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Species richness and spatial diversity of spiders among fodder crops

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Abstract

The present study was designed to record species richness and spatial diversity of spiders among fodder crops at Okara district. Sampling was made from berseem and mustard crops through pitfall traps. Equal number of traps were placed in three rows e.g. along the boundary, middle of the field and centre of the field. Each trap was filled with mixture solution of alcohol and glycerin (70:30%) along with few drops of kerosene oil. After 5 days interval sample traps collected and spider specimens were washed with distilled water and permanently stored in labeled glass vials. Each spider specimen was identified according to the taxonomic material and internet source. Maximum spatial distribution of spider species was documented in middle transect than boundary and centre of the fodder crops. Population variations were recorded during the months of February, March and April in 2015, due to rise of temperature, decrease of humidity and availability of prey. It was concluded that spider species have direct correlation with temperature and suitable local conditions. Moreover, spiders are cost effective, functionally significant and play a key role in insect pest management.

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Introduction

Fodder crops are particularly refer to food for animals or live-stock. They comprise of straw, hay, pelleted feed, silage, oils, legumes and sprouted grains. Currently in Pakistan, various fodder crops are cultivated over 15 million hectares with 52 million ton annual fodder production (Anonymous, 2013). However, suitable rainfall and temperature range can enhance the present outcomes (Hussain *et al.*, 2010). Because, in many parts of Pakistan, there is abrupt shortage of fodder for live-stock, and also the available fodder is of poor quality. The farmers are facing a lot of problems to get maximum forage yield to meet the feed requirements. Improved fodder varieties along with control of damage by invading insect pest can overcome the situation. In this context, berseem provides valuable supplemental food to live-stock community e.g. nitrogen, energy, minerals and vitamins. Consequently, it increase the availability of nutrients for maintenance and ideal production status. (Douglas *et al.*, 2000).

To enhance the yield, control of insect pests is a major issue and use of spiders to control these insect pests is of profound importance. Spiders have globally more than 40,000 identified species (Platnick, 2012). They have remarkable abundance and are highly diversified terrestrial predator especially in agro-ecosystems (Wise, 1993). They can play a pivotal role in keeping insect and pest populations in check and balance and they are also serve as food for birds, snakes, fish and other animals. They eat insects and bugs which destroy different crops and consequently safe guard the agro-ecosystems. By habitat management. We can conserve the diversity of natural enemies (including spiders) of arthropod pest (Douglas *et al.*, 2000).

Spider's abundance and diversity vary in different agro-ecosystems and they have temporo-spatial distribution in all agricultural lands to effectively destruct the insect pest population (Seyfulina and Tshernyshev, 2001; Seyfulina, 2003). Their breeding success is directly related to amount of precipitation which act as potential factors to affect the abundance and species richness (Thomas *et al.*, 2014). Spider population have some correlation with temperature, humidity and suitable local conditions. Moreover, spiders are cost effective, functionally significant and play a key role in insect pest management (Rana *et al.* 2016). They are most important arthropods for economic point of view playing role as biological control agent and their adaptation towards different habitats (Kazim *et al.*, 2014).

Keeping in view the importance of spider densities and role of fodder crops in live-stock sector, the present study was designed to record the species richness and spatial diversity of ground dwelling spiders among fodder crops at Okara district.

Materials and methods

Study area

The present study was designed to estimate the species richness and spatial diversity of ground dwelling spiders among fodder crops at Okara district. Because information about their distribution in any agro-ecosystem was pre-requisite to formulate any strategy to use them for bio-control purposes. Presently, these informations were recorded from Okara district. Fodder crops were cultivated in one acre rectangular fields in village 36-/2L located at Okara district, Punjab, Pakistan. The sampling field was surrounded by wheat fields from two sides, where as on third side, it was surrounded by a Berseem and Mustard field.

