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Occurrence of spider fauna in relation to biotic and abiotic factors in rice eco system

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Abstract
Occurrence of spider fauna in relation to biotic and abiotic factors in rice eco system was studied at Central Research Station and Department of Entomology, Odisha University of Agriculture and Technology, Bhubaneswar, during *Kharif* 2018-2019 and *kharif* 2019-20. A total of 622 spider specimens belonging to 9 species, 7 genera and 4 families were collected from rice ecosystem under Bhubaneswar conditions by various sampling methods. The four recorded spider families in order of abundance were Araneidae < Tetragnathidae < Lycosidae < Oxyopidae. Araneidae and Tetragnathidae were the two dominant spider families as four species *viz.*, spotted orb weaver, *Neoscona elliptical* (Tikader and Bal), grass cross spider, *Argiope catenulate* (Doleschall), orb weaving spider, *Araneus* sp, Larinia orb weaver, *Larinia* sp were recorded under family Araneidae where as three species *viz.*, big jawed spider, *Tetragnatha mandibulata* (Walckenaer), long jaw spider, *Tetragnatha maxillosa* (Thorell), tailed tetragnathid spider, *Tetragnatha javana* (Thorell) were recorded under family Tetragnathidae. The families Lycosidae and Oxyopidae were represented by single species viz., wolf spider, *Pardosa pseudoannulata* (Boes and Strand) and lynx spider, *Oxyopes bharatae* (Gajbe), respectively. All the nine spider species recorded were active at vegetative stage, reproductive stage and ripening stage of the crop. Maximum population of spider (1.40/ $m^{2)}$ was noticed at reproductive phase during 45th std week (Nov 4-10) synchronizing with the peak activity period of BPH (18/hill) and WBPH (17/hill). A highly significant positive correlation existed between population of spiders irrespective of species and the incidence of leaf folder, WBPH, BPH and gundhi bug in both the seasons. Spider population regardless of species showed non significant negative correlation with minimum temperature, morning relative humidity, evening relative humidity and rainfall.

Keywords: rice, abiotic, biotic, spider, Odisha, temperature, relative humidity, ecosystem, correlation, predator, vegetative stage, reproductive stage and ripening stage

Introduction
Rice, *Oryza sativa* L. (Family: Graminae) an important cereal crop is grown successfully in humid to sub humid regions under subtropical and temperate climate. This predominant cereal crop plays a pivotal role in our national food security and is a means of livelihood for millions of rural households. Attack of an array of insect pest at various growth stages of the crop is pondered as one of the primary biotic constraints in rice production systems. More than 100 species of insect are known to attack the crop out of which about 20 species are of economic importance. The overall losses due to insect pest damage in rice are estimated at 18.5 per cent [1]. Spiders, the most familiar and ubiquitous obligatory carnivores which feed on different types of prey are potential biological control agents in agroecosystems [2]. As predators, these are important components of natural ecosystems, playing a vital role in structuring arthropod communities and thus having a significant role in the balance of nature [3]. Nearly 350 species of spiders are reported to occur as early season predator in the rice ecosystem in south and South East Asia [4]. Spiders, the boon to rice farmers are being used effectively in managing the pests in South East Asia. Several studies showed spiders as suppressant of the rice pests like brown plant hopper, *Nilaparvta lugens* (Stal), white backed plant hopper, *Sogatella furcifera* (Horvath), green leaf hopper, *Nephotettix virescens* (Distant) [5], yellow stem borer, *Scirpophaga incertulas* (Walker) [6]. It is an established fact that meteorological factors play an important role on the population fluctuation of spiders at various growth stages of rice along with the impact of other factors for their survival. Further, the crop having more insect or insect visitors always had more spiders [7]. Information on seasonal occurrence of spider in relation to weather parameters and insect pests of rice is imperative for evolving sustainable

pest management strategies. However, meager information is available on these aspects under the coastal agroecosystem of Odisha. Hence, the present investigation was undertaken to study the population dynamics of spiders at different growth stages of rice in relation to biotic and abiotic factors.

Materials and Methods

Field experiments were carried out at the Central Research Station, Department of Entomology, Odisha University of Agriculture and Technology, Bhubaneswar during *Kharif* 2018 and *Kharif* 2019. The study area was located at an altitude of 45.9 M ($45^0$52'E /20^0 15' N) and receives 1505mm rainfall annually. Documentation of spider in rice ecosystem was carried out from the observational strip. The rice crop (var swarna) was raised under the unprotected conditions following the standard agronomic package of practices. Three methods viz., direct counting method, sweep net method and pit fall trap method were followed to gather information regarding the aerial and ground species composition of spiders at weekly interval during morning hours starting from 7th day after transplanting. Activity of spiders irrespective of species was monitored at weekly intervals in rice (var Swarna) from 33rd std week (Aug12-18) to 50th std week (Dec9-15) during both the years for which its population per each quadrant of one square meter canopy area was recorded. Simultaneously, observation on incidence of major insect pest of rice were also recorded from the same 20 quadrants of one square meter of observation plot selected for spider occurrence study by following standard method [8].

For yellow stem borer **c**ounts were taken of dead hearts / white ears and total number tillers/ panicle from the selected hills. The percent incidence of (dead heart/ white ears) was calculated. The number of motile stages of brown plant hopper, *Nilaparvata lugens* and white backed plant hopper, *Sogatella furcifera* was recorded from all the selected hills. The total count was averaged and expressed in number per hill basis**.** For leaf folder **t**he damaged leaves and total leaves from the selected hills were observed in the rice field from which the percentage of leaf damage was calculated as follows. The observations on gundhi bug were recorded by sweeping insect collecting nets five times across the rice field and number of nymphs and adults bugs are counted from the selected quadrants. The meteorological data such as maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and rainfall were collected from the Agro-meteorology Center, Orissa University of Agriculture and Technology, Bhubaneswar. The relationship between the abiotic factors and the incidence of major insect pests of rice along with the population of spiders was established using correlation analysis.

Results and Discussion

A total of 622 spider specimens belonging to 9 species, 7 genera and 4 families were collected from rice ecosystem under Bhubaneswar conditions by various sampling methods. The four recorded spider families in order of abundance were Araneidae < Tetragnathidae < Lycosidae < Oxyopidae. Araneidae and Tetragnathidae were the two dominant spider families as four species *viz.*, spotted orb weaver, *Neoscona elliptical* (Tikader and Bal), grass cross spider, *Argiope catenulate* (Doleschall), orb weaving spider, *Araneus* sp, Larinia orb weaver, *Larinia* sp were recorded under family Araneidae where as three species *viz.*, big jawed spider, *Tetragnatha mandibulata* (Walckenaer), long jaw spider, *Tetragnatha maxillosa* (Thorell), tailed tetragnathid spider, *Tetragnatha javana* (Thorell) were recorded under family Tetragnathidae. The families Lycosidae and Oxyopidae were represented by single species viz., wolf spider, *Pardosa pseudoannulata* (Boes and Strand) and lynx spider, *Oxyopes bharatae* (Gajbe), respectively. All the nine spider species recorded were active at vegetative stage, reproductive stage and ripening stage of the crop.

Seasonal occurrence of spiders in rice ecosystem: Results on the seasonal occurrence of spiders irrespective of species during *kharif* 2018-19 unraveled that they appeared during 33rd std week (Aug12-18) with a population of 0.1/m^2 and their population gradually increased reaching a peak (1.15/ m^2) during 45th std week (Nov4-10) (Table 1). Thereafter its activity gradually started declining but remained active till 50th std week (Dec 9-15) with a population ranging from 0.45 to 1.0 / m^2. The maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and rainfall during peak activity period of spiders were 31.5 ^{0}C, 21.30 ^{0}C, 95.10 per cent, 52.97 per cent and 1.54 mm respectively. Mean population of spider over the period of observations during the year was 0.74/ m$^{2.}$

During *kharif* 2019-20 the population of spiders ranged between 0.1-1.65/m^{2}during its period of activity (Table 1). It first appeared during 33rd std week (Aug12-18) (0.10m^2) and its population continued to increase attaining its peak (1.5/m^2) during 46th std week (Nov11-17). Then its population declined but remained active till the harvest of crop. During its peak period of activity prevailing meteorological parameters *viz.*, maximum temperature, minimum temperature, morning relative humidity, evening relative humidity and rainfall were 30.9 ^{0}C, 19.60 ^{0}C, 92.30 per cent, 51.3 per cent and 0.00 mm, respectively. Mean population of spider over the period of observations during the year was 0.97/ m^2.

