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Faunistic and diagnostics of predaceous spiders in rice ecosystem under Terai region of West Bengal

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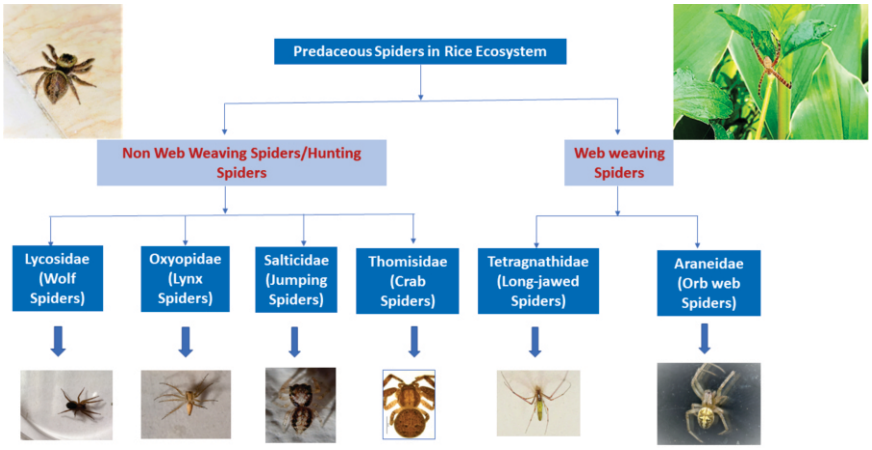
Abstract

Aim: Analyzing the community structure of predatory spider fauna in rice ecosystems to facilitate conservation biological control and sustainable pest management programmes.

Methodology: The spiders were collected from rice field with cultivated variety (MTU-7029) during both *Kharif* and *Rabi* seasons at different rice growth stages. The spiders collected by various sampling methods such as direct catch in polythene carry bags, ground collection and foliage collection were kept in collection bottles and killed by inserting a strip of cotton dipped in chloroform and transferred separately on a white sheet of paper.Thereafter, using a stereo zoom microscope (ZEISS Stemi 508), the spiders were sorted, separated, counted, identified based on the available keys and literature described by Tikader (1987) and Barrion and Litsinger (1995). The unidentified samples were sent to the Zoological Survey of India, Kolkata for authorized identification.

Results: In total, sixteen different species of predatory spiders belonging to six families of order Araneae and representing four functional/foraging guilds were identified in the rice ecosystem of Sub-Himalayan Terai region of West Bengal. These included *Lycosa pseudoannulata* Boesenberg & Strand and *Arctosa tanakai Barrion* & Litsinger; *Oxyopes lineatipes* C.L. Koch, *Oxyopes javanus* Thorell and *Oxyopes salticus* Hentz; *Bianor* sp. and *Hasarius adansoni* Audouin, while the family Thomisidae was represented by a single species *Thomisius* sp. All these eight species constituted the non web former group of spiders. The web weaving spiders recorded were *Tetragnatha maxillosa* Thorell, *Tetragnatha mandibulata* Walckenaer. *Tetragnatha javana* Thorell, *Leucage decorate* Walckenaer, *Leucage celesbesiana* Walckenaer and *Neoscona theisi* Walckenaer, *Neoscona mukerjