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Original article

Species composition, seasonal abundance and population dynamics of predatory spiders from cotton field plots of irrigated and semi-arid regions of Punjab, Pakistan

Amir Nadeem [a], Hafiz Muhammad Tahir [a], Azhar Abbas Khan [b,*], Naheed Bano [c], Zeshan Hassan [b], Arif Muhammad Khan [d]

[a] *Department of Zoology, Government College University, Lahore, Pakistan*
[b] *College of Agriculture, University of Layyah, Layyah, Pakistan*
[c] *Department of Zoology, Wildlife and Fisheries, MNS-University of Agriculture, Multan, Pakistan*
[d] *Department of Biotechnology, University of Sargodha, Sargodha, Pakistan*

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ABSTRACT

The purpose of the current study was to document the variety of predatory spider species present in the cotton fields of two major cotton-producing districts in Punjab, Pakistan, as well as the population dynamics of those spiders. The research was carried out between May and October 2018 and 2019. Manual picking, visual counting, pitfall traps, and sweep netting were the procedures used to collect samples on a biweekly basis. A total of 10,684 spiders comprising 39 species, 28 genera, and 12 families were documented. Araneidae and Lycosidae families contributed a major share to the overall catch of spiders, accounting for 58.55 percent of the total. The Araneidae family's *Neoscona theisi*) was the most dominating species, accounting for 12.80% of the total catch and being the dominant species. The estimated spider species diversity was 95%. Their densities were changed over time in the study, but they were highest in the second half of September and the first half of October of both years. The cluster analysis distinguished the two districts and the sites chosen. There was a relationship between humidity and rainfall and the active density of spiders; however, this association was not statistically significant. It is possible to increase the population of spiders in an area by reducing the number of activities detrimental to spiders and other useful arachnids. Spiders are considered effective agents of biological control throughout the world. The findings of the current study will help in the formulation of pest management techniques that can be implemented in cotton growing regions all over the world.

1. Introduction

Cotton is Pakistan's most important cash crop, and its textile industry relies on it as a primary raw material source. It helps to earn foreign exchange for the country and provides livelihood to its growers. Pakistan harvested 10.671 million bales in 2016–2017 and 11.935 million bales in 2017–2018 (Government of Pakistan, 2017, 2018). However, during the next three cropping seasons, Pakistan's annual cotton production fell by 17.5% (with an annual yield of 9.861 million bales), 7.2% (with an annual yield of 9.148 million bales), and 22.8% (with an annual yield of 7.064 million bales), respectively (Government of Pakistan, 2019, 2020, 2021). After three consecutive years of low cotton yield, the last season (i.e., 2021–2022) yields 8.329 million bales and represents a 17.9% increase over the previous year's yield (Government of Pakistan, 2022). Cotton crop is also a source of edible oil production (Abid et al., 2011; Shuli et al., 2018). Among cotton-producing nations of the world, Pakistan stands in the fourth position (Hanif and Jafri, 2008; Ashraf et al., 2018).

Cotton crops are susceptible to attacks from many insect pests at several phenological stages including vegetative, flowering and boll formation stages (Nadeem et al., 2022, 2023; Sahito et al.,

* Corresponding author at: College of Agriculture, University of Layyah, Layyah, Pakistan.

E-mail addresses: amir.nadeem@gcu.edu.pk (A. Nadeem), dr.hafiztahir@gcu.edu.pk (H. Muhammad Tahir), azharkhan@ul.edu.pk (A. Abbas Khan), naheed.bano@mnsuam.edu.pk (N. Bano), zeshan.hassan@ul.edu.pk (Z. Hassan), arif.khan@uos.edu.pk (A. Muhammad Khan).

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2017). These pests are responsible for 5–10% production losses, but under favorable conditions, they are capable of causing 40–50% damage to the overall crop yield (Naqvi, 1976). Although chemical insecticides are a quick solution to these pest problems, their intensive usage is considered of prime importance for bringing the quick decline to different insect populations, including natural predators (Brühl and Zaller, 2019; Sánchez-Bayo and Wyckhuys, 2019). Several reasons for this decline include pesticide applications, non-availability of adult food, and lack of other hosts (Montgomery et al., 2020; Powell et al., 1986). However, the injudicious use of chemical-based pesticides in different crop production agroecosystems is a threat to the successful implementation of biological control in agricultural fields.

Natural arthropod predators such as spiders, coccinellids, green lacewings, syrphid flies, etc., provide their services as biological control of insect pests in agroecosystems (Losey and Vaughan, 2006). As they restrict the growth of insect pests, their higher diversities in the fields ensure better pest suppression. They might attack pests differently, i.e., each species attack at different life stages of these pests and exert regulatory pressure on pests (Snyder, 2019). Even if predators cannot keep pest populations below the economic injury level, they can slow down the reproductive rate of pests (Michalko et al., 2019). Along with other arthropod predators, spiders are the most important generalist predators and consume a wide range of insect pest species (Michalko et al., 2019). They are voracious predators at the soil–plant interface in cotton crops (Rendon et al., 2019), and female spiders of family Linyphiidae were reportedly consuming more pest of their choice (mostly aphids) than males (Harwood et al., 2004).

Although some local researchers had conducted studies on different predators of the cotton fields of Pakistan, their main focus was on the predators like spiders, syrphid fly, coccinellids, and green lacewings (Mohyuddin et al., 1989; Dhaka and Pareek, 2007; Amin et al., 2008; Ashfaq et al., 2011; Ramzan et al., 2019). The other predators were mostly just named or briefly described. Studies related to seasonal abundance, percentage composition, inventory completeness, population dynamics, the association of predators with crop phenology and the functional role of predators in cotton fields of Pakistan have not been explored. By keeping these facts in mind, the objective of the present study was to report the diversity of spiders and other arthropod predators. These were collected from cotton fields in the districts of Vehari (irrigated region) and Layyah (semi-arid region) in the province of Punjab, Pakistan and to record their seasonal abundance and different parameters. The outcome of this study will help devise insect pest management strategies for the area under study or any related cotton-growing areas present throughout the cotton-growing countries of the world. The purpose of this research is to gain first-hand experience with spiders in irrigated and semi-arid cotton fields and to catalogue the most common species. This knowledge can be used to include sustainable practices into future IPM strategies, leading to improved pest management and less reliance on insecticides. Different spider species will be found from different locations of cotton growing regions. If they were ''all alone,'' would that be enough time for biological control? How similar or unlike are the spider communities in irrigated and semi-arid cotton fields?

2. Materials and methods

2.1. Study areas

During the cotton crop seasons of 2018 and 2019, the research was conducted in Pakistan's Punjab province in the two major cotton-producing districts, namely district Vehari (29.9719° N, 72.4258° E) and district Layyah (31.0998° N, 71.0022° E). Three research locales were chosen from each district to collect and record the data. About 25 km (km) separated each of the district Layyah's sites that were put up for consideration. However, the distance between each site of the district Vehari ranged from 15 to 25 km. The area selected at every study site comprised two acres, i.e., 8094 square meters. It was divided into five equal plots (five replications) at each district's selected location. *Bt* cotton, FH-142 variety was selected and sowing was completed from May 14 to May 17, 2018, and 2019 at all field plots of different selected locations of both districts. All selected plots shared an almost similar set of environments. The first germination was observed in the second week, and the first squares were observed by the end of the fifth or sixth week, starting from the date of sowing (DOS) at all locations. The first flower was observed at different locations by the end of the third week of July. Standard agronomic practices (like weeding, irrigation, use of fertilizers, etc.) were performed when and where needed at all the selected locations. Both districts' understudy shows some geographical differences, but the climatic conditions are similar, with minor, neglectable differences. Moreover, overall general agronomic practices are the same in both districts under study.

2.2. Collection/estimation of arthropod abundance

For the collection of different predatory fauna, methods like pitfall traps, sweep nets, beat sheets, visual counting, and hand-picking were used for estimating arthropod abundance and collection of different arthropod specimens. In hot hours of the day, fewer pests and predators were observed, so to avoid this bias, all sampling was conducted twice a day, i.e., early in the morning and then late in the evening on every mentioned date. After every visit, all obtained data was formulated, and averages, means, and percentages were calculated for further statistical analyses.

2.2.1. Pitfall method

The pitfall method was used for capturing ground-dwelling arthropods. Twenty-five pitfall jars were placed in a three-layered pattern (the center, the middle, and the outer) to acquire a good sense of the species that lived in the cotton fields of these districts. The pitfall jars were installed at 7.5 m apart and at a distance of 1.25 m toward the inside from the outer boundaries of the field. So, in this pattern, 25 pitfall jars were installed in three layers covering the outer, middle, and central areas of each experimental plot (Five replications at every selected site of both districts). Each jar was of seven-inch height and 3 in. in width. Each pitfall trap was buried into the soil, so its mouth was parallel to the soil surface (Tahir and Butt, 2008). One-third portion of every jar was filled with a mixture of glycerol (30%) and alcohol (70%). A few drops of a liquid detergent were also added to reduce the surface tension of the mixture. Every field was visited bi-weekly to refill pitfall traps and collect already trapped or fallen insects.

2.2.2. Sweep netting

Sweep nets were also used for sampling as this method was preferred for sampling invertebrates because of their lightweight and simple usage technique (Buffington and Redak, 1998; Southwood and Henderson, 2000, 2009). We performed twenty vigorous sweeps per session while walking in an eight (8) fashion through each selected site's cotton field plot. The captured spiders were counted to gauge their abundance in the cotton fields. It is also believed that some more predatory spider species were there, which might be skipped by our eye and sweep-net.

2.2.3. Visual counting

It was performed to sample and estimate the relative abundance and the total number of different predators. Twenty-five plants were selected for thorough observation from the five field plots, according to the Random Complete Block Design (RCBD) format. Then, the whole data for those observed spiders was formulated, and means, or percentages were calculated for every field plot after every visit and kept the record for comparison and further evaluation of it and other parameters.

2.2.4. Hand-picking

Only 25 randomly selected plants (and webs attached to them) were observed in each field plot. Approximately 8–9 plants were observed from different boundaries, 8–9 plants from the middle, and 7–8 plants from the central area of the plot. So, all areas, i.e., boundaries, middle and central areas, were observed on each visit during all eight trapping sessions. Hand-picking was also done for different species of spiders from their respective webs, which they had installed for capturing prey. Still, it was done from those randomly selected twenty-five plants and spider webs attached to them. Spiders can be found just about anywhere in cotton fields, including on the ground, in the cotton plants' lower, middle, and upper regions, and even up near the canopy of the fields.

2.3. Preservation and data storage

All collected specimens were kept in 20 ml vials or larger plastic bottles filled with alcohol (95%) as per the requirement of the sample (according to their body size). Then every bottle was labeled with specific field numbers, the details of the site, the date, and the collection time with the collector's name right there in the fields before leaving the site of their capture and then moved to the Laboratory at Government College University for more research to be done there. In the end, all of the specimens were preserved in alcohol (95%) after giving them careful washing with 70 % alcohol to remove any soil particles, part of some leaves, or any other material attached to their bodies. Samples were again checked for properly marked numbers, and data needed to be noted before shifting them to specific low-temperature-maintained freezers.

2.4. Morphological identification

Under a stereo-zoom dissecting microscope (BCVS 121 & BIO-COM UK), numerous morphological characteristics of every spider were scrutinized in great detail to arrive at the most accurate classification possible. For identification purposes, several different keys and catalogues available, such as Tikader (1982), Tikader and Malhotra (1982), Vreden and Ahmadzabidi (1986), Barrion and Litsinger (1995), were consulted along with the databases that were available on BOLD, were evaluated. All identified spiders were photographed using a dissecting microscope bearing a canon power shot G9 digital camera.

2.5. Diversity indices and inventory completeness

During this study, we found that the differences between the two years' worth of data were not statistically significant, so we combined both years' data and analyzed it using the SPDIVERS. BAS program, which was developed by Ludwig and Reynolds (1988), the species accumulation curves were generated. The ratio between Chao1 and observed richness was determined to check the completeness of the spider inventories. For the diversity analysis of different spider species collected across different selected sites, two most trusted and widely used indices, viz., the Simpson index and the Shannon-Wiener index, were selected, which are sensitive to changes in the most abundant species in a community and changes in the abundance of rare species in a community, respectively (Solow, 1993). Margalef index highlighted the relationship between species richness and the total number of individuals observed, and its value grows with increasing sample size. Menhinick index gives a good relationship between the present species (in the given sample) and the total number of individuals observed (in the given sample). The evenness index measures how evenly species are distributed in a sample. The modified Hill's ratio (E5) is the best evenness index, the least ambiguous, the most easily interpreted, and independent of the number of species in the sample (Ludwig & Reynolds, 1988). The Shannon-Wiener, Simpson, Margalef, and Evenness (E5) indices were computed using the statistical software SPDIVERS.BAS of Ludwig & Reynolds (1988). For cluster analysis, abundance data of predators during different trapping dates was utilized. Multi-Variate Statistical Package (MVSP Version 3.22) was used for this analysis.

3. Results

A sum of 10,684 spiders belonging to 39 species, 28 genera, and 12 families was recorded from the study area. Of this collection, 3544 were immature and could only be identified up to the genus level due to the lack of keys specifically designed to identify juveniles. However, the remaining 7140 spiders were mature adults. Maximum numbers of spiders (6288) were captured from the district Vehari than from district Layyah (4396). Table 1 provides an

Table 1
The relative abundance (R. A) of spiders associated with the cotton ecosystem of Punjab, Pakistan.

Family	Species	Layyah	Vehari	Total	R. A
Araneidae	*Araneus species*	144	228	372	3.48
	Eriovixia excelsa	84	252	336	3.14
	Neoscona rumpfi	84	108	192	1.8
	Neoscona mukerjei	156	252	408	3.82
	Neoscona sinhagadensis	268	404	672	6.29
	Neoscona theisi	564	804	1368	12.8
	Neoscona species	132	112	244	2.28
Cloubionidae	*Cheiracanthium inclusum*	156	192	348	3.26
	Clubiona species	84	108	192	1.8
Sparassidae	*Olios species*	64	132	196	1.83
Gnaphosidae	*Gnaphosa jodhpuriensis*	188	252	440	4.12
	Gnaphosa species	60	84	144	1.35
Linyphiidae	*Erigone species*	164	272	436	4.08
Lycosidae	*Arctosa species*	72	108	180	1.68
	Hogna species	76	108	184	1.72
	Lycosa species	96	152	248	2.32
	Pardosa pseudoannulata	196	288	484	4.53
	Pardosa sumatrana	180	312	492	4.61
	Pardosa species	48	60	108	1.01
	Pirata species	168	132	300	2.81
	Trochosa alvioli	140	188	328	3.07
	Trochosa species	36	60	96	0.9
	Wadicosa fidelis	72	172	244	2.28
Oxyopaidae	*Oxyopes aspirasi*	276	348	624	5.84
	Oxyopes species	108	140	248	2.32
	Peucetia species	48	84	132	1.24
Pholcidae	*Pholcidae species*	36	28	64	0.6
Pisauridae	*Thalassius species*	48	88	136	1.27
Salticidae	*Bianor albobimaculatus*	108	68	176	1.65
	Menemerus bivittatus	20	28	48	0.45
	Pseudicius admirandus	36	32	68	0.64
	Phlegra fasciata	28	64	92	0.86
	Plexippus species	44	92	136	1.27
	Thyene imperialis	124	192	316	2.96
Scytodidae	*Scytodes lugubris*	12	8	20	0.19
Thomisidae	*Thanatus dhakuricus*	68	36	104	0.97
	Thomisus okinawensis	100	60	160	1.5
	Thomisus spectabilis	72	148	220	2.06
	Thomisus species	36	92	128	1.2
	Total	**4396**	**6288**	**10,684**	**100**

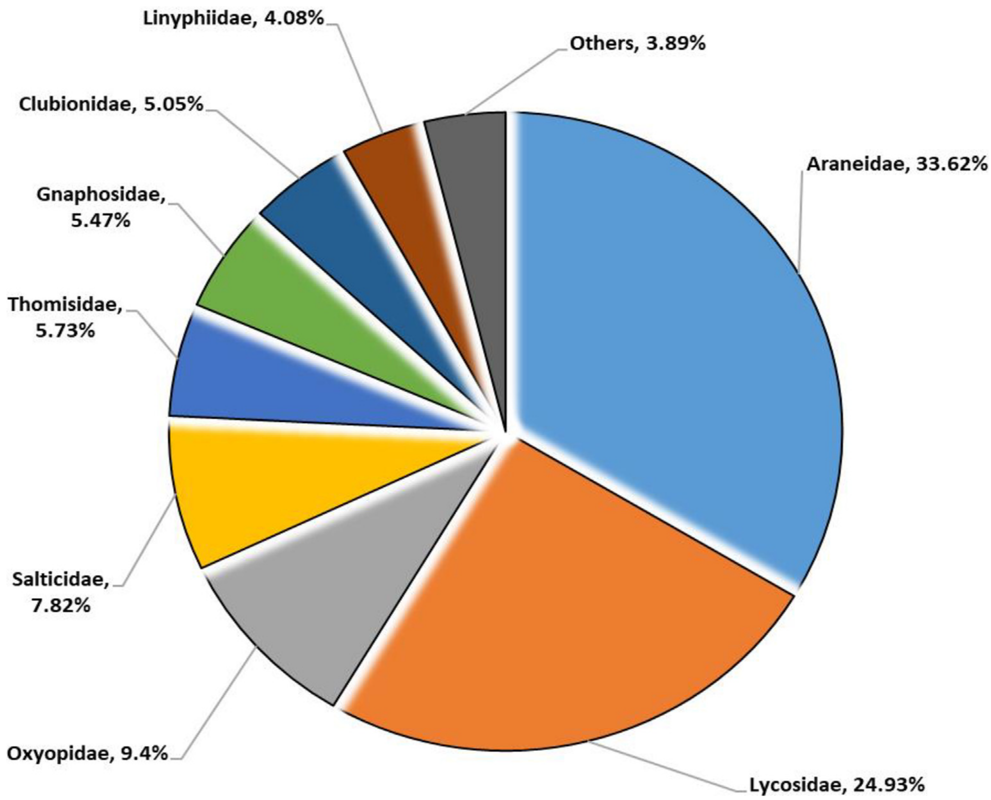

Fig. 1. Family composition of spiders recorded from the cotton agroecosystems of the two selected districts (District Layyah and Vehari) of the Province of Punjab, Pakistan.

exhaustive listing of the spider species identified based on their morphological characteristics.

It was found that the family with the highest prevalence was the Araneidae (33.62%), followed by the Lycosidae (24.93%), Oxyopaidae (9.40%), Salticidae (7.82%), Thomisidae (5.73%), Gnaphosidae (5.47%), Cloubionidae (5.05%), Linyphiidae (4.08%), Sparassidae (1.83%), Pisauridae (1.27%), Pholcidae (0.60%), and Scytodidae (0.19%). The Araneidae family's *Neoscona theisi* was the most booming species, comprising 12.80% of the total catch and being the dominant species (Table 1). There were ten different species (n = 10) that belonged to the Lycosidae family, making them the largest family with the most number of species, followed by the family Araneidae (n = 7), Salticidae (n = 6), and Thomisidae (n = 4). Family Oxyopaidae was represented by three species, i.e. (n = 3), family Cloubionidae and Gnaphosidae by two species each, i.e. (n = 2), while Sparassidae, Linyphiidae, Pholcidae, Pisauridae, and Scytodidae were all represented by one species each. Fig. 1 shows the family share of major spider families in cotton agroecosystems of both districts during two consecutive years of this research.

Fig. 2 depicts the accumulation curves for the pooled species of spiders, which were merged data from two districts. The number of spider species that were caught has been steadily climbing along with the size of our sample as it has grown. The rate at which species are increasing was found to be substantially slower after a count of 4,000 specimens. Initially, there was a significant spike in the total number of species. The asymptote stage of the accumulation curves could not be achieved in any district. According to the Chao 2 estimates, the species richness was 41.25 and 40.50 in the Layyah and Vehari districts, respectively. The ratio of the observed spider species to the estimated number of spider species was 95%, which indicates another 5% more spider species were present at the study locales (Table 2).

The seasonal dynamics of the spiders collected from the cotton field plots of districts Vehari and Layyah are shown in Fig. 3. In the Layyah district, spiders' peaks were observed during the first half of September and October in 2018 and 2019, respectively. However, the district Vehari peaked during the second half of September 2018 and in the first half of October during the cotton season of 2019.

Table 3 shows the evenness, diversity, richness, and total abundance indices computed for the two years of the research (cumulative) for spiders captured from the districts of Vehari and Layyah. The sum of spiders recovered from the district Vehari (6288) was higher in number than the total spiders captured from the district Layyah (4396). The Margalef and Menhinick indices were used for computing richness. It is evident from the table that both richness indices were higher for district Layyah as compared to district Vehari. Both districts' Shannon-Weiner index and Simpson index values were almost the same, as shown in Table 3. Similarly, the evenness index showed a bit higher value for the district Vehari than for district Layyah.

Based on abundance data of various beneficial arthropod species, the cluster analysis separated both districts and their selected sites (Fig. 4). The correlation between active spider density and relative humidity or precipitation was not statistically significant. However, there was a significant negative correlation between temperature and abundance data of spiders (Table 4).

4. Discussion

In the present study, two spider families, i.e., Araneidae and Lycosidae, dominated during both years. These two families collectively constituted more than 50 percent of the family share among all spider families (Fig. 1). Members of both these families feed on

