weeds. As sugarcane is a perennial crop it comprises of diverse vegetation, which provide breeding sites and feeding resources, in addition least disturbances either anthropogenic or farm management that makes the environment more suitable for the settlement of arthropods communities. Moreover, they noticed low arthropods communities including spiders abundance in the colder months like December and January, while higher in the warmer months (April, May etc) similar to present study. Likewise Ruby *et al*. (2011) documented similar results, while studying on the mustard, fodder, wheat and sugarcane crop in the central Punjab, Pakistan. Bukhari *et al*. (2012) explained high abundance in the warmer months in cotton fields. The maximum abundance of spider in the spring and summer season coincides with reproductive periods and the emergence of juveniles. Furthermore, the ground vegetation greatly grow ,in this season that provides stable microhabitats, and shelter as well as a wide availability of prey for spiders. Method of collection also influences the diversity and abundance of insects. For instance, pitfall trapping is controversial in ecological studies due to several reasons like they are affected by physiological state and behaviour of animals, weather, density of vegetation and type of habitat and so on (Topping and Sunderland, 1992). Further, they are unable to reflect true picture of community composition and diversity, variation in trap ability and dilute the habitat effect. Irrespective of this, the method is extensively used in the ecological studies as it is least expensive method, monitoring is convenient and collection of wide array of species is possible.

Abundance of spider families. Lycosidae, Thomicidae, Chlubionide, Salticidae and Philodromidae families were recorded from the Indian mustard, sunflower and soybean of which Lycosidae and Clubionidae were common and found abundant in all studied crops. However, former was recorded highly dominant particularly in soybean. As these crops were adjacently located that might influence the movement of spider species among the studied crops, whereas, the family Philodromidae was only resident of sunflower (Table 1 and Fig. 3).

Overall Lycosidae formed almost 80% of spider fauna collected from oilseed crops and was found most abundant family followed by Thomisidae and Clubionidae, while Philodromidae (0.58%) was found least abundant spider family (Table 1). Bukhari *et al*. (2012) found Lycosidae (57.39%) the most dominant family. Further they also recorded Salticidae (25.59), Thomicidae (6.50%) and clubionidae (2.36%) in the cotton in district Gujranwala, Pakistan. Muthukumaravel *et al*. (2013) also documented similar findings while studying mangroves in India.

Table 1. Number of spider individuals per family and functional group (guilds) found in Indian mustard, sunflower and soybean Faisalabad district. HAM: Hunting - Ambushers; AHU: Active-Hunters; HRU: Hunting – Runners

		Agricultural crops			Total	Percentage %
Families	Guild	*Brassica juncea*	Sunflower	Soybean		
Lycosidae	HRU	290	185	496	971	80.25
Thomicidae	HAM	51	61	-	112	9.26
Clubionidae	AHU	77	19	16	112	9.26
Salticidae	HAM	4	4	-	08	0.66
Philodromidae	HAM	-	7	-	7	0.58
Total		422	276	512	1210	100.00

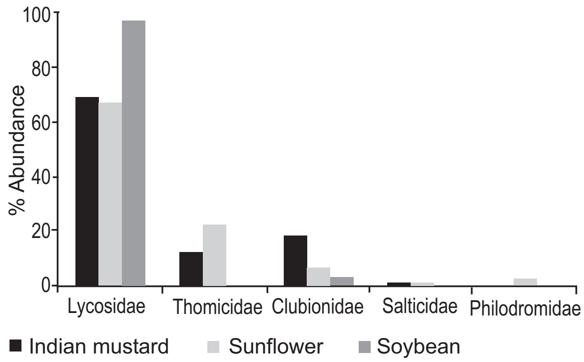

Fig 3. Percentage abundance for the spider families in Indian mustard, sunflower and soybean in Faisalabad, Pakistan.

Spider species richness and diversity. In this study, a total of 68 spider species were identified from the oil crops (Table 2). Thirty five of the 68 species were exclusively recorded only on single crop. Of which soybean had 18 spider species, while 10 spider species in sunflower and seven in Indian mustard were found exclusively. The more suitable explanation of this phenomenon, however, is the involvement of structural complexity of vegetation, which provides stable micro-habitat and shelter. Johnson *et al*. (1996) also suggested relationship between ground vegetation and arthropod species.