Okara district

Okara district is situated in Punjab province at 30, 8081 (304829.160"N) latitude and 73, 4458 (732644.880"E) longitude. This district is bounded on the East by Kasur district, Sahiwal and Pakpattan districts on the West, Sheikhupura and Faisalabad districts on the North and Bahawalnagar district on the South. The Indian border also lies on the South-Eastern side of the district. Okara district has a total area of 4,377 square kilometres and comprises of three tehsils i.e. Okara, Depalpur and Renala Khurd.

Sampling design and techniques

The sampling was carried out from October, 2014 through April, 2015 to collect the ground dwelling spider fauna in berseem and mustard crops.Total thirty traps were set in the field for five successive days. The two successive traps were at equal distance from each other and the distance from outer boundary of the field was 5m. Pitfall traps were 12cm long glass jars with 6cm (diameter) wide mouths. Each trap contained 150 ml of 70% ethyl alcohol and a small amount of kerosene oil which served as preservative and killing agent.Ten pitfall traps were laid along each transect line i.e. boundary, middle and centre at an equal interval from each other.

Collection of data

For berseem and mustard crops, ideal field measuring 7200 sq. ft. were selected to observe the spatial distribution of ground dwelling spiders through pitfall trap method. However, trapping was made by three layers inside the field radius wise to observe the infestation along the entire field. Data was collected fortnightly and collected specimens were brought into the Pest Control Laboratory, Departmentof Zoology, Wildlife and Fisheries, University of Agriculture, Faisalabad. All the specimens were identified according to the reference material. The field of berseem was sampled after 5 days intervals right from the pre-harvest stage. More over, minimum and maximum temperature and humidity of area was also recorded.

Preservation

All traps were taken to Pest Control Laboratory, Department of Zoology, Wildlife and Fisheries, University of Agriculture, Faisalabad. Where the specimens were washed with xylene and preserved in 95% ethanol containing few drops of glycerin. Specimens were preserved separately in small glass vials indicating with trap number and the date of capture.

Identification

The collected samples were identified with the aid of naked eye, magnifying glass and under the microscope. All the specimens were identified up to species level according to the taxonomic and reference material (Tikader and Malhotra (1982), Tikader and Biswas (1981), Barrion and Litsinger (1995), Zhu *et al.* (2003), Platnick (2012), other relevant literature and internet source.

Statistical analysis

Thereafter, all the identified specimens were arranged in table form according to their morphological characters e.g. family, genus and species. To determine the various aspects of diversity, Shannon Diversity Index was used (Magurran, 1988). Analysis of Variance was made to compare the population means between three transects, i.e. Boundary, middle and centre of berseem and mustard crops. The richness, diversity and evenness indices were computed by using the Programme SPDIVERS.BAS.

Results

Spatial diversity of spider species in berseem c

Data presented in Table 1, is pertaining the month wise comparison of diversity indices among species at three trasects i.e. boundary, middle and centre of the berseem crop. During the month of November maximum diversity (H') at boundary recorded was 2.6701, eveness 0.9860 and dominance was 0.014 when compared with middle, maximum diversity was 2.5650, eveness 1.0000, and dominance 0.000. and at centre, maximum diversity 1.3863, eveness 1.0000 and dominance 0.0000.During the month of December maximum diversity (H) at boundary recorded was 1.9459, eveness 1.0000 and dominance was 0.0000 when compared with middle, maximum diversity was 1.6094, eveness 1.0000, and dominance 0.000. and at centre, maximum diversity 0.6932, eveness 1.0000 and dominance 0.0000.During the month of January maximum diversity (H) at boundary recorded was 1.0986, eveness 1.0000 and dominance was 0.0000 when compared with middle, maximum diversity was 1.6094, eveness 1.0000, and dominance 0.000. During the month of February maximum diversity (H") at boundary recorded was

3.0625, eveness 0.9908 and dominance was 0.0092 when compared with middle, maximum diversity was 3.4463, eveness 0.9856, and dominance 0.0144 and at centre, maximum diversity 1.3863, eveness 1.0000 and dominance 0.0000.