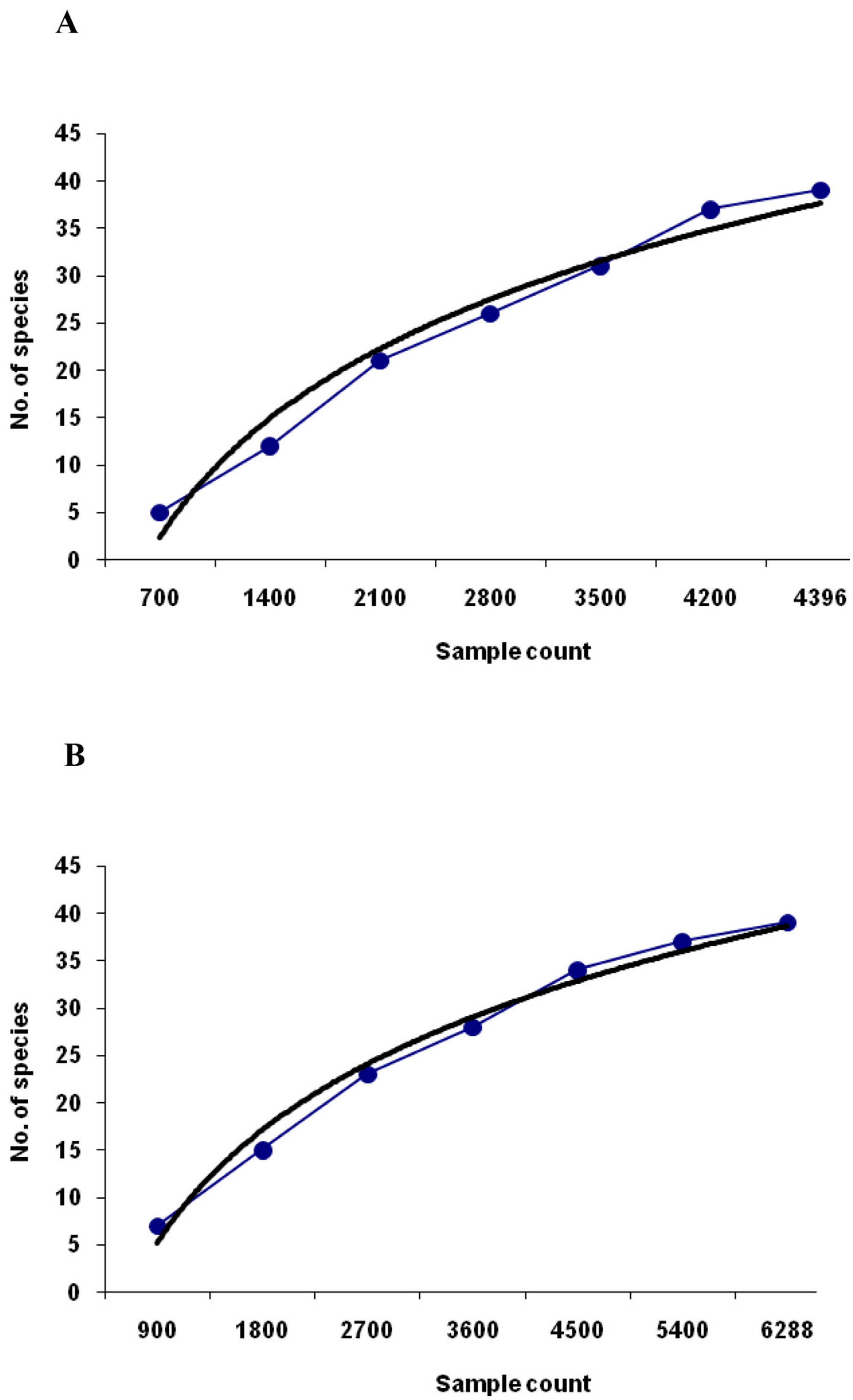

Fig. 2. Species accumulation curves for the spider species collected from the cotton agroecosystems of the district Layyah (A) and the district Vehari (B) of the Province of Punjab, Pakistan.

different pests of the cotton crop, which invade the cotton crop at its early phenological stages. Due to the immediate availability of food sources, the dominance of these two families has also been reported by other researchers from different crop fields in Punjab, Pakistan (Tahir and Butt, 2009; Sherawat et al., 2012).

Spiders of the family Araneidae are known as orb-web spiders. They construct their webs in different shapes, sizes, and heights from the ground (Butt and Tahir, 2010). They are sit-and-wait types of predators and do not actively chase their prey. Araneidae is the most dominant foliage family in cotton ecosystems, as observed in the present study. Spiders of the family Lycosidae are cursorial hunters, found on either the aerial parts like the leaves and flowers of cotton plants or the ground. While on the ground, they hide in soil crevices and under dry leaves (Van den

Table 2
The diversity and the inventory completeness of spiders, as recorded from the two targeted districts.

Spiders	District Layyah	District Vehari
Specimens recovered	4396	6288
Observed richness	39	39
Number of singletons	3	3
Number of Doubletons	2	3
Chao 2	41.25	40.5
% completeness	94	96

Berg, 1989). Genus *Pardosa* actively feeds on the first two instars of pink bollworm (Whitcomb et al., 1963).

Moreover, the early moth stage of bollworms was also vulnerable to them for some short time while staying on the ground (Lincoln et al., 1967; Whitcomb, 1967). In China, researchers noted that more than 30 insect pest species, including cotton bollworms and aphids, were attacked by different species of Lycosidae (Zhao, 1984; Zhao et al., 1989). Some lycosids also consume cotton bollworm larvae when pupating in the soil (Rendon et al., 2016, 2018, 2019).

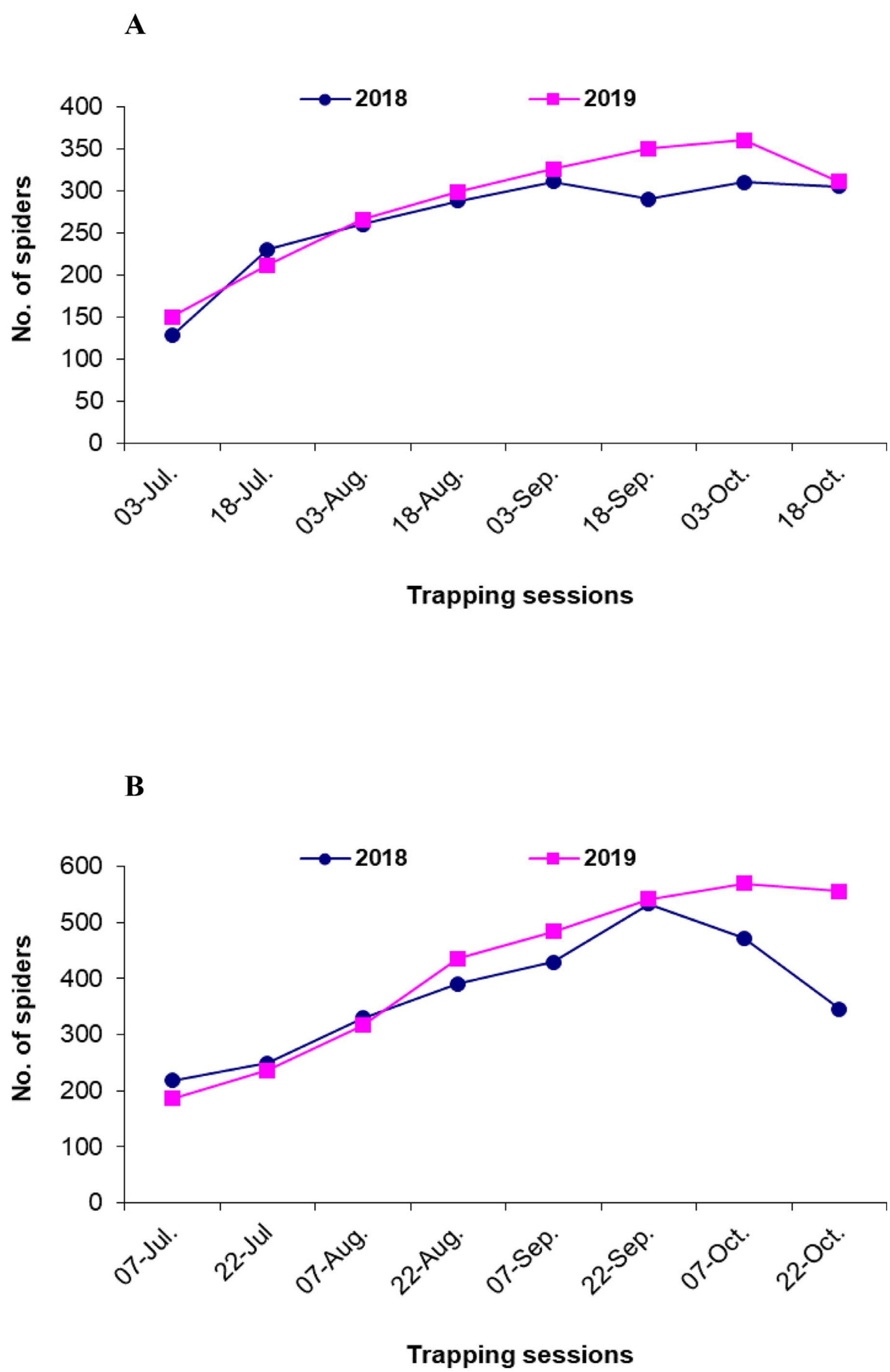

Fig. 3. Seasonal abundance of spiders recorded from the cotton agroecosystems of the district Layyah (A) and the district Vehari (B) of the Province of Punjab, Pakistan.

Spiders of the family Oxyopidae and Thomisidae were found with ease after mid-August. These families are major predators of different bollworm species and other insect pests. Their presence indicates the availability of bollworms in the fields (CCRI, 2020). *Thomisidae* spp. were collected from the aerial parts of cotton plants, like leaves, stems, and bracts, and they were also found on the ground, hiding under dry leaves (Van den Berg, 1989). These spiders are mostly sit-and-wait predators (Dean et al., 1982), but some species move actively in search of prey (McDaniel and Sterling, 1982). They are active even during day time (Leigh and Hunter, 1969). They keep them waiting in ambush in terminals for prey upon second-instar larvae of cotton bollworm (Whitcomb, 1967). They also preyed on bug species like *Geocoris*, *Lygus*, etc., beetles and Syrphid flies (Whitcomb and Bell, 1964). *Oxyopes* are considered active predators among spiders. Whitcomb (1967) reported that compared to other arthropod predators, different *Oxyopes* species destroyed more second instar larvae of cotton bollworms. They also preyed on other pests like cotton leaf hoppers, mirids, tarnished plant bugs (Whitcomb et al., 1963), and aphids (Kagan, 1943; Nyffeler et al., 1992). *Salticidae* spiders, also known as stalkers, are found on foliage and the ground. They are highly polyphagous but can become selective when prey is available in high numbers (Nyffeler et al., 1994). Salticids prey on boll weevils, bollworms (first to the third instar), and other pest species (Whitcomb and Bell, 1964; Roach, 1987).

Species accumulation curves of spiders' collection from both districts did not reach asymptote (Fig. 2), which indicated the presence of some more species in the fields which were not collected during the field visits as those spider species might have different times of activity or due to the inadequate efforts made for their collection during collection. About 94–96% of the spider species in the region were successfully collected, and the remaining 4–6% may be comprised of some uncommon and rare spider species. They might have had different times of activity, which were surely different from our sampling time, due to which they were not captured (Table 2). It was reported that different arthropod species use different times of the day and night to avoid competition (Schmidt and Balakrishnan, 2015). There was also the potential that certain species of spiders only appeared briefly throughout the growing season. The maximum number of spiders or their peaks was observed almost by the end of September in both districts (Fig. 3). At that time, the maximum diversity and abundance of different pest species were recorded in the cotton agroecosystems. Hence, as more food opportunities (pest abundance) were available during that period, they might have increased their population as a hard-and-fast rule of nature.

Researchers locally and globally recorded various spider species from different agricultural crop fields. Riaz et al. (2017) reported 68 spider species from oilseed crops, including soybean, sunflower, and Indian mustard. Tahir (2009) reported 44 spider species from rice fields in Punjab, Pakistan, while Sebastian et al. (2005) reported 92 spider species from the rice ecosystem in central Kerala, India. Sherawat (2012) observed 47 spider species from wheat crop fields of the district Sheikhupura, Punjab, Pakistan, while Naseem (2016) collected 54 spider species from citrus orchards in Pakistan. Bao et al. (2018) also collected 61 spider species from rice fields, and Kerzicnik et al. (2013) recovered 119 spider species from the wheat agroecosystems. Avalos et al. (2013) captured 200 spider species from citrus cultures. Yang et al. (2018) observed 375 spider species from rice fields, while Dippenaar-Schoeman et al. (1999) documented 127 spider species from cotton fields in a study conducted between 1979–1997. Nadeem (2022) documented 39 spider species from the cotton fields of Southern Punjab, Pakistan.

Table 3
The evenness, diversity, richness, and total abundance of the spiders collected from both districts (Layyah and Vehari).

Parameters	District Layyah	District Vehari
Total abundance	4396	6288
Richness indices		
Menhinick Index	0.588	0.491
Margalef Index	4.53	4.345
Diversity indices		
Simpson's Index	0.044	0.045
Shannon-Wiener Index	4.882	4.856
Evenness index		
Evenness (E5)	0.67	0.71

Table 4
Association of humidity, temperature, and rainfall with the spiders' population size during the cotton cropping seasons.

	Humidity	Temperature	Rainfall
Spiders	r = -0.602 P = 0.114	r = -0.759* P = 0.029	r = 0.274 P = 0.512

* Correlation is significant at the 0.05 level.

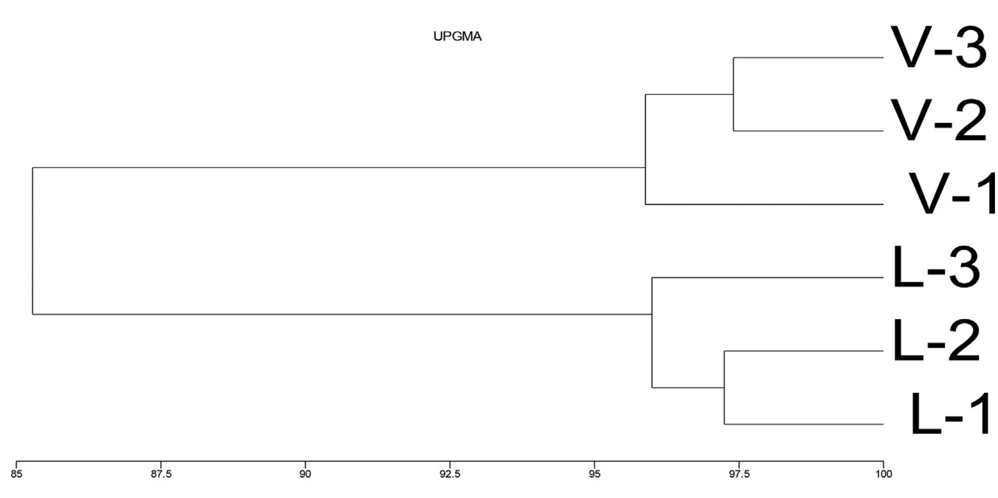

Fig. 4. Cluster analysis of six selected locales, based on abundance data of different spider species of the two selected districts (district Vehari and district Layyah). **Note: L** stands for the district Layyah, **V** stands for the district Vehari, while numbers 1, 2, and 3 represent the three selected locales of each district.

The collected 39 spider species were quite less in number than the spider species reported from other major crops of the region. Different factors played their role in determining this low number of spider species in cotton fields. The region of these districts under consideration is known as "the cotton belt of Punjab, Pakistan." The environment of the area was quite harsh and dry. Moreover, consistent and repeated applications of different chemicals on the cotton crop were widely practiced (Cook et al., 2011). Spiders and many other predatory insect species were also adversely affected by such broad-acting insecticides (Brühl and Zaller, 2019; Hayes and Hansen, 2017; Men et al., 2003, 2004; Nadeem et al., 2022a; Naranjo et al., 2003, 2004). Mounting evidence suggests that this decline in biodiversity among natural predatory fauna weakens the natural biological control (Straub et al., 2008; Letourneau et al., 2009; Jonsson et al., 2017; Greenop et al., 2018). The values of different indices about spider abundances, richness, and diversity showed almost similar trends (Table 3), which might result from a similar set of environment and biota in the cotton fields of both districts.

5. Conclusion

Spiders, being arthropod predators are found as the first predators that colonies the cotton fields. In cotton field plots, these predators were present on the ground and plant surfaces. Many members of this predatory fauna have a wide range of prey, and they attack differently or all stages of the life cycle of different pests, like eggs, larvae, pupae, and final moth stages. Hence, they are categorized as one of the major biological control agents against different damaging pests of the cotton crop. The cotton agroecosystem supports a rich diversity of predatory fauna and spiders. The populations of different spider species show fluctuations concerning crop phenology and the density of available resources in the cotton field plots of the region. It is believed that the findings of the present study may help the researchers working on generalist predator communities, especially spiders, in different areas of the world with similar topographical conditions. And these findings may also contribute significantly towards devising their future strategies.

CRediT authorship contribution statement

Amir Nadeem: Writing – original draft, Formal analysis, Conceptualization. **Hafiz Muhammad Tahir:** Supervision, Methodology. **Azhar Abbas Khan:** Supervision, Methodology, Conceptualization. **Naheed Bano:** Formal analysis, Software. **Zeshan Hassan:** Writing – review & editing, Software. **Arif Muhammad Khan:** Writing – review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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