Among the three habitats, spider species were greatly abundant in soybean. Forty two species were recorded distributing among Lycosidae and Clubionidae families. The family Lycosidae made almost 97% of total collected spider individuals. It constituted of four genera, of which *Pardosa* was remained highly abundant with 194 (39.11%) individuals followed by *Evippa* 118 (23.05%), and *Lycosa* 84 (16.40%) were the least abundant. *Pardosa oakleyi* (n= 40) was recorded highly abundant species followed by *Evippa sohani* (n= 37), *Evippa shivajii* (n= 33), *Pardosa fletcheri* (n= 30), *Pardosa sutherlandi* (n= 28), *Pardosa timida* (n= 25), *Lycosa wroughtoni* (n= 23), *Hippasa olivacea* and *Hippasa partita* (n= 19). These spider species contributed almost 50% to the total number of spider individuals collected from soybean. Whereas, *Arctosa indicus*, *Evippa praelongipes*, *Pardosa birmanica*, *Clubiona maya*, *Clubiona pomoa*, *Pardosa chambaensis*, *Lycosa masteri, Lycosa chaperi, Evippa rajasthanea, Arctosa mulani* were least abundant and collectively made almost 10% of the collected spiders. Furthermore 9% spider species of the collected data were exclusively determined from the soybean.

Sunflower (37 spp) stood second in species richness among the three habitats, while third in total abundance 22.80% (n= 276). Only six spider species *viz*., *Evippa shivajii* (n= 18), *Evippa sohani* (n= 26), *Lycosa wroughtoni* (n= 17), *Pardosa fletcheri* (n= 21), *Pardosa*

Table 2. Abundance of spider fauna recorded from Indian mustard, sunflower and soybean

Taxa	*Brassica juncea* (%) Pitfall	*Brassica juncea* (%) Shaking	Sunflower (%) Pitfall	Sunflower (%) Shaking	Soybean (%) Pitfall	Soybean (%) Shaking	Total (%)
Lycosidae							
Arctosa indicus	-	-	-	-	-	1(0.36)	1(0.08)
Arctosa mulani	-	-	-	-	-	3(1.09)	3(0.25)
Evippa banarensis	2(1.47)	9(3.15)	-	-	8(3.39)	10(3.62)	29(2.40)
Evippa eltonica	2(1.47)	2(0.70)	-	-	-	-	4(0.33)
Evippa praelongipes	1(0.74)	8(2.80)	-	-	-	2(0.72)	11(0.91)
Evippa rajasthanea	-	-	-	1(0.60)	-	3(1.09)	4(0.33)
Evippa rubiginosa	4(2.94)	11(3.85)	1(0.91)	1(0.60)	9(3.81)	7(2.54)	33(2.73)
Evippa shivajii	4(2.94)	5(1.75)	6(5.45)	12(7.23)	16(6.78)	17(6.16)	60(4.96)
Evippa sohani	9(6.62)	7(2.45)	7(6.36)	19(11.45)	19(8.05)	18(6.52)	79(6.53)
Evippa solanensis	5(3.68)	9(3.15)	4(3.64)	8(4.82)	-	9(3.26)	35(2.89)
Hippasa greenalliae	3(2.21)	11(3.85)	-	-	5(2.12)	9(3.26)	28(2.31)
Hippasa himalayensis	1(0.74)	7(2.45)	4(3.64)	4(2.41)	6(2.54)	7(2.54)	29(2.40)
Hippasa loundesi	-	-	-	-	6(2.54)	2(0.72)	8(0.66)
Hippasa lycosina	-	-	-	-	4(1.69)	3(1.09)	7(0.58)
Hippasa madhuae	-	-	-	-	3(1.27)	2(0.72)	5(0.41)