Mean pooled data on the population fluctuation of spiders in rice ecosystem of both the years *kharif* 2018-19 and *kharif* 2019-20 indicated that its activity commenced during 33rd std week (Aug12-18)(0.10/ m$^{2.}$) and continued its activity upto 50th std week (Feb19-25) (0.42/ m$^{2.}$). Peak spider population (1.40/ m$^{2.}$) was noticed during 45th std week (Nov4-10). On average 0.85 nos of spider / m^2 was recorded over the period of observation of both the years (Table 1).

The present findings on peak activity period of spider during 45th std week (Nov4-10) was in accordance with the report of maximum population of spider found during November [9]. However, the result of present studies on peak activity of spider were not in agreement with the findings of [10, 11] as they found the peak occurrence during first week of September at Jammu and during July- August at Faizabad, respectively. Such variations might be due to impact of various abiotic factors and prey availability.

Table 1: Seasonal occurrence of spider irrespective of species in rice at during *kharif* 2018-19 and *kharif* 2019-20

Standard Week	Population of spiders (No /m^2)		
	***kharif* 2018-19**	***kharif* 2019-20**	**Mean**
A. Vegetative phase			
33rd(Aug12-18)	0.10	0.10	0.10
34th(Aug19-25)	0.40	0.50	0.45
35th(Aug26-Sep1)	0.40	0.65	0.52
36th(Sep2-8)	0.60	0.85	0.72
37th(Sep9-15)	0.55	0.85	0.70
38th(Sep16-22)	0.65	1.00	0.82
39th(Sep23-29)	0.95	1.25	1.10
B. Reproductive phase			
40th(Sep30-Oct6)	1.00	1.15	1.07
41st(Oct7-13)	0.85	1.40	1.12
42nd(Oct14-20)	1.15	0.90	1.02
43rd(Oct21-27)	0.70	1.05	0.87
44th(Oct28-Nov3)	1.15	1.25	1.20
45th (Nov4-10)	1.15	1.65	1.40
C. Ripening phase			
46th(Nov11-17)	0.95	1.75	1.35
47th(Nov18-24)	1.00	1.35	1.17
48th(Nov25-Dec1)	0.90	0.95	0.92
49th(Dec2-8)	0.45	0.55	0.50
50th(Dec9-15)	0.45	0.40	0.42
Mean	0.74	0.97	0.85

Influence of meteorological factors on activity of spider: Results on the correlation studies during *kharif* 2018-19 revealed that among the meteorological factors, only maximum temperature(r= 0.243) showed a non significant positively correlation with the population of spider (Table 2). A non-significant negative correlation existed between the spider population with minimum temperature (r= -0.098), morning relative humidity (r= -0.307) and evening relative humidity (r= -0.156) rainfall (r = -0.375). The multiple regression analysis evinced that the meteorological parameters contributed for 70.69 per cent of total variation in the total spider population.

Data on correlation studies during *Kharif* 2019-20 indicated that all the meteorological factors *viz*., maximum temperature (r = -0.114), minimum temperature (r = -0.174), morning relative humidity (r = -0.117), evening relative humidity (r = -0.357) and rainfall (r = -0.033) exhibited non significant negative correlation with spider population (Table 2). A total variation of 54.33 in population count of spider was brought about by meteorological factors as inferred from multiple regression analysis.

Present findings are reported that most of the abiotic factors had negative correlation with spider population [12]. Non significant negative correlation of spider population with maximum temperature and minimum temperature was also established [13]. Except maximum relative humidity rests of the meteorological parameters were not found to have a significant effect on the spider families [14]. Negative influence of rainfall on spider population has also been highlighted [15].

Influence of biotic factors (host insect) on population dynamics of spiders: About five insect species *viz*., yellow stem borer, *Scirphophaga incertulus* (Walker), leaf folder, *Cnaphalocrosis mendinalis* (Guenee), white backed plant hopper, *Sogatella furcifera* (Horvath), brown plant hopper, *Nilaparvata lugens* (Stal) and gundi bug, *Leptocorisa oratoria* (Fabricius) were found attacking the crop at various growth stages during both the years. Results on insect pest infestation during *kharif* 2018-19 unraveled that dead heart (%) by yellow stem borer varied from 3.21 to 8.30 during 33rd week (Aug12-18) (1stweeks after transplanting) to 40th std week (Oct 30-Nov6) (8weeks after transplanting) (Table 3). Maximum dead heart damage (8.30%) was noticed during 40th std week (Oct 30-Nov6) (8weeks after transplanting). At reproductive stage of growth white ear head damage by yellow stem borer (8.27%) was observed during 44th std week (Oct 28-Nov 3) (12th week after transplanting) and continued its activity till the harvest of crop. Maximum white ear head damage (10.2%) was recorded during 50th std week. Leaf folder damage ranged from (1.21%) to (17.60%) during 34rd week (Aug 19-25) (2nd weeks after transplanting) to 50th std week (Dec 9-15) (18 weeks after transplanting). Highest leaf folder damage was noticed during 42nd (Oct 14-20) (10th weeks after transplanting). Incidence of BPH (1.0/10hill) commenced during 38th std week at reproductive stage and continued its activity till harvest of the crop. Maximum BPH population (18.00/10hill) was recorded during 45th std week (Nov4-10) (13thweeks after transplanting). Population of WBPH varied from 1.00/10hill to 17.00 /10hill during vegetative to ripening stage of the crop (34th std week to50th std week). Its peak activity (17.00 /10hill) was recorded during 45thstd week (Nov4-10) (13thweeks after transplanting). Gundhi bug population was very low (1.00/five sweep nets) in the vegetative stage 39 (Sept 23-29) (7thweeks after transplanting). Its highest population (17.00/five sweep nets) was noticed during 47th std week (Nov 18-24) (15th week after transplanting. Later its activity gradually declined.

Results on insect pest infestation during *kharif* 2019-20 evinced that dead heart (%) by yellow stem borer varied from 2.50 to 6.30 during 34th std week (Aug21-27) (2nd weeks after transplanting) to 40th std week (Oct 30-Nov6) (8weeks after transplanting) (Table 4) Maximum dead heart damage (6.30%) was noticed during 40th std week (Oct 1-6) (8weeks after transplanting). At reproductive stage of growth white ear head damage by yellow stem borer (3.42%) was observed during 44th std week (Oct 28-Nov 2) (12th week after transplanting and continued its activity till the harvest of crop.

Maximum white ear head damage (10.2%) was recorded during 50th std week (18). Leaf folder damage ranged from 1.14 to 18.60 during 35thstdweek (Aug 27- Sept 2) (3 weeks after transplanting) to 50th std week (Dec 7-13) (18 weeks after transplanting). Highest leaf folder damage was noticed during 43rd (Oct 21-27) 11thstd weeks after transplanting. Incidence of BPH (1.0/10hill) commenced during 39th std week at reproductive stage and continued its activity till harvest of the crop. Maximum BPH population (16.00/10hill) was recorded during 45th std week (Nov 3-9) (13th weeks after transplanting). Population of WBPH varied from 1.00/10hill to 17.00 /10hill during vegetative to ripening stage of the crop (35th std week to 50th std week). Its peak activity (17.00 /10hill) was recorded during 45th std week (Nov 3-9) (13th weeks after transplanting). Gundi bug population was very low (1.00/5 sweep nets) in the reproductive stage during 42nd std week (Oct 14-20) (10 weeks after transplanting).Its highest population (14.00/5 sweep nets) was noticed during 46th std week (Nov 10-16) (14week after transplanting). Later its activity gradually declined.

Table 2: Correlation coefficients(r)/regression equations of the occurrence of spider species in rice with weather parameters at Bhubaneswar during *kharif* 2018-19 and 2019-20

Population of spider (No /m^2 plant)	Temperature (^{0}C)		Relative humidity (%)		Total rainfall (mm)	R^2	Regression equation (Y= A+Bx$_1$+Cx$_2$+Dx$_3$+Ex$_4$+Fx$_5$)
	Max	Min	Morn.	Even.			
Kharfi 2018- 19	0.243 NS	-0.098 NS	-0.307 NS	-0.156 NS	-0.375 NS	70.69%	Y= -7.10 + 0.28x$_1$ - 0.02x$_2$ +0.00x$_3$ + 0.00x$_4$ - 0.14x$_5$
Kharif 2019-20	-0.114 NS	-0.174 NS	-0.117 NS	-0.357 NS	-0.033 NS	54.33%	Y= 3.57-0.09 x$_1$ + 0.19x$_2$ + 0.01x$_3$ - 0.08x$_4$ + 0.00 x$_5$

NS = Non Significant

Table 3: Incidence of major insect pests of rice at Bhubaneswar during *kharif* 2018-2019.

Standard weeks	Stage of the crop (week after transplanting)	Yellow stem borer		Leaf folder (%leaf infestation)	Brown plant hopper (No of insects/10 hills)	White backed plant hopper (No of insect/10 hills	Gundi bug (No of insects/5 sweep nets)
		Dead heart (%)	White ear head (%)				
A. Vegetative phase							
33(Aug12-18)	1	3.21	0.00	0.00	0.00	0.00	0.00
34(Aug 19-25)	2	3.78	0.00	1.21	0.00	3.00	0.00
35(Aug 26-1)	3	4.90	0.00	2.24	0.00	6.30	0.00
36(Sept 2-8)	4	4.97	0.00	3.50	0.00	8.00	0.00
37(Sept 9-15)	5	5.21	0.00	4.90	0.00	9.00	0.00
38(Sept 16-22)	6	6.48	0.00	5.13	1.00	10.10	0.00
39(Sept 23-29)	7	6.71	0.00	9.40	10.00	14.40	1.00
B. Reproductive phase							
40(Oct 30-6)	8	8.30	0.00	9.70	12.83	13.00	3.00
41(Oct 7-13)	9	0.00	0.00	12.20	15.00	15.40	4.00
42(Oct 14-20)	10	0.00	0.00	17.60	15.70	16.70	9.00
43(Oct 21-27)	11	0.00	0.00	17.12	15.70	14.40	10.30
44(Nov 28-3)	12	0.00	8.27	13.30	16.00	16.70	11.60
45(Nov 4-10)	13	0.00	9.43	11.20	18.00	17.00	14.33
C .Ripening phase							
46(Nov11-17)	14	0.00	10.11	5.40	14.40	6.30	15.00
47(Nov 18-24)	15	0.00	10.19	7.14	12.00	2.00	17.00
48 (Nov 25-1)	16	0.00	10.20	7.12	7.00	1.00	7.00
49(Dec 2-8)	17	0.00	10.20	2.28	3.00	1.00	2.00
50(Dec 9-15)	18	0.00	10.20	1.16	2.00	1.00	1.00

Table 4: Incidence of major insect pests of rice at Bhubaneswar during *kharif*2019-2020

Standard weeks	Stage of the crop (week after transplanting)	Yellow stem borer		Leaf folder (%leaf infestation)	Brown plant hopper (No of insects/10 hills)	White backed plant hopper (No of insect/10 hills	Gundi bug (No of insects/5 sweep nets)
		Dead heart (%)	White ear head (%)				
A. Vegetative phase							
33(Aug 14-20)	1	0.00	0.00	0.00	0.00	0.00	0.00
34(Aug 21-26)	2	2.50	0.00	0.00	0.00	0.00	0.00
35 (Aug27-2)	3	3.51	0.00	1.14	0.00	1.00	0.00
36 (Sept 3-9)	4	4.10	0.00	2.50	0.00	3.00	0.00
37(Sept 10-16)	5	4.50	0.00	4.90	0.00	6.30	0.00
38(Sept 17-23)	6	5.48	0.00	5.13	0.00	8.00	0.00
39(Sept 24-30)	7	5.71	0.00	9.40	1.00	9.00	0.00
B. Reproductive phase							
40(Oct 1-6)	8	6.30	0.00	9.70	2.00	10.10	0.00
41(Oct 7-13)	9	0.00	0.00	12.20	4.30	14.40	0.00
42(Oct 14-20)	10	0.00	0.00	17.00	8.80	16.00	1.00

43(Oct 21-27)	11	0.00	0.00	**18.60**	12.80	16.70	3.00
44(Oct 28-2)	12	0.00	3.42	13.30	14.40	16.70	9.00
45(Nov 3-9)	13	0.00	4.12	11.20	**16.00**	**17.00**	11.60
C .Ripening phase							
46(Nov 10-16)	14	0.00	6.11	7.16	14.00	12.40	**14.00**
47(Nov17-23)	15	0.00	7.19	5.43	12.00	10.30	12.40
48(Nov24-30)	16	0.00	9.20	4.58	8.00	6.30	7.00
49(Dec1-6)	17	0.00	9.20	2.21	4.00	2.00	2.00
50(Dec 7-13)	18	0.00	10.20	1.18	2.00	1.00	1.00

Results on the correlation between the incidence of insect pest of rice and population fluctuation of spider during *kharif* 2018-19 indicated that spider population showed a highly significant and positive correlation with leaf folder (r = 0.797**), WBPH (r = 0.603**), BPH (r = 0.830**) and gundi bug (r = 0.714**) (Table 5). A negative but non-significant correlation existed between yellow stem borer (dead heart) and spider population (r = - 0.247).While the incidence of yellow stem borer (white ear head) showed a non significant positive correlation (r = 0.291) with spider population.

Interaction between population fluctuation of spiders and the incidence of insect pests of rice during *Kharif* 2019-20 revealed that spider population exhibited a highly significant and positive correlation with leaf folder (0.594**), WBPH (r = 0.767**), BPH (r = 0.670**) and gundi bug (r = 0.656**). A negative but non-significant correlation endured between yellow stem borer (dead heart) and spider population (r = - 0.095).While the incidence of yellow stem borer (white ear head) had a non significant positive correlation (r =0.035) with spider population (Table 5).

Table 5: Correlation (r) between the population of spider species with incidence of major insect pest of rice at Bhubaneswar during *kharif* 2018-19 and 2019-20

Population of spider (No /m^2 plant)	Yellow stem borer (Dead Heart%)	Yellow stem borer (White ear head%)	Leaf folder	WBPH	BPH	Gundi bug
Kharif 2018- 19	-0.247 NS	0.291 NS	0.797**	0.603**	0.830**	0.714**
Kharif 2019-20	-0.095 NS	0.035 NS	0.594**	0.767**	0.670**	0.656**

** Significant at 1% level of significance
NS = Non Significant

The insect pest population of rice had positive correlation with spider population at Faizabad [16]. Spider population exhibited significant positive correlation with GLH, BPH and WBPH at various locations [17, 18]. The population of yellow stem borer showed significant positive impact on activity of *Lycosa pseudoannualata* and *Oxyopes javanus* in rice [19]. positive significant correlation between spider population and leaf folder [20]. The present results get ample support from the work of above authors.

Conclusion

A total of 622 spider specimens belonging to 9 species, 7 genera and 4 families were collected from rice ecosystem under Bhubaneswar conditions by various sampling methods. The four recorded spider families in order of abundance were Araneidae < Tetragnathidae < Lycosidae < Oxyopidae. Studies on the seasonal occurrence of spiders irrespective of species in rice under unprotected conditions revealed that spider abundance was observed throughout the entire crop growth period. Its activity commenced from 33rd std week (Aug12-18) with a mean population of 0.10/ $m^{2.}$and was found till 50th std week (Dec9-15) with a mean population of 0.42/ m^2.Maximum population of spider (1.40/ $m^{2.}$) was noticed at reproductive phase during 45th std week (Nov4-10) synchronizing with the peak activity period of BPH (18/hill) and WBPH (17/hill). Maximum temperature had a significant positive influence on spider population during *Kharif*, 2018-19 but was negatively correlated with maximum temperature during *Kharif* 2019-20.Interaction between population fluctuations of spiders and the incidence of insect pests of rice unraveled that a highly significant positive correlation existed between the incidence of leaf folder, WBPH, BPH and gundi bug and population of spiders irrespective of species in both the seasons.

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