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Impact of Different Rice Agro-Ecosystem on Spider Population Dynamics

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Abstract

Survey for spiders in the rice fields in Bangalore and Mandya districts of Karnataka yielded 16 spider species. Hunting spiders were more common in both rice monocropping (76.19%) and multiple cropping (80.65%) systems. Among the hanting spiders, *Pardosa sumatrana* Thorell was the most dominant spider species both in monocropping (36.45%) and multiple cropping systems (31.06%). Spider population density was significantly high under monocropping system (31.93 spiders/20 hills) compared to multiple cropping systems (19.93 spiders/20 hills). However Simpson's (λ) and Shannon's Weaver diversity indices indicated higher spider diversity in multiple cropping systems compared to monocroppig systems. Similarly, Pielou's (J^1) and Hill's Evenness (H^1) indices showed more revenness in the spider fauna in multiple cropping systems compared to monocropping systems.
Key words : Rice, Spiders, Hunting spiders, Diversity index, Evenness index, *Pardosa.*

Spiders, as representatives of 'sit and wait' predators constitute 35% of the predatory arthropod fauna of rice agroecosystems. The spider species dominant in different rice ecosystems of Philippine were *Tetragnatha mandibulata, Tetragnatha javana* and *Oxyopes javanus* in dry land, *Tetragnatha javana, Lycosa pseudoannulata* and *C. formosana* in rainfed wet lands and *C. formosana* and *L. pseudoannulata* in irrigated wet land environments (Barrion and Litsinger 1981). There was a small difference in the spider fauna of plain, piedmont, mountainous and coastal areas of Japan (Togasi and Taka 1988). Yu and Wang (1993) observed microphantids, *U. insecticeps* as most dominant, *E. graminicolum* as co-dominant spider species in fields surrounded by dry land crops such as cotton, ramie, legumes. *Gnathonarium dentatum* was dominant in rice growing areas of 1000 m above mean sea level. Survey in Karnataka indicated that *Lycosa* sp. and *T. maxillose* were present at moderate level (6—25%) in IPM plots compared to low to traces (1—5%) in non-IPM plots (Misra et al. 1994).

(The authors are grateful to Dr B. K. Biswas, Zoological Survey of India, Culcatta for identifying the spider specimens).

Methods

The rice fields in Bangalore and Mandya districts of Karnataka were surveyed for spiders during 1994-95. The representative locations and cropping systems in each district are furnished in Table 1. Spiders were collected by hand and insect sweep net in the main field and on the bunds during cropping season and on the stubbles after harvest and were brought to laboratory in separate vials. The specimens were preserved in absolute alcohol with proper labeling. The spiders were identified by Dr B. K. Biswas, Zoological Survey of India, Calcutta.

Sampling for Spiders

In the main field, observations on spiders were recorded visually from 20 stratified hills in each plot. The observations were made at 15-day intervals starting from transplanting till the harvest of the crop. Spider population in nursery and after harvest was recorded visually in 0.5 m^2 area from five randomly selected places. Spider population on bunds was recorded from one stratified meter area during crop period and after the harvest.

Different Cropping Systems

The rice fields where only rice is grown season after season in Bangalore, Mandya and Maddur area were classified as monocropping system. The rice

Table 1. Details of rice fields surveyed for spider fauna.

Locations	No. of fields surveyed	Cropping system	Cropping sequence
		Bangalore Dist	
Hebbal	2	Monocropping	Double
Thindlu	2	Monocropping	Single
Vidyaranyapura	1	Multiple cropping	Double
		Mandya Dist	
VC Farm	2	Monocropping	Double
Shivalli	2	Multiple cropping	Double
Maddur	2	Monocropping	Double
Shivapura	1	Multiple cropping	Double

fields where rice is cultivated in only one season per year (single cropping) or two continuous seasons per year (double cropping) were classified as multiple cropping systems. Here rice crop is rotated with other crops viz. sugarcane, ragi, vegetable. The observations on spiders and pest population were made at fornightly interval.

Diversity Index

The diversity of the spider fauna was worked out using the following Simpson's index (λ) (Simpson 1949) and Shannon's Weaver Index (H^1) (Shannon and Weaver 1949) formulae to assess the species richness in different cropping systems and within the cropping season at different stages.

$$\lambda_{i=1} = \sum^{s} P_i^2$$

where, P_i is the proportional abundance of the ith species given by,

$$P_i = n_i / N, i=1,2,3.......s$$

where, n_i is the number of individuals of the ith species and N is the total number of individuals for all s species in the population.

$$H^1{}_{i=1} = \sum^{S}(P_i \ln P_i)$$

where, H^1 is the average uncertainty per species in an infinite community made up of s species with know

Table 2. Abundance of spiders in the mainfield of monocropping and multiple cropping system in Karnataka.

Spider species	Per cent abundance Mono-cropping	Multiple cropping
Pardosa sumatrana Thorell	36.45	31.06
Pardosa sp.	21.06	15.76
Tetragnatha andamanensis Tikader	8.96	8.65
Theridion sp.	9.83	7.07
Clubiona ludhianensis Tikader	6.89	2.33
Zygoballus sp.	3.68	3.50
Tetragnatha sp.	1.99	4.25
Zygoballus narmadensis Tikader	1.53	1.03
Thomisus sp.	1.53	1.55
Tibellus pateli Tikader	1.23	3.40
Argiope sp.	1.23	–
Pardosa birmanica Simon	1.07	5.18
Zygoballus pashanensis Tikader	1.07	1.30
Oxyopes ratanae Tikader	0.31	4.39
Zygiella indica Tikader	0.15	0.90
Myrmarachnae sp.	0.15	6.23
Sosticus sundergarhensis Gajbe	–	5.18

proportional abundance.

$$P_i = P_1, P_2, P_3........P_s$$

Evenness Indices

Indices of evenness of Pielou's (J^1) (Pielou 1969) and Hill's (E) (Hill 1973) were calculated using the following equations.

Pielou's Evenness

$$J^1 = H^1 / \ln(s) = H^1 / Hmax$$

where, P_1 is the proportion of individuals found in ith species given by n_i / N. n_i and N are the number of individuals of ith species and total number of individuals respectively.

Hmax is the maximum diversity given by ln (s), where, s is the total number of species.

Hill's Evenness

$$E = 1 / \lambda / eH^1 = N_2 / N_1$$
$$N_1 = eH^1$$
$$N_2 = 1 / \lambda$$

where, $1 / \lambda$ is the Simpson's Index. H^1 = is the

Table 3. Effect of cropping systems on spider abundance. Means followed by same letters are within the student's t range.

Cropping system	Main field (No. of spiders/ 20 hills)	Bund (No. of spiders/ 4 linear m)
Multiple-Single cropping	10.43^{a}	2.87^{a}
Multiple-Double cropping	19.93^{b}	2.64^{a}
Monocropping	31.93^{c}	8.29^{b}
SE ±	1.444	0.507
CD at 5%	4.259	1.495

Shonnon's Index. N_1, measures the number of abundant species in the samples. N_2, measures the number of very abundant species.

Simpson's (λ) and Shannon-Weaver's (H^1) indices were used for measuring species diversity where Simpson' (λ) index range from 0 to 1, with a negative relationship with the diversity. As the diversity increase the value of λ approaches 0 and when the diversity is the least, the value tends towards 1. Shannon-Weaver's index (H^1) gives the values from 0 and onwards, and has a positive correlation with the diversity of species. Therefore, in Shannon-Weaver's index, the increasing values represent an increase in the diversity of species.

Pielou's (J^1) and Hill's Evenness (H^1) indices were used to measure the evenness of spider fauna, and both the values range from 0 to 1. When all the species represented are equal in numbers than the value of these indices approaches to 1, if not, then the values tend towards 0.

Results and Discussion

Monocropping and multiple cropping systems recorded 16 spider species each (Table 2). The results also indicated that the hunting and webbing spiders accounted for 76.19 and 23.9% respectively, in monocropping and 80.65 and 19.35%, respectively in multiple cropping system.

Pardosa sumatrana Thorell was the dominant spider species in both monocropping and multiple cropping accounting 36.45 and 31.06% of the total spider population, respectively followed by *Pardosa* sp. accounting 21.06 and 15.76%, respectively, *Tetragnatha andamanensis* Tikader accounting 8.96 and 8.65%, respectively and *Theridion* sp. accounting 9.83 and 7.07%, respectively. *Clubiona ludhianensis* Tikader was predominant in monocropping (6.89) than multiple cropping. While, *Myrmarachne* sp., *Pardosa birmanica* Simon, *Oxyopes ratanae* Tikader, *Tetragnatha* sp. and *Tibellus pateli* Tikader were more predominant in monocropping (6.23, 5.18, 4.39, 4.25 and 3.40%, respectively) than in multiple cropping system. *Sosticus sundargharensis* Gajbe confined to multiple cropping systems whereas, *Argiope* sp. confined to monocropping systems.

Table 4. Abundance of spiders in the main field and on the bunds of monocropping and multiple cropping systems during *kharif* of 1995. DAT, Days after transplanting. Means followed by the same letter are within the student's t range.

Cropping system	Stage of the crop (DAT)	Main field (spiders/ 20 hills)	Bund (spiders/ 4 linear m)
	15	5.0^{a}	2.5^{ab}
	30	8.5^{ab}	2.0^{ab}
Multiple-Single	45	15.5^{abcd}	2.5^{ab}
rice cropping system	60	12.0^{abc}	3.0^{abc}
	75	14.5^{abcd}	4.5^{abc}
	90	9.5^{ab}	3.2^{abc}
	105	8.0^{ab}	3.0^{abc}
	15	9.5^{ab}	1.0^{a}
	30	11.5^{abc}	3.0^{abc}
	45	15.5^{abcd}	2.0^{ab}
Multiple-double	60	22.0^{cdef}	3.0^{abc}
rice cropping system	75	24.5^{defg}	3.0^{abc}
	90	34.5^{gh}	4.0^{abc}
	105	22.0^{cdef}	2.5^{ab}
	15	18.0^{bcde}	4.5^{abc}
	30	27.0^{efgh}	6.5^{cd}
	45	36.5^{h}	5.0^{bcd}
Monocropping system	60	50.5^{i}	6.0^{abc}
	75	29.0^{efgh}	16.0^{e}
	90	33.0^{fgh}	8.5^{d}
	105	29.5^{fgh}	15.5^{e}
SE ±		3.821	1.341
CD at 5%		11.269	3.955

Spider population was significantly high under monocropping systems in the main field and on the bunds (31.93/20 hills and 8.29/4 linear m row, respectively) followed by multiple-double and multiple-single rice cropping systems (Table 3).

The lowest spider populations of 5.0, 9.5 and 18.0

Table 5. Diversity and evenness indices in different cropping systems in Karnataka during 1995.

Cropping Systems	Species richness (S)	Diversity indices: Simpson's Index (λ)	Shannon-Weaver Index (H′)	Evenness indices: Pielou's Index (J′)	Hill's Index (E′)
Monocropping	16	0.20	2.06	0.71	0.63
Multiple cropping	16	0.14	2.36	0.82	0.71

spiders per 20 hills were recorded at 15 DAT in multiple-single sequence, multiple-double sequence and monocropping fields, respectively. Spider population over the crop growth stages indicated that highest spider population of 15.50 spiders per 20 hills was recorded in multiple-single rice cropping systems at 45 DAT which was at par with rest of crop growth. Multiple-double rice cropping system recorded highest spider population of 34.50 per 20 hills at 90 DAT which was at par with 75 DAT, but significantly different form rest of the crop growth. Monocropping system recorded highest population of 50.50 spiders per 20 hills at 60 DAT which was significantly highest than rest of the crop growth.

Spider population on the bunds was highest at 75 DAT (16.0 spiders/4 linear m.) in monocropping system which was at par with population at 105 DAT, but significantly high compared to rest of the crop growth and also when compared to multiple cropping systems. Overall, the spider population increased with crop growth under all the rice growing systems.

Simpson's (λ) and Shannon-Weaver's (H^1) diversity indices showed higher spider diversity in multiple cropping system ($\lambda = 0.14$; H^1=2.36, respectively) compared to monocropping system (λ=0.20; H^1 = 2.06, respectively). Multiple cropping system recorded higher Pielou's evenness index (J^1=0.82) and Hill's evenness index (H^1=0.71) compared to the monocropping system (J^1=0.71; H^1=0.63) (Table 4).

Spider species richness (S) increased with the crop growth and reached maximum of 16 at 90 DAT (Tables 5 and 6). Simpson's diversity index (λ) was highest at 45 DAT (λ=0.25) and decreased with crop age and reached lowest value at 90 DAT (λ=0.13). Whereas, Shannon-Weaver's (H^1) diversity index was lowest at 30 DAT (H^1=0.60) and increased with crop age and reached highest diversity at 105 DAT (H^1=2.40). Evenness indices such as Pielou's evenness (J^1) and Hill's evenness (E^1) indices were highest at 15 DAT (J^1=0.86) and 30 DAT (E^1=0.85), respectively. Further, the evenness indices decreased with crop growth and recorded lowest Pielou's evenness (J^1) and Hill's evenness (E^1) indices at 105 DAT (J^1=0.66) and 75 DAT (E^1=0.55).

Hunting spiders represented the highest percentage of Araneae in both multiple and monocropping systems. Webbing spiders had higher representation in monocropping fields compared to multiple cropping fields which is in agreement with the observations of Nakamura (1982).

Some of the lycosid species which are sensitive to moisture, dominated the monocropping fields and some species which are dependent on high prey population were confined only to monocropping (viz., *Theridion* sp. and *Argiope* sp.). The spider species which have better capacity of survival in dry conditions during the off-season or non-rice crops such as sugarcane, ragi or vegetable were represented in higher populations in multiple cropping fields (viz., *Myrmarachne* sp., *Tibellus pateli* Tikader, *P. birmanica* and *Oxyopes ratanae* Tikader) than those in monocropping fields. Similarly, Yu and Wang (1993) reported *Erigone graminicolum* as co-dominant species in rice fields surrounded by dryland crops such as cotton, ramie, and legumes.

Significantly, higher population of spiders was recorded in the main field and on the bunds of monocropping systems compared to multiple cropping systems. However, spider population was higher in the double sequence cropping fields compared to single sequence multiple cropping fields. Similar observations were made by Ansari and Pawar (1992) who recorded less number of spider in single cropped areas compared to double cropped and monocropped areas.

In single cropped fields, the spider population was low and without distinct peaks in early stages of the crop because of lack of spider population in the surrounding areas. In monocropped fields, there was a high initial spider population. This is possibly due to the fact that spider population in these fields was less subjected to the drastic ecological changes between the season or over the seasons in a year because bunds and natural grass lands served as alter-

Table 6. Diversity and evenness indices of spiders at different stages of the crop growth during *kharif* of 1995. DAT, Days after transplanting.

		Diversity indices		Evenness indices	
Stage of the crop (DAT)	Species richness (S)	Simpson's Index (λ)	Shannon-Weaver Index (H′)	Pielou's Index (J′)	Hill's Index (E′)
15	8	0.21	1.80	0.86	0.80
30	9	0.24	1.60	0.73	0.85
45	12	0.25	1.86	0.72	0.63
60	14	0.21	2.02	0.76	0.63
75	14	0.22	2.12	0.76	0.55
90	16	0.13	2.39	0.84	0.70
105	16	0.14	2.40	0.66	0.66
Pooled over the crop growth period	16	0.18	2.23	0.76	0.61

native habitats (Kim and Lee 1994). Drastic drop in the spider population prior to harvesting in single cropped fields might be attributed to scanty water and/or prey.

The spider population in double-multiple cropping systems showed a steady increase upto 90 DAT, whereas in the monocropped fields, it was subjected to greater fluctuations within a crop growth period. These fluctuations in monocropped fields can be attributed to a migration of spiders from the natural grass lands and embankments which were usually more in monocropped fields and also to the availability of suitability of suitable prey in the main field as reported by Kobayashi and Shibata (1973) and Sarma (1987).

Both Simpson's index (λ) and Shannon-Weaver index (H^1) showed a higher diversity of spider species in multiple cropping systems compared to the monocropping systems. The spider fauna was more even in the multiple cropping system than in monocropping system as indicated by the Pielou's and Hill's evenness indices, which might have contributed input to the observed higher diversity value in multiple cropping system.

However, reports from the Philippines suggest greater diversity of spiders in lowland cropping systems compared to upland system (Anon 1983). The observed difference in the present study might be due to fact that monocropping systems studied here were discontinuous, whereas those studied at the Philippines were continuous. The continuous cropping may favor increased survival and greater immigration rates of spider species and discontinuous cropping system may result in lower immigration rates and lower survival rates with the presence of the crop. Further, the reason that multiple cropping system indicated higher diversity values suggests a situation similar to that of continuous cropping system. In other words, it is likely that some of the species of spiders occurring on rice, may also survive in other crops, which allows them to migrate over to rice when the crop is available.

Both Simpson's (λ) and Shannon's (H^1) indices of diversity are in agreement in showing a general pattern of species diversity of spiders in rice ecosystem. The diversity in spider fauna was less at early stages of the crop growth and increased with the crop maturity. This observation is in agreement with those of Nishida et al. (1983) and Zhang (1989). The diversity of spiders increased greatly at 75 days after transplanting and reached peak at 105 DAT. The increased complexity of rice plant with age probably explains the reasons for increased species diversity of the spiders (Brown and Southwood 1987).

The Pielou's evenness index which takes all the species into consideration, showed less deviations in the number of species of spiders at the beginning and end of the crop growth period. However, this pattern was also evident during earlier studies, which indicated a monotonous increase in evenness indices values with increasing age of the crop (Zhang 1989). The spiders were subjected to greater fluctuations at maximum vegetative stage and were stabilized as crop matured which might be due to two possible reasons. One is that the initial colonization pattern of spider species is more or less uniform at the beginning of the cropping period. Later, with increasing age some species might increase in number due to regular immigration and/or *in situ* multiplication. The second reason is that the diminishing pattern of prey (insects) with the age of crop might lead to greater migration to other field or the spiders might perish (death) because of age or cannibalism.

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