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Hippasa madraspatana	2(1.47)	13(4.55)	-	-	-	-	15(1.24)
Hippasa olivacea	7(5.15)	10(3.50)	4(3.64)	2(1.20)	10(4.24)	9(3.26)	42(3.47)
Hippasa partita	3(2.21)	17(5.94)	1(0.91)	4(2.41)	9(3.81)	10(3.62)	44(3.64)
Hippasa pisaurina	-	-	-	-	2(0.85)	3(1.09)	5(0.41)
Lycosa basiri	-	-	-	2(1.20)	-	-	2(0.17)
Lycosa chaperi	-	-	-	-	2(0.85)	1(0.36)	3(0.25)
Lycosa choudhuryi	-	-	-	-	3(1.27)	3(1.09)	6(0.50)
Lycosa gobiaensis	3(2.21)	13(4.55)	2(1.82)	6(3.61)	10(4.24)	10(3.62)	44(3.64)
Lycosa madani	-	-	-	-	3(1.27)	3(1.09)	6(0.50)
Lycosa masteri	-	-	-	-	1(0.42)	2(0.72)	3(0.25)
Lycosa poonaensis	-	-	5(4.55)	4(2.41)	12(5.08)	11(3.99)	32(2.64)
Lycosa wroughtoni	3(2.21)	1(0.35)	6(5.45)	11(6.63)	11(4.66)	12(4.35)	44(3.64)
Pardosa birmanica	7(5.15)	17(5.94)	2(1.82)	1(0.60)	1(0.42)	1(0.36)	29(2.40)
Pardosa chambaensis	-	-	-	-	2(0.85)	2(0.72)	4(0.33)
Pardosa fletcheri	2(1.47)	11(3.85)	3(2.73)	18(10.84)	15(6.36)	15(5.43)	64(5.29)
Pardosa kupupa	12(8.82)	5(1.75)	-	-	6(2.54)	6(2.17)	29(2.40)
Pardosa lahorensis	-	-	7(6.36)	2(1.20)	13(5.51)	-	22(1.82)
Pardosa leucopalpis	-	-	2(1.82)	18(10.84)	-	13(4.71)	33(2.73)
Pardosa mukundi	-	-	-	-	7(2.97)	5(1.81)	12(0.99)
Pardosa mysorensis	9(6.62)	7(2.45)	3(2.73)	1(0.60)	4(1.69)	4(1.45)	28(2.31)
Pardosa oakleyi	3(2.21)	9(3.15)	1(0.91)	4(2.41)	19(8.05)	21(7.61)	57(4.71)
Pardosa sinensis	7(5.15)	10(3.50)	-	-	-	-	17(1.40)
Pardosa songosa	-	-	-	-	4(1.69)	3(1.09)	7(0.58)
Pardosa sumatrana	9(6.62)	10(3.50)	7(6.36)	2(1.20)	-	-	28(2.31)
Pardosa sutherlandi	-	-	-	-	14(5.93)	14(5.07)	28(2.31)
Pardosa timida	-	-	-	-	12(5.08)	13(4.71)	25(2.07)
Trochosa infausta	-	-	-	-	-	6(2.17)	6(0.50)
Thomicidae							
Cupa kalawitana	2(1.47)	-	8(7.27)	1(0.60)	-	-	11(0.91)
Camaricus florae	3(2.21)	11(3.85)	-	-	-	-	14(1.16)
Loxobates kawilus	2(1.47)	16(5.59)	-	-	-	-	18(1.49)
Misumena maputiyana	-	-	5(4.55)	2(1.20)	-	-	7(0.58)
Misumena menoka	-	-	2(1.82)	4(2.41)	-	-	6(0.50)
Misumena oblonga	-	-	2(1.82)	1(0.60)	-	-	3(0.25)
Misumena picta	-	-	2(1.82)	1(0.60)	-	-	3(0.25)
Misumena tapyasuka	-	-	6(5.45)	1(0.60)	-	-	7(0.58)
Misumenoides matinikus	-	-	4(3.64)	1(0.60)	-	-	5(0.41)
Thomisius italongus	10(7.35)	-	8(7.27)	6(3.61)	-	-	24(1.98)
Thomisius	3(2.21)	-	-	-	-	-	3(0.25)
Thomisius okinawensis	4(2.94)	-	2(1.82)	5(3.01)	-	-	11(0.91)
Salticide							
Chalcotropis luceroi	2(1.47)	2(0.70)	-	1(0.60)	-	-	5(0.41)
Plexippus paykulli	-	-	-	1(0.60)	-	-	1(0.08)
Plexippus petersi	-	-	-	2(1.20)	-	-	2(0.17)
Clubionidae							
Clubiona analis	-	-	-	1(0.60)	-	3(1.09)	4(0.33)
Clubiona charleneae	2(1.47)	15(5.24)	-		-	-	17(1.40)
Clubiona comta	2(1.47)	12(4.20)		4(2.41)	-	-	18(1.49)
Clubiona drassodes	2(1.47)	5(1.75)	-	6(3.61)	-	6(2.17)	19(1.57)
Clubiona forcipa	-	-	-	-	-	2(0.72)	2(0.17)
Clubiona hysgina	2(1.47)	2(0.70)	-	7(4.22)	-	-	11(0.91)
Clubiona japonica	3(2.21)	15(5.24)	-		-	-	18(1.49)
Clubiona maya	-	-	-	1(0.60)	-	2(0.72)	3(0.25)
Clubiona pomoa	-	-	-	-	-	3(1.09)	3(0.25)
Clubiona tikaderi	1(0.74)	16(5.59)	-	-	-	-	17(1.40)
Philodromidae							
Philodromus medius	-	-	6(5.45)	1(0.60)	-	-	7(0.58)
Total	136	286	110	166	236	276	1210

leucopalpis (n= 20) and *Thomisius italongus* (n= 14) were found highly abundant that made up almost 43% to the spiders collected from sunflower. Remaining 31 spider species identified on this agroecosystem contributed 57%, of which most of spider species only reached a least number (approximately 2%). Interestingly, *Philodromus medius* (6.05%) was the only single representative of the family and was exclusively resident on the sunflower.