During the month of March maximum diversity (H) at boundary recorded was 3.5794, eveness 0.9840 and dominance was 0.016 when compared with middle, maximum diversity was 3.8377, eveness 0.9810, and dominance 0.019 and at centre, maximum diversity 2.6391, eveness 1.0000 and dominance 0.0000.During the month of April, maximum diversity (H") at boundary recorded was 3.7836, eveness 0.9672 and dominance was 0.0328 when compared with middle, maximum diversity was 3.8037, eveness 0.9492, and dominance 0.0508 and at centre, maximum diversity 3.0412, eveness 0.9569 and dominance 0.0431. Overall maximum diversity (H") recorded in the month of April at the middle was 3.8037, eveness 0.9492 and dominance was 0.0508 respectively, when compared with boundary and centre of the berseem crop.

Table 1. Number of species(S), total number of samples (N), Shannon diversity index, Lambda value and Evenness for transect-wise monthly record of berseem crop for different species.

Site	Month	S	N	H' Shannon	Lambda	Evenness	Dominance
Boundary	November	15	17	2.6701	0.0727	0.9860	0.014
	December	7	7	1.9459	0.1429	1.0000	0.000
	January	3	3	1.0986	0.3333	1.0000	0.000
	February	22	24	3.0625	0.0486	0.9908	0.0092
	March	38	45	3.5794	0.0301	0.9840	0.016
	April	50	73	3.7836	0.0265	0.9672	0.0328
Middle	November	13	13	2.5650	0.0769	1.0000	0.000
	December	5	5	1.6094	0.2000	1.0000	0.000
	January	5	5	1.6094	0.2000	1.0000	0.000
	February	33	40	3.4463	0.0338	0.9856	0.0144
	March	50	66	3.8377	0.0234	0.9810	0.019
	April	55	103	3.8037	0.0278	0.9492	0.0508
Center	November	4	4	1.3863	0.2500	1.0000	0.000
	December	2	2	0.6932	0.5000	1.0000	0.000
	January	0	0	0.000	0.000	0.000	0.000
	February	4	4	1.3863	0.2500	1.0000	0.000
	March	14	14	2.6391	0.0714	1.0000	0.000
	April	24	39	3.0412	0.0546	0.9569	0.0431

Where S = Number of species

N = Total number of species (sum).

Spatial diversity of spider species in mustard crop

Data presented in Table: 2, is pertaining the month wise comparison of diversity indices among species at three trasects i.e. boundary, middle and centre of the berseem crop. During the month of November maximum diversity (H) at boundary recorded was 2.9125, eveness 0.9892, and dominance was 0.0108. When compared with middle, maximum diversity was 2.5650, eveness 1.0000, and dominance 0.000 and at centre, no diversity was found. During the month of December maximum diversity (H") at boundary recorded was 1.6094, eveness 1.0000 and dominance was 0.0000 when compared with middle, maximum diversity was 1.6094, eveness 1.0000, and dominance 0.000. and at centre, no diversity was found.During the month of January maximum diversity (H") at boundary recorded was 1.0986, eveness 1.0000 and dominance was 0.0000 when compared with middle, maximum diversity was 0.6932, eveness 1.0000, and dominance 0.000 and at centre, no diversity was found . During the month of February maximum diversity (H") at boundary recorded was 3.3285, eveness 0.9885 and dominance was 0.0115 when compared with middle, maximum diversity was

3.4858, eveness 0.9804, and dominance 0.0196 and at centre, maximum diversity 2.3979, eveness 1.0000 and dominance 0.0000.During the month of March maximum diversity (H") at boundary recorded was 3.5029, eveness 0.9775 and dominance was 0.0225 when compared with middle, maximum diversity was 3.5367, eveness 0.9654, and dominance 0.0346 and at centre, maximum diversity 2.527, eveness 0.9796 and dominance 0.0204.During the month of April, maximum diversity (H") at boundary recorded was 3.5158, eveness 0.9737 and dominance was 0.0263 when compared with middle, maximum diversity was 3.5653, eveness 0.9732, and dominance 0.0268 and at centre, maximum diversity 2.9020, eveness 0.9856 and dominance 0.0144.Overall maximum diversity (H") recorded in the month of April at the middle was 3.5653, eveness 0.9732 and dominance was 0.0268 respectively, when compared with boundary and centre of the mustard crop.

Table 2. Number of species (S), total number of samples (N), Shannon diversity index, Lambda value and Evenness for transect-wise monthly data of Mustard crop for different species.

Site	Month	S	N	H' Shannon	Lambda	Evenness	Dominance
Boundary	November	19	21	2.9125	0.0567	0.9892	0.0108
	December	5	5	1.6094	0.2000	1.0000	0.000
	January	3	3	1.0986	0.3333	1.0000	0.000
	February	29	33	3.3285	0.0377	0.9885	0.0115
	March	36	50	3.5029	0.0328	0.9775	0.0225
	April	37	53	3.5158	0.0331	0.9737	0.0263
Middle	November	13	13	2.5650	0.0769	1.0000	0.000
	December	5	5	1.6094	0.2000	1.0000	0.000
	January	2	2	0.6932	0.5000	1.0000	0.000
	February	35	46	3.4858	0.0331	0.9804	0.0196
	March	39	63	3.5367	0.0335	0.9654	0.0346
	April	39	75	3.5653	0.0311	0.9732	0.0268
Center	November	1	1	0.000	0.000	0.000	0.000
	December	1	1	0.000	0.000	0.000	0.000
	January	1	1	0.000	0.000	0.000	0.000
	February	11	11	2.3979	0.0909	1.0000	0.000
	March	13	16	2.5127	0.0859	0.9796	0.0204
	April	19	22	2.9020	0.0579	0.9856	0.0144

Where S = Number of species

N = Total number of species (sum).

Comparison of diversity indices among berseem crop

Data presented in Table 3, is pertaining the month wise comparison of diversity indices among species from Berseem crop. Overall species wise maximum diversity (H") recorded in Berseem crop during the month of November was 3.3705, evenness 0.9910 and dominance 0.009 respectively. During the month of December maximum diversity 2.6391, evenness 1.0000 and dominance 0.0000 was recorded. During the month of January maximum diversity 1.9062, evenness 0.9796 and dominance 0.0204 was recorded. During the month of February maximum diversity 3.6433, evenness 0.9748 and dominance 0.0252 was recorded. During the month of March maximum diversity 3.8835, evenness 0.9648 and dominance 0.0252 was recorded.

During the month of April maximum diversity 3.8478, evenness 0.9476 and dominance 0.0524 was recorded. Maximum diversity 3.8835 was recorded during the month of March while evenness 1.0000, and dominance 0.0524 were recoded during the month of December and April respectively.

Table 3. Number of species(S), total number of samples (N), Shannon diversity index, Lambda value, Evenness and dominance for transect-wise monthly record of berseem crop for different species.

Month	S	N	H Shannon	Lambda	Evenness	Dominance
November	30	34	3.3633	0.0363	0.9889	0.011
December	14	14	2.6391	0.0714	1.000	0.000
January	7	8	1.9062	0.1563	0.9796	0.0204
February	42	68	3.6433	0.0286	0.9748	0.0252
March	56	125	3.8835	0.0234	0.9648	0.0352
April	58	215	3.8478	0.0263	0.9476	0.0524

Comparison of diversity indices among mustard crop

Data presented in Table: 4, is pertaining the month wise comparison of diversity indices among species from mustard crop. Overall species wise maximum diversity (H") recorded in mustard crop during the month of November was 3.2631, evenness 0.9792 and dominance 0.0207 respectively. During the month of December maximum diversity 2.3979, evenness 1.0000 and dominance 0.0000 was recorded. During the month of January maximum diversity 1.7918, evenness 1.0000 and dominance 0.0000 was recorded. During the month of February maximum diversity 3.6101, evenness 0.9598 and dominance 0.0402 was recorded. During the month of March maximum diversity 3.6241, evenness 0.9577 and dominance 0.0423 was recorded. During the month of April maximum diversity 3.6485, evenness 0.9641 and dominance 0.0359 was recorded.

