Pak. j. life soc. Sci. (2013), 11(2): 107-111 E-ISSN: 2221-7630;P-ISSN: 1727-4915

Pakistan Journal of Life and Social Sciences
www.pjlss.edu.pk

RESEARCH ARTICLE

Trophic Niche Breadth and Niche Overlap among Different Guilds of Spider Species in Wheat Agro-ecosystem

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ARTICLE INFO

Received:	Mar 14, 2013
Accepted:	Apr 11, 2013
Online:	Apr 21, 2013

Keywords
Coexistence
Competition
Niche breadth
Niche overlap
Spiders
Utilization curve

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ABSTRACT

Trophic niche breadth and niche overlap of nine spiders including *Pardosa timidula* (Roewer, 1951), *Hippasa olivacea* (Thorell, 1887), *Plexippus paykulli* (Audouin, 1826), *Oxyopes javanus* (Thorell, 1887) (hunters), *Leucauge decorata* (Blackwall, 1864), *Tetragnatha javana* (Thorell, 1890), *Neoscona mukerji* (Tikader, 1980), *Argiope aemula* (Walckenaer, 1841) and *Cyclosa spirefera* (Simon, 1889) (web builders) inhabited in wheat fields of University of Agriculture, Faisalabad, Pakistan were verified. Study was planned to know how the most abundant spiders of wheat are coexisted in terms of habitat and food resources. Evidences of predation in fields were used to compute the coefficients of niche breadth and niche overlap. Diet breadth values were approximately 1 to 2 times greater than the minimum, which specifies substantial differing degree of feeding specialization. All overlap values were <1.00 (range, 0.05-0.92), which indicated that each species had its own feeding niche in the wheat ecosystem. It was concluded that separation of guild members in microhabitat, high plasticity in their foraging patterns may results in reduced competition and coexistence. Thus, such abundantly found spiders are highly responsible to enhance their biological control potential in wheat agro-ecosystems.

INTRODUCTION

Spiders are the best biological control agents and significantly reduce the prey densities in crops (Symondson et al., 2002). Agro-ecosystems are variable environments with wide niche dimensions that reduce the niche competition among species and allow them to coexist. Spider guilds in same area can never change their microhabitats, prey niche dimensions and separation of their members in time for their cohabiting (Butt and Tahir, 2010). Niche divergences are the result of directional selection when resources are abound in supply, species can share them without detriment to one another and niche overlap may be high with reduced competition (Molles, 2007).

According to other studies, spiders of family Tetragnathidae were found responsible to coexist due to their similar spatial niches in comparison of trophic niches (Novak et al., 2010). Lycosids and salticids have similar habitat partitioning, which allows them to coexist in same microhabitats (Carrel, 2003) while habitat complexity and lower encounter rates may reduce cannibalism among spiders (Wise, 2006). Moreover, different species may be narrowed to the same resources but fluctuate in time when they utilize them on their extensive demand. This might be due to the ecological character divergence among sympatric populations (Dayan and Simberloff, 2005). The niche axes of two endemic sympatric desert species, *Syspira (S.) tigrina* (Simon, 1885) and *S. longipes* (Simon, 1885) of family Miturgidae showed that coexistence was the result of variances in choice of microhabitat, temporal activity and occupation of space or size (Nieto-Castan˜eda and Jime´nez-Jime´nez, 2009).

The present study deals with nine species of spiders that are abundant in wheat fields of the University of Agriculture, Faisalabad (UAF). All of these species have the same ecological requirements. High diversity of such controlling agents in fields may affect on pest populations that would ultimately have triggered the niche diversification within the ecosystem. Therefore, such large niche dispersal of organisms would be supportive to identify the exact species that may eventually help in biological control of various pests in wheat fields. On account of these influences, the present study was designed to understand how the most abundant nine spider species of wheat fields were coexisted in terms of habitat and food resources.

MATERIALS AND METHODS

Study area

Wheat fields of $4060m^2$ were surveyed for spider fauna from December through April, during 2008 and 2009 at the UAF, Pakistan. No pesticide was applied in the experimental fields throughout the experimental period. All fields were harvested in mid May. During the course of study the average temperature and relative humidity ranged 17.0-32.5, 55.5-33.6 (2008) and 11.5-31.8, 68.9-41.7 (2009), respectively. Meteorological data was obtained from Agricultural Meteorology Cell, Department of Crop Physiology, UAF, Pakistan.