Indian mustard contributed almost 35% (n= 422) to the total spider fauna with five families. Of which only Lycosidae made almost 70% of spider collected from Indian mustard. A total of 34 spider species were identified, of which, 11 species were recorded highly abundant, which added almost 50% of spider fauna. *Pardosa birmanica* 5.69% (n= 24), *H. partita* 4.74% (n= 20), *Pardosa sumatrana* 4.50 (n=19), *Clubiona japonica* and *Lycosa kawilus* individually contributed 4.27% (n= 18), while *Pardosa kupupa, Pardosa sinensis, Clubiona tikaderi* and *Clubiona charleneae* species individually added 4.03% (n= 17). Further 3.79% (n= 16) was constituted by *Lycosa gobiaensis* and *Pardosa mysorensis* individually. Whereas, 10 species hardly reached the approximately to 1%. Previously Bukhari *et al*. (2012) studied cotton fields in the Faisalabad district. They documented overall 21 spider species. Of which most dominant species e.g., *Lycosa madani*, *Pardosa birmanica, Pardosa oakleyi, Lycosa kempi*, *Hippasa holmerae* and *Plexipus bengalensis* were distributed in Lycosidae family like present study. Ghafoor and Mahmood (2011) captured 22 spider species from rice and sugarcane from district Gujranwala, Pakistan. However, the number of spider species remains low as compared to present work, which might be due to the difference in sampling method, number, kind and heterogeneity level of sampled agricultural crop. Whereas, Rodrigues *et al*. (2009) reported 85 spider species, belonging to 15 families from grassland, forest and rice agroecosystem in Brazil. This higher richness of spider species particularly in forest and grassland indicates that natural habitats still have least anthropogenic disturbance. Furthermore, availability of wide range of prey species, breeding and reproduction sites providing better opportunity to survive.

The overall spider richness, (S), eveness (E) and diversity (H´) differed among these crops and significantly varied. However, non-significant difference was found between Indian mustard and soybean (Table 3). Whitmore *et al*. (2002) documented that increase in the level of disturbance in any environment lead to decrease in spider richness. Rodrigues *et al*. (2009) suggests that a terrestrial habitat with least perturbation particularly by anthropogenic activity has triggering impact to enhance the spider diversity in any habitat.

Guild comparison among spiders. Overall hunting runners were predominant (80%) in the oil crops and remained abundant in all these environments. In soybean, hunting runners (approximately 96%) were highly abundant, due to the large number of Lycosidae recorded, whereas, active hunters made a negligible portion (Fig. 4).

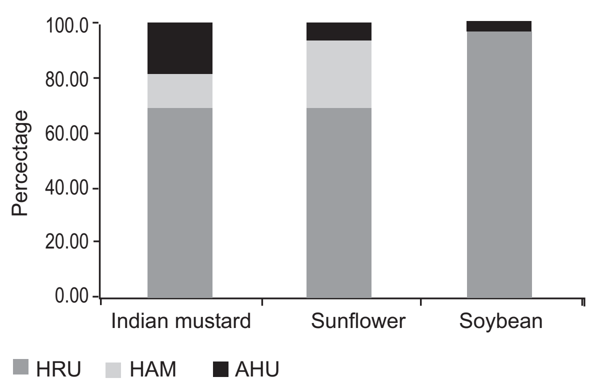

Fig 4. Spiders feeding guilds for the Indian mustard, sunflower and soybean crops in Faisalabad district. HAM: Hunting-Ambushers; AHU: Active-Hunters; HRU: Hunting-Runners.

Table 3. Richness, diversity and evenness values for spider fauna recorded from Indian mustard juncea, sunflower and Soybean

Crops	S	H´	E	S	H´	E	df	t-value	p-value
Brassica juncea/Sunflower	34	3.405	0.88	37	3.311	0.74	>120	2.39	0.017**
Brassica juncea/Soybean	34	3.405	0.88	42	3.403	0.71	>120	0.08	0.935ns
Sunflower/ Soybean	37	3.311	0.74	42	3.403	0.71	>120	-2.09	0.036**

These results coincide with the findings of Rimbing and Memah (2008). They found high abundance of Lycosidae, that constituted 34% to the collected predator species while studying the abundance of different predatory arthropods on soybean in North Minahasa. While Liljesthrom *et al*. (2002) reported 84% Lycosidae during study on the agricultural crops. Agro-ecosystems are the largely disturbed sites by anthropogenic intervention that highly favour roving hunters over the web-builder. Further, the absence of regular supporting structure for the web-builder in an agro-ecosystem might be responsible for their rarity (Muma and Muma, 1949).

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