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Diversity and Population Dynamics of Spiders in Spring and *Kharif* Maize (*Zea mays*) Crops of Punjab

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Abstract: The present study investigated the occurrence of 15 spider species, belonging to families Tetragnathidae, Araneidae, Oxyopidae, Lycosidae, Salticidae, and Araneidae in spring and 20 spider species of families Oxyopidae, Lycosidae, Salticidae, Pisauridae, and Phylodromidae in *kharif* maize crop. Spiders of family Lycosidae (40.0-53.33%) and genus *Pardosa* (nine species) were the predominant of all. In spring maize, higher spider population was during May (3.57 individuals/plot) with *Pardosa amenata* (56.51 individuals/plot) predominating significantly as compared to other spider species. In *kharif* maize, a higher spider population was recorded during August (2.76 individuals/plot) after which the spider population starts declining. *Lycosa pseudoannulata* (44.5 individuals/plot) and *Pardosa milvinia* (40.88 individuals/plot) predominated significantly as compared to other spider species. Increase in the Shannon-Wiener index, species richness and decrease in species evenness and Simpson's index was recorded in *kharif* as compared to spring maize crop. The higher spider population (29.34%) was in spring maize crop during May as compared to that in August in the *Kharif* maize crop. The study concludes that maize is a good host for the survival of spiders.Hence, pest management strategies, especially the use of pesticides should be used with caution during these times.

Keywords: Diversity, *kharif* maize, Population dynamics, Spider, Spring maize

Spiders are dominant arthropod predators in all ecosystems providing different ecosystem services, acting as models to evaluate ecological and evolutionary hypotheses (Michalco et al., 2019, Lowe et al., 2020) andact as biological indicators by responding differently to natural and anthropogenic activities (Rajeevan et al., 2019). Spiders act as biocontrol agents due to their potential for competition, catching more than consumption, intraguild predation, and resistance against starvation and desiccation (Sumitha and SudhiKumar 2020). They act as sources of molecules that may be useful for biotechnology and the development of medicines (Matavel et al., 2016). Spider venom contains more than ten million bioactive peptides which leadto the development of drugs against a wide range of pathophysiological conditions for the betterment of mankind (Prakash et al., 2023).

Globally, 52,590 spider species have been described which belong to 4,376 genera and 134 families (World Spider Catalogue 2024). Indian spider diversity constitutes about 1,971 species belonging to 500 genera under 61 families and constitutes about 3.79% of the total world's spider diversity (Sen et al., 2024). Spiders have been distributed almost in every ecosystem except Antarctica and can survive in the most extreme environmental conditions. Their evolution has led to a change in their morphological and behavioral characteristics, which allows multiple species to coexist within an ecosystem leading to vertical spatial distribution, due to which a variety of species can inhabit different niches throughout the same habitat (Yadav et al., 2005). Some species of spiders build webs to trap and kill the prey, and some actively seek out or ambush their prey (Selifa and Ganesh 2020). Species found in temperate climates adapt to significant temperature fluctuations throughout the year (Bukhari et al., 2012). Species belonging to Philodromidae and Clubionidae families have adapted to sub-zero winter temperatures by reducing the supercooling point of their hemolymph through the production of specialized proteins and glycerol, whereas in hot climates spiders can also regulate their internal temperature (Raghul and Kumar 2021).

Agricultural ecosystemspossess high spider diversity as compared to the natural ecosystem and it regulates terrestrial arthropod populations in different crops (Mathew et al., 2014). Spiders consume a variety of insect pests in different agricultural crops, reduce pesticide load in the environment, play a valuable role in pest management without causing damage to crops (Raji et al., 2024) and thus help boosting the economy of farmers. Many surveys have been conducted in different terrestrial areas and agroecosystems to estimate spider diversity (Dave and Trivedi 2024). However, there is a gap regarding the diversity of spiders in crops which vary from place to place. The

present work intends to study the abundance and diversity of spiders from spring and *Kharif* maize crops in Punjab.