Experimental organisms

Nine spider species of winter wheat were selected for the present study including: *Pardosa timidula* (Roewer, 1951), *Hippasa olivacea* (Thorell, 1887), *Plexippus paykulli* (Audouin, 1826), *Oxyopes javanus* (Thorell, 1887), *Leucauge decorata* (Blackwall, 1864), *Tetragnatha javana* (Thorell, 1890), *Neoscona mukerji* (Tikader, 1980), *Argiope aemula* (Walckenaer, 1841) and *Cyclosa spirefera* (Simon, 1889).

Collection of spiders

Two types of sampling methods (Pitfall traps and suction device) were applied throughout the growth period of wheat to study the active density of spiders. After every two weeks from December through April, 25 pitfall traps (14 cm long and 7 cm wide rounded mouthed) were set for five days to attain the ground spiders. After 48 hours, the traps were replaced by the fresh ones that were taken out after 72 hours of operation. Five pitfall traps were installed at each margin of the field and five in centre. Plotted jars were filled with a mixture of 150 ml of 70% ethyl alcohol and a small quantity of kerosene oil for the preservation and protection of captured contents.

Foliage spiders and other insects were collected by suction device (Siemens VK 20C01). Plants were selected randomly and vacuumed completely for 1 to 2 minutes. All captured individuals were carried to the Araneae Laboratory, Department of Zoology and Fisheries, UAF where they were strained, washed, dehydrated and stored in 95% ethanol, containing a little quantity of glycerine. Collected spiders were identified from the reference keys and catalogues provided by Tikader and Malhotra (1980), Tikader and Biswas (1981) and Barrion and Litsinger (1995).

Diet composition

To obtain the predators with their insect prey, sampling was done in morning only for two hours at dawn (6:30-8:30) and dusk (17:00-19:00) in every week by five different observers. Observed predation events were recorded and all captured predators along prey were stored and brought to the Laboratory. Insect prey was identified up to genus level with the help of related taxonomic information in the “Fauna of British India” and online electronic keys available on different websites.

Statistical analysis

The average active density of the both ground and foliage spiders were compared by *t*-test. Utilization curves (Petraitis, 1979) were computed for each guild of species. To quantify niche breadth, one common measure Levins (1967) was used: $B = 1/\sum p_i^{\,2}$;

where, B is the Levins measure of niche breadth and P_i is the proportion of individuals found using resource i. Species niche overlap was estimated by following measure, developed by MacArthur and Levins (1967): $M_{jk} = \sum P_{ij}\, p_{ik} \,/\, \sum P_{ij}^{2}$; where, M_{jk} is the MacArthur and Levins niche overlap measure of species k on species j, P_{ij} is the proportion that resource i is of the total resource that species j utilizes and p_{ik} is the proportion that resource i is of the total resource that species k utilizes. Statistical software (Ludwig and Reynolds, 1988) was used to estimate such ecological indices.

RESULTS

The total number of individuals was 1209 during the sampling period. Out of these, 495 belonged to the studied species (Table 1). The difference in the active densities of different species during both years was not significant (P = 0.23). Foraging preferences of all the nine spider species were different towards the nine insect prey orders (Homoptera, Diptera, Hymnoptera, Orthoptera, Lepidoptera, Coleoptera, Thysanoptera, Odonata and Araneae). According to their choice, some were observed to exceedingly prefer Homopteran, Dipteran and Hymenopteran insects, though other prey groups were slightly favored (Table 2).

Utilization curves show that the dependence of different spider species differ on nine insect orders. Utilization curve of *P. paykulli* was found maximum (0.36) with Homoptera while *H. olivacea* marked the least utilization with the same order constituted the value (0.14). Species *O. javanus* was reported as a voracious predator of homopteran insects instead of *P. timidula.* The overall most utilized prey orders were Homoptera, Diptera, Hymnoptera and Orthoptera while less reliant were Lepidoptera and Odonata (Fig. 1).

Niche breadth (B) highest values were approximately 1 to 2 times greater than the minimum, which specifies substantial differing degree of feeding specialization. *Hippasa olivacea* was found to be a generalist predator in all studied period, having a very wide niche because of relying on all prey groups. No doubt, the number of

Table 1: Total abundance of dominant spider predators captured from wheat fields during 2008 and 2009

Species	Ground (2008)	Foliage (2008)	Ground (2009)	Foliage (2009)	Total
NM	-	39	-	43	82
AA	-	21	-	30	51
LD	-	22	-	23	45
PP	25	-	26	-	51
CS	-	15	-	25	40
OJ	-	32	-	26	58
HO	28	-	24	-	52
PT	24	-	35	-	59
TJ	-	28	-	29	57
Total	77	157	85	176	495

Table 2: Observed diet records of web builder and hunter spiders from wheat fields during 2008 and 2009

	Web Builders				Hunters			
Spiders	NM	AA	LD	TJ	CS	PP	OJ	HO	PT
Hom	12	8	5	5	3	7	2	5	3
Dip	13	9	4	6	2	3	1	2	1
Hym	15	7	4	2	1	7	6	4	2
Ort	11	4	4	4	1	1	1	2	2
Lep	8	6	5	2	2	2	1	3	2
Col	17	6	3	10	4	4	2	4	2
Thy	4	6	5	1	1	2	5	3	1
Odo	6	4	2	1	1	3	2	3	1
Ara	9	6	3	1	3	6	2	4	2
Total	95	56	35	32	18	35	22	30	16

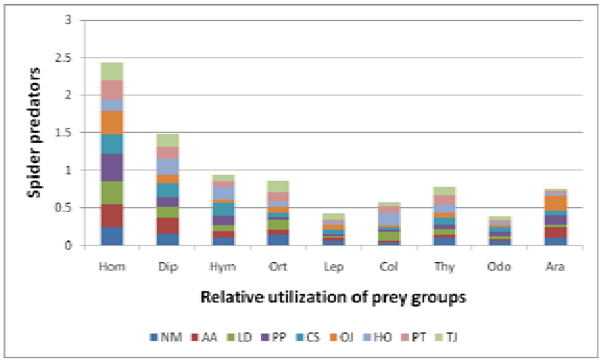

Fig. 1: Utilization curves of nine synoptic species

prey utilized by *O. javanus* (specialist predator) was high in amount but it preferably consumed the Homopteran, Dipteran, and Araneanoid insect species and showing least attention towards other prey groups (Table 3).

The Levins niche overlap (LO) values were calibrated for nine synoptic spiders with the assistance of their utilization curves. For each of the pairs, two Levins overlap values were compared in a way that the overlap by first member on to the second member and *vice versa*. Those species pairs which showed >50% overlap values (*AA×TJ, LD×OJ, OJ×TJ, HO×PT, HO×TJ, PT×TJ*) are mentioned here while those showed no apparent interactions were not discussed. The extreme overlap values were documented between *O. javanus* (0.91) and *T. javana* (0.92) species both represents almost complete overlap. Similarly, another very marked overlap comparison of *H. olivacea* with *T. javana* was studied, former species (0.66) cover the later one (0.58) (Table 3).

Table 3: Niche breadth and niche overlap values between nine pairs of spider species captured from wheat fields during 2008 and 2009

		Species								
	B	*NM*	*AA*	*LD*	*PP*	*CS*	*OJ*	*HO*	*PT*	*TJ*
NM	7.06	-	0.09	0.13	0.08	0.14	0.11	0.15	0.40	0.09
AA	5.66		-	0.24	0.17	0.17	0.22	0.33	0.24	0.43
LD	6.02			-	0.37	0.26	0.56*	0.21	0.12	0.16
PP	5.26				-	0.19	0.23	0.41	0.27	0.28
CS	6.78					-	0.39	0.08	0.09	0.24
OJ	5.90						-	0.21	0.41	0.91*
HO	7.19							-	0.09	0.66*
PT	6.76								-	0.28
TJ	6.94									-

*>50 overlap values, *B*= Levins measure of niche breadth

DISCUSSION

The current study showed that although all spiders were generalist predators but served on the similar prey groups of different sizes that resulted in reduced competition among coexisting species. Remarkably, proportion of all prey orders in the diet of spiders were found in different frequencies while ratio of Homopteran, Dipteran and Hymnopteran insects was observed highest in the diet of web weavers. Results of our study were similar with findings of Nyffeler (1999) but contrasting with report of Miyashita (1991) that prey compositions usually never change among coexisting species. It’s worth mentioning here that an optimized diet composition is always necessary for the best survival and reproduction of spiders that may extract by mixing food items (prey groups) (Uetz et al., 1992). This might be expected that more insects caught in the webs were due to the temporal web weaving activity of the spiders. Hence, the low visibility and freshly weaving webs was the hub of species as compared to others (Kraker et al., 1999).

Diet breadth that is inversely associated to feeding specialization was figured out for each guild to gain perceptions about how specialized or unspecialized a species is within a given environment. All values were standardized by maximum value ranged from 0.0 to 1.0 that showed that each spider has its own feeding niche in wheat agro-ecosystem. The results of species specialization were directly consistent with the results of Butt and Tahir (2010) they reported that coexisting guilds of orb web and hunting spiders have no difference in niche breadth values e.g., *Pardosa birmanica* performed to be a territory specific, *Oxyopes javanus* was a professional chaser, *Tetragnatha javana* and *Neoscona theisi* both were time and habitat specialized and generalized in prey selection.

During the study, niche value of hunters was broader due to their early appearance that remained in the field till its harvesting. Nyffeler (1999) reported the similar results that hunting guilds have broader niche as compared to orb web-weavers. Likewise, the increase in preferred prey size and widened potential prey spectrum lead to niche extension of species. Thus, impact of environmental changes on distribution and availability of prey may interact with individual based complex behavior that is too enough to cause niche variations among species (Bolnick et al., 2003; Santoro, 2011). Generalist predators were found more effective than specialists to reduce and stabilize the insect prey densities within the fields that usually fed on aphids and fleas while making a little impact on plant bugs, weevils, leaf beetles and caterpillars. Typically, generalists have greater propensity to meet their desires and use several food items despite of having adverse circumstances. In other words more specialized species are more reliant of a particular food (Swihart et al., 2003).

A total of 36 pairs were studied for the niche overlap, five of them showed >50% values (complete overlap) and the remaining, coexist in the same environment due to <50% overlap values. Such findings were highly comparable with the standard values of MacArthur and Levins (1967) which suggested that species can coexist if overlap values are not exceeded more than 54%. The only reason of such lower number was not the limited supply of resources but due to the interspecific and intraspecific predation which ultimately limits the each guild in agro-ecosystem. Similarly, the overlap values were >50% while overall niche values were <50% for orb web species in rice agro ecosystem (Tahir et al., 2012). In reality a very large value of prey taxa overlap may be found when it is being portioned and highly correlated with size/microhabitat, but implemented independently (May, 1975). After reaching the resources at their maximum carrying capacity, utilization also increase, while among higher competition coexistence may persist by nonlinearities of niche dimensions in all environments (Vandermeer et al., 2002). So, the results can also be compared with sympatric species of Louisiana that exploit the resources in a number of ways that could ultimately lessen the overlap values and flourish coexistence of individuals (Perkins, 2009).

The study indicated that maintenance of these spiders would be beneficial to make an extensive check against the insect pest of wheat by reducing their intra-guild predation among them. Conclusively, competition among selected spiders has negligible effect on their continued existence at the same area, guild's niche breadth and niche overlap revealed the useful competitive interactions in community ecology that may lead to conservation and co-existence of species.

Acknowledgements

The authors are highly acknowledged to the University of Agriculture, Faisalabad for providing financial assistance to accomplish this task.

Abbreviations used

Some abbreviations have been used in the paper viz. NM= N. mukerji, AA= A. aemula, LD= L. decorata, PP= P. paykulli, CS= C. spirefera, OJ= O. javanus, HO= H. olivacea, PT= P. timidula, TJ= T. javana, Hom= Homoptera, Dip= Diptera, Hym= Hymnoptera, Ort= Orthoptera, Lep= Lepidoptera, Col= Coleoptera, Thy= Thysanoptera, Odo= Odonata and Ara= Araneae.

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