Table 4. Number of species(S), total number of samples (N), Shannon diversity index, Lambda value, Evenness and dominance for transect-wise monthly record of mustard crop for different species.

Month	S	N	H Shannon	Lambda	Evenness	Dominance
November	28	35	3.2631	0.0416	0.9793	0.0207
December	11	11	2.3979	0.0909	1.000	0.000
January	6	6	1.7918	0.1667	1.000	0.000
February	43	90	3.6101	0.0311	0.9598	0.0402
March	44	129	3.6241	0.0314	0.9577	0.0423
April	44	150	3.6485	0.0294	0.9641	0.0359

Maximum diversity 3.6485, and evenness 0.9641 was recorded during the month of April while dominance 0.0423 were recoded during the month of March respectively.

It is obvious from the t-test analysis that population dynamics was with least differences whereas genera wise non-significant ($p > 0.01$) and species wise highly significant ($p < 0.01$) results were also owing to least difference between population sizes in both the fodder crops. However, in berseem crop, population sample increase slightly due to increase in resistant strains, nature of crop rotation and surrounding. Because, when samples were taken, there were wheat fields all around.

Effects of temperature and humidity

During present study, effects of temperature and humidity on relative abundance were much convincing. With the increase in temperature, increase in population and breeding success was recorded. While, with the increase in humidity reduction in breeding out put and population size was observed. Some species also showed preference towards micro-habitat while mojority showed generalist behavior. It was also estimated that start of breeding season, enhancment in growth and acceleration in maturity were proportional to

temperature and humidity. As temperature reached above 25°C, start in breeding occur and with decrease in temperature up to the same situation and increase in humidity, it comes to the end. Maximum relative abundance was recorded during start of March and April. However, ratio of relative abundance was equal in start of February and the end of April.

Table 6. Monthly average temperature (maximum and minimum), percentage of humidity recorded from Okara district.

Month	Average maximum temperature °C	Average minimum temperature °C	Average relative humidity
Novermber	27.2	8.7	85%
December	18.9	4.1	90.50%
January	16.6	4.1	93.00%
February	22.3	6.7	78.50%
March	25.1	10	77.00%
April	32.5	16.6	78.00%

During December and January lowest relative abundance of spider fauna was recorded due to decrease in temperature and humidity (Table 6). Relative abundance of common species was accelerating among both the fodder crops at Okara district whereas, numeral frequency of rare species was exceeding at some extent, but they make bulk up to 03% only.

As far as frequency of common families and species is concerned, they make immensity up to 75% randomly of total catch among both fodder crops. Generally, frequency of relative abundance was recorded highest from February to August, while, lowest was recorded in December and January due to fluctuation in temperature and humidity (Fig.1).

Similarity Index

During entire collection, population and specices abundance was dominated by berseem crop, in all aspects viz. number of families, genera and species. But, species wise similarity was observed in the data from berseem and mustard crops. However, decline in population was recorded during the month of December and Januaryt due to decrease in temperature and increase in humidity (Table 6).

Table 7. Similarity index between berseem and mustard crops at Okara district.

Type	Similarity index
Berseem---mustard species	0.274
Berseem---mustard genera	0.174

To underline the detailed abundance of data, similarity index was calculated. Similarity index performed well with the change in species abundance. Indices explored the effects of pesticides on sample size and on species diversity recorded from two fodder crops, with subject to temperature, humidity and level of pesticide used. Similarity index recorded genera wise was 0.174 as compared to species wise 0.274 from berseem and mustard crops. In contrast, species wise ratio of similarity indices was recorded high between berseem and mustard (Table 7).

However, similarity indix was nearly same between families. Results of similarity indices confirmed our expections. Indices performed well accordingly as sample size between thefodders crops were with moderate differences during the entire study period. Consequently, these indices behaved moderately species wise (0.274). Where as, genera wise (0.174) recorded between berseem and mustard crops.

Table 8. Analysis of variance table for transect-wise abundance of different species for different crops.

Source of variation	Degrees of freedom	Sum of squares	Mean squares	F-value
Months	5	16291.6	3258.32	21.15**
Crop	1	51.4	51.36	0.33NS
Transect	2	4483.5	2241.75	14.55**
Crop x Transect	2	25.4	12.69	0.08NS
Error	25	3850.9	154.04	
Total	35	24702.8		

NS = Non-significant (P>0.05); * = Significant (P<0.05); ** = Highly significant (P<0.01).

Month wise mean ± SE.

Month	Mean ± SE	
November-14	11.50±3.12	D
December-14	4.17±0.91	D
January-15	2.33±0.71	D
February-15	26.33±6.73	C
March-15	42.33±9.22	B
April-15	60.83±11.79	A

Means sharing similar letters are statistically non-significant (P>0.05).

Crops x Transect interaction mean ± SE.

Transect	Fodder Crop				Mean ± SE	
	Berseem		Mustard			
Boundary	28.17	± 10.83	27.50	± 8.82	27.83	± 6.66 A
Middle	38.67	± 16.14	34.00	± 12.87	36.33	± 9.87 A
Center	10.50	± 6.03	8.67	± 3.71	9.58	± 3.39B
Mean	25.78	± 6.97A	23.39	± 5.66A		

Means sharing similar letter in a row or in a column are statistically non-significant (P>0.05).

Analysis of variance

Firstly, Analysis of Variance was made between two fodder crops to check theground dwelling spiders' fauna. Results of ANOVA between two fodder crops were highly significant (F = 21.15). Because, calculated F-ratio was higher than tabulated and it was depicting that population means were not equal. Data represented in Table 8, pertaining to Analysis of variance for transect-wise abundance of different speciesof spiders for different fodder crops.

The mean number of spider population inboth foddercrops i.e. berseem and mustard at district Okara were statistically similar. The mean number ofspider's population month wise and transect wise were statistically highly significant (P<0.01). The mean number of spider's population during the month of January (2.33±0.71), February (26.33±6.73), March (42.33±9.22) and April (60.83±11.79) were statistically significan (P<0.05), where as in November (11.50±3.12), December (4.17±0.91) and January (2.33±0.71) were statistically nonsignificant (P>0.05) in both fodder crops. Transect-wise mean number ofspider's population in boundary (27.83±6.66) and centre (9.58±3.39), and middle (36.33±9.87) and centre (9.58±3.39) were statistically significant (P<0.05), while in boundary (60.83±11.79) and middle (60.83±11.79)

werestatistically non significant (P>0.05) in both fodder crops. Overall mean number of spider's population in berseem (25.78±6.97) and mustard (23.39±5.66) crops were statistically non significant (P>0.05).

It is obvious from the indices calculations that species abundance decrease with the decrease in temperature and increase in humidity. With the decrease in species abundance, ratio of generalist predators (spiders) would decrease. Resultantly, ecological imbalance of prey verses predators develops which upset the all ecological pyramids and natural cycling. Sustainable prey and predator status is limiting for integrity of any natural system for long term functions.

Discussion

Ecological distribution

Due to global warming, temperature and humidity are alarming in Pakistan (Govt. of Pakistan, 2010) resulting imbalancement in ecological conditions (Schmidt *et al.*, 2005). According to Rittschof (2012); Herberstein and Fleisch (2003); Rana *et al.* (2016), temperature is limiting factor in the life history of spiders' community. For instance, in temperate region, decline in temperature result as end of the reproductive season (Herberstein and Fleisch, 2003). According to these researchers, spiders also alter their web-site with regard to temperature and during *in-situ* conditions; low temperature affects egg development and the female's ability to oviposit. Mushtaq *et al.* (2003 & 2005); Schmidt *et al.* (2008) reported that sustainable agricultural practices can enhance spider population as well as species diversity, relative abundance and richness. The coexistence of more species during February, March and April is due to increase in temperature, availability of excess insect prey and increased structural forms of fodder plants during these months (Rana *et al.* 2016). The findings of present study were according to views of these researches in Pakistan and other geographic regions of the world. These findings have also confirmed our expectation about impact of temperature and humidity.

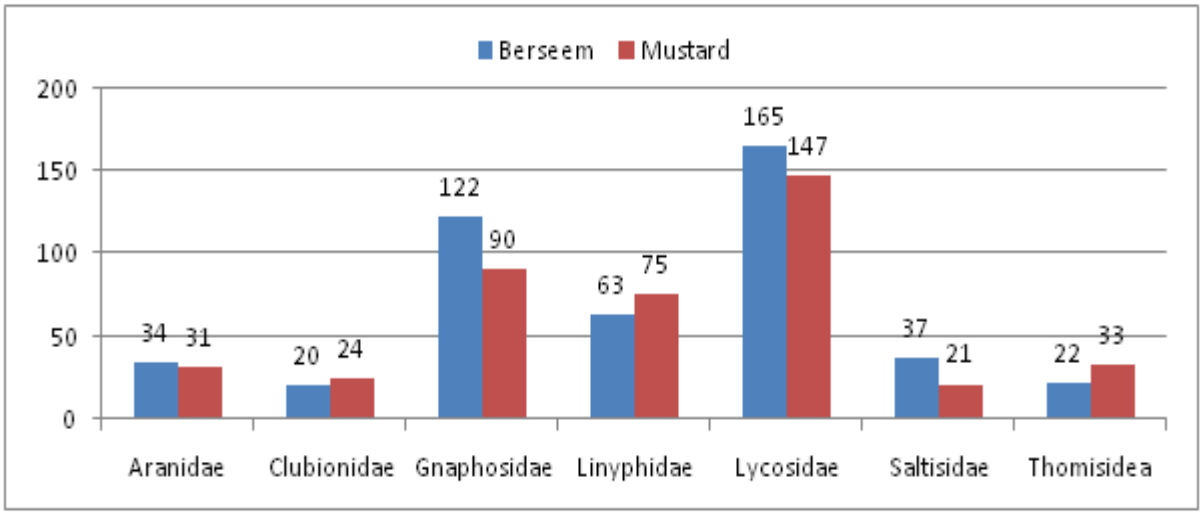

Fig. 1. Bar graph represent the family-wise abundance of spiders in berseem and mustard crop.

Seasonal variations

Evidences regarding sesaonal variations of spider population was underlined by considering the findings of previous researchers because field type, management pattern, agronomic operations, soil culture and floral structures significantly affect spider's population (Heidger and Nentwing, 1989; Thomas and Waage, 1996; Liljesthrom *et al.*, 2002; Ahmad *et al.*, 2005). It was also estimated that start of breeding season, enhancment in growth and acceleration in maturity were proportional to temperature and humidity (Rittschof, 2012; Rana *et*

al. 2016). As temperature reached above 25°C, start in breeding occur and with decrease in temperature up to the same situation and increase in humidity, it comes to the end. These findings are also in same context as already reported in Pakistan (Mushtaq *et al.*, 2003, 2005; Ghafoor, 2002; Ghaffar *et al.*, 2011; Rana *et al.*, 2016). Findings of present study were in-line with these researchers. It was noted that seasonal distribution trend was affected by temperature, humidity, migration, micro-habitat preferences as well as prey availability (Table 6).

Conclusion

However, it was concluded that spider species have direct correlation with temperature and suitable local conditions. Moreover, spiders are cost effective, functionally significant and play a key role in insect pest management. So, there is necessity of future research for the proper use of spider fauna as biological control agent in IPM programmes.

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