MATERIAL AND METHODS

Study area: The present study was carried out at maize crop fields of the Department of Plant Breeding & Genetics (Maize Section) and Department of Zoology, Punjab Agricultural University, Ludhiana on both *Kharif* and spring maize crops in2022. The selected experimental fields were prepared as per the Package and Practices for maize crops (Anonymous 2022) and were leveled and divided into plots according to the layout plan. The maize varieties selected were PMH-13 for *Kharif* and PMH-10 for spring crops, respectively, and sown in plots (each of size 8 x 3 m) with a planting distance of 20 x 60 cm (plant-plant and row-row). The spring maize crop was sown on February 17, 2022 and harvesting was completed on June 22, 2022. Similarly, the *Kharif* maize crop was sown on May 26, 2021 and its harvesting was done on September 27, 2021. Both *Kharif* and spring maize crops were raised using agronomic practices as recommended by the Package of Practices, Punjab Agricultural University, Ludhiana. No pesticides were sprayed in the selected plots.

Abundance and dynamics of spider population: Spiders were counted from the whole maize plant (leaves/stem) by visual searching method from randomly selected five blocks/plots covering all the geological sites as well as the center of the field at fortnight intervals. The size of each block was 1×1m and one plot (8×3 m) represented one replication, each plot having three replications. Spiders were counted on the plants and soil surface of both *kharif* and spring maize crops, respectively during morning hours (7.00-9.00am). Some samples of spiders were collected using hand-picking method for identification using suitable keys and confirmed by experts fromthe Zoological Survey of India, Calcutta. The collected spiders were transferred into glass vials having 70% alcohol.

Calculation of various indices

Relative abundance: The following formula was used to measure the percentage of individuals of a particular species:

$RA = ni/N \times 100$

where, RA= Relative abundance

n_i = Total number of individuals in a particular sample, N = Total population of all species

Biodiversity indices: To calculate biodiversity indices, the following formulae were used:

Simpson index: $D = \Sigma n_i(n_i-1) / N(N-1)$

where, D = Simpson index, n_i = Total number of individuals in a particular species, N = Total population of all species

Shannon-Wiener index:

$H = \sum[(pi)\times ln(pi)]$

pi = Proportion of total sample represented by species, where H' = Shannon-Wiener index, n_i = Total number of individuals in a particular sample, N = Total population of all species

Species evenness:

$$J' = \frac{H}{\ln(S)}$$

Where, J' = Species evenness, H= Shannon-Wiener index

Statistical analysis: Different indices like relative abundance, Shannon diversity index, species evenness, and species dominance were calculated.

RESULTS AND DISCUSSION

Diversity of spiders in *kharif* and spring maize crops: Results from fortnight surveys in spring maize crops revealed the occurrence of 15 different spider species belonging to five families namely Tetragnathidae, Araneidae, Oxyopidae, Lycosidae and Salticidae. The family Lycosidae accounted forhigher dominance (53.33%) by including eight spider species followed by Tetragnathidae, Oxyopidae and Salticidae (each having 13.33% dominance) whereas, family Areneidae accounted as of lowest dominance (6.66%) as compared to others (Table 1). In the family Lycosidae, spiders of genus *Pardosa* (nine species) predominate in both *kharif* and spring maize crops.

Similarly, in *Kharif* crop, 20 different spider species belonging to six families namely Araneidae, Oxyopidae, Lycosidae, Salticidae, Pisauridae and Phylodromidae were recorded. Among all those families, Lycosidae (40.0%) showed the highest dominance which included eight spider species followed by Areneidae and Oxyopidae (20.0%) each having four spider species whereas Pisauridae and Phylodromidae accounted as of lowest (5.0%) dominance (Table 1). The Shannon-Wiener index, species evenness, species richness, and Simpson's index for spider population were s 2.29, 0.84, 15, 0.12 and 2.411, 0.81, 20, 0.11 in spring and *Kharif* maize crops, respectively. There was a slight increase in the Shannon-Wiener index and species richness whereas a slight decrease in species evenness and Simpson's index was recorded.

Population dynamics of spiders in spring maize crop: In spring maize crop, all the spider species showed their first appearance during 1st fortnight of March whereas the appearance of spider species namely *Pardosa monticola, Oxyopes javanus, Oxyopes birmanica, Thyene imperalis, Leucage argyra* and *Telamonia dimidiate* was recorded during 2nd fortnight of March. The first appearance of *Trochosa terricola* was during 1st fortnight of April, whereas

Metepeiro labyrinthea and *Tetragnatha versicolor* were recorded during 2nd fortnight of April. Among all the recorded spider species only *M. labyrinthea* was not recorded one month before harvesting of spring maize crop. The increasing trend of spider population was recorded from March to June, however, a higher spider population was during 1st fortnight of May (3.7 individuals/plot) after which the spider population started declining. During June, due to the harvesting stage of the maize crop, the lowest spider population was recorded (2.02 individuals/plot). During the overall crop season of spring maize crop, *Pardosa amenata* (56.51 individuals/plot) predominated significantly followed by *Lycosa pseudoannulata* (42.57 individuals/plot) and *Pardosa pseudoannulata* (28.38 individuals/plot) as compared to other spider species.

Population dynamics of spiders in *kharif* maize crop: Mostly, all the spider species showed their first appearance during 2nd fortnight of June whereas the appearance of species *O. birmanica, Neoscona mukerjei,* and *Neoscona nautical* was during 1st fortnight of July. However, the first appearance of *T. imperalis* and *Gea theridiodes* was recorded during the 2nd fortnight of July. Also, among all spider species only *T. imperalis* was not recorded one month before the harvesting of *kharif* maize crop. The increasing trend of spider population was from June to July, however, a higher spider population was during 1st fortnight of August (2.92 individuals/plot) after which the spider population started declining. During September, due tothe harvesting stageof maize crop and change in environmental conditions, lowest spider population was recorded (1.48 individuals/plot). During the overall crop season of *kharif* maize crop, *L. pseudoannulata* (44.5 individuals/plot) and *Pardosa milvinia* (40.88 individuals/plot) predominated significantly followed by *P. pseudoannulata, Pirata piraticus, P. amenata* and *Pardosa agricola* (19.44-21.85 individuals/plot) as compared to other spider species.

Overall29.34% higher spider population was in the spring maize crop during May as compared to August of the *kharif* maize crop due to congenial environmental conditions. *P. amenata* was the predominant species in the spring maize crop but its population declined by 2.77 times in the *kharif* maize crop. Similarly, an increase in *P. milvinia* (2.04 times),*L. pseudoannulata* (1.04 times) and *P. pseudoannulata* population (1.05 times) was in the *kharif* maize crop as compared to the spring maize crop. Interestingly, among all spider species, eight species namely *Pardosa pravitaga, Pardosa uintana, Pardosa monticola, Leucauge argyra, Telamonia dimidiate, Metepeira labyrinthea, T. terricola, T. versicolor* were from spring maize but not from *kharif* maize crop. These species may have shifted to surrounding rice crop sown during June. Similarly, 14 spider species namely *Pirata piraticus, P.agricola,*

Table 1. Dominance of spider species recorded in spring maize crop

Family	Scientific name	% Dominance (Family)
Tetragnathidae	*Leucauge argyra*	13.33
Tetragnathidae	*Tetragnatha versicolor*	
Araneidae	*Metepeira labyrinthea*	6.66
Oxyopidae	*Oxyopes birmanicus*	13.33
Oxyopidae	*Oxyopes javanus*	
Lycosidae	*Pardosa amenata*	53.33
Lycosidae	*Pardosa milvinia*	
Lycosidae	*Pardosa monticola*	
Lycosidae	*Pardosa pravitaga*	
Lycosidae	*Pardosa pseudoannulata*	
Lycosidae	*Pardosa uintana*	
Lycosidae	*Lycosa pseudoannulata*	
Lycosidae	*Trochosa terricola*	
Salticidae	*Telamonia dimidiate*	13.33
Salticidae	*Thyene imperalis*	

Table 2. Dominance of spider species recorded in *kharif* maize crop

Family	Scientific name	% Dominance (Family)
Araneidae	*Gea theridiodes*	20
Araneidae	*Neoscona mukerjei*	
Araneidae	*Neoscona nautica*	
Araneidae	*Neoscona theisi*	
Oxyopidae	*Oxyopes birmanicus*	20
Oxyopidae	*Oxyopes heterophthalamus*	
Oxyopidae	*Oxyopes javanus*	
Oxyopidae	*Peucetia viridians*	
Lycosidae	*Pardosa Agricola*	40
Lycosidae	*Pardosa amenata*	
Lycosidae	*Pardosa milvinia*	
Lycosidae	*Pardosa Modica*	
Lycosidae	*Pardosa pseudoannulata*	
Lycosidae	*Pardosa pullata*	
Lycosidae	*Lycosa pseudoannulata*	
Lycosidae	*Pirata piraticus*	
Salticidae	*Patu digua*	10
Salticidae	*Thyene imperalis*	
Phylodromidae	*Philodromous possiblepratariae*	5
Pisauridae	*Dolomedes tenebrosus*	5

Table 3. Mean number of spiders recorded in spring maize crop

Scientific name	March		April		May		June		Total population (mean)
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	
Pardosa amenata	0.93	1.53	6.2	8.2	10.06	13	9.66	6.93	56.51[g]
Lycosa pseudoannulata	0.26	1.46	3.4	6.33	8.13	10.4	8.13	4.46	42.57[f]
Pardosa pseudoannulata	0.2	0.93	2.33	3.4	6.2	5.13	6.06	4.13	28.38[e]
Pardosa milvinia	0.13	1.4	1.8	3.3	5.8	4.53	2.2	0.8	19.96[d]
Pardosa uintana	0.06	1.2	1.86	2.73	3.33	6	3.06	1	19.24[d]
Pardosa prativaga	0.2	1.06	2.86	5.26	7.13	1.6	0.73	0.26	19.1[d]
Pardosa monticola	0	0.6	1.4	3.53	3.4	3.4	2.86	0.93	16.12[c]
Oxyopes javanus	0	0.66	1.8	3.66	4.2	3	1.2	0.8	15.32[c]
Oxyopes birmanica	0	0.33	2.46	1.6	1.8	2.53	3.73	1.73	14.18[c]
Thyene imperalis	0	0.46	1.13	1.6	1.86	0.53	0.66	0.2	6.44[b]
Leucage argyra	0	0.06	1.06	2.06	0.66	0.33	0.4	0.06	4.63[a]
Telamonia dimidiate	0	0.13	0.33	1.26	1.33	0.4	0.06	0.06	3.57[a]
Metepeiro labyrinthea	0	0	0	1.13	0.53	0.33	0	0	1.99[a]
Trochosa terricola	0	0	0.13	0.33	0.4	0.46	0.26	0.06	1.64[a]
Tetragnatha versicolor	0	0	0	0.2	0.73	0.2	0.26	0.06	1.45[a]
Total	0.12	0.65	1.78	2.97	3.70	3.45	2.62	1.43	16.74
Species richness					15				
Species evenness					0.84				
Shannon diversity index					2.29				
Simpson index					0.125				

Pardosa modica, Pardosa pullata, Patu digua, Dolomedes tenebrosus, Neoscona theisi, Oxyopes heterophthalamus, Philodromous possiblepratariae, Thyene imperalis, N. mukerjei, Neoscona nautica, Peucetia viridians, and *Gea theridiodes* were only from *kharif* crop.

Siliwal et al. (2003) observed the diversity of spiders in the temperate maize ecosystem of Kashmir and recorded 13 families, 37 species, and 28 genera. Most spiders belonged to families Lycosidae, Theridiidae, Tetragnathidae, and Salticidae. Ekka et al. (2015) recorded 118 species of spiders in the maize crop of district Raigarh, Chhattisgarh which belonged to 52 genera under 17 families out of which seven families were dominant such as Araneidae (26 species), Oxyopidae (10 species), Gnaphosidae (18 species), Thomisidae (22 species), and Lycosidae (14 species).Investigations done by Saranya et al. (2018) on the diversity of spiders in the maize ecosystem throughout the crop growth (seedling to maturity stage) in Tamil Nadu Agricultural University recorded 2,821 spiders belonging to 16 species, 10 genera and 6 families. The most abundant families recorded were Lycosidae (1671 individuals) followed by Salticidae (459 individuals) and Oxyopidae (352 individuals). The dominant species of spiders in the maize ecosystem included *Lycosa barnesi, L. pseudoannulata, Pardosa birmanica, Salticus* sp. and *Hippasa lycosina*.Tiwari and Singh (2021) recorded 29 species of spiders under 11 genera from 18 states and 3 union territories out of which 12 species were endemic. Kacar (2015) observed 212 spider species from maize cropsin Turkey of 21 genera and 18 families with Philodromidae, Salticidae, and Thomisidae as predominant and *Cyclosa algerica* as first record in spider fauna from maize crop. In Punjab, surveys of 21 fruit crops revealed the presence of 43 spider species, belonging to 23 genera and 13 families with Salticidae, Araneidae and Oxyopidae exhibiting high diversity with Araneidae (35%) as predominant (Singh et al., 2020).

CONCLUSION

Spring and kharif maize crops have abundant spider diversity especially of family Lycosidae and genus *Pardosa* during May and August months. Hence, pest management strategies, especially the use of pesticides should be used with caution during these times.

Table 4. Mean number of spiders recorded in *kharif* maize crop

Scientific name	March		April		May		June		Total population (mean)
	1st	2nd	1st	2nd	1st	2nd	1st	2nd	
Lycosa pseudoannulata	0	1.46	4.13	7.06	8.53	10.06	8.46	4.8	44.5[e]
Pardosa milvinia	0	1.26	3.4	6.66	7.4	9.5	7.86	4.80	40.88[e]
Pardosa pseudoannulata	0	1.06	2.73	3.6	6.33	5.53	6.2	4.4	29.85[d]
Pirata piraticus	0	1.06	1.93	2.9	4.8	5.93	3.2	1.2	21.05[d]
Pardosa amenata	0	1.46	1.86	3.33	5.8	4.75	2.33	0.86	20.39[d]
Pardosa agricola	0	1.2	3	5.26	7.26	1.66	0.8	0.26	19.44[d]
Pardosa modica	0	0.73	1.46	3.73	3.5	3.46	2.33	1.06	17.27[c]
Pardosa pullata	0	0.86	1.86	3.66	4.33	3.13	1.2	1.06	16.1[c]
Patu digua	0	0.33	2	1.53	1.93	2.73	3.86	1.86	14.24[c]
Dolomedes tenebrosus	0	0.46	1.06	1.8	1.86	1.26	0.73	0.26	7.43[b]
Neoscona thewasi	0	0.33	1	0.93	1.06	0.86	0.13	0.06	5.37[b]
Oxyopes birmanica	0	0	1.13	2.2	0.73	0.4	0.33	0.13	4.92[a]
Oxyopes javanus	0	0.13	0.73	1.33	1.2	1	0.26	0	4.65[a]
Oxyopes heteropthalamus	0	0.2	0.6	0.73	0.33	0.2	0.13	0.13	2.32[a]
Philodromous possiblepratariae	0	0.06	0.33	0.6	0.73	0.26	0.26	0.06	2.3[a]
Thyene imperalis	0	0	0	1.13	0.66	0.4	0	0	2.19[a]
Neoscona mukerjei	0	0	0.2	0.26	0.53	0.46	0.26	0.06	1.77[a]
Peucitia viridans	0	0.2	0.26	0.46	0.46	0.13	0.06	0	1.57[a]
Gea theridiodes	0	0	0	0.26	0.6	0.13	0.06	0.06	1.1[a]
Neoscona nautica	0	0	0.06	0.26	0.46	0.2	0.06	0.06	1.1[a]
Total	0	0.54	1.38	2.38	2.92	2.60	1.92	1.05	12.92
Species richness	20								
Species evenness	0.81								
Shannon diversity index	2.411								
Simpson index	0.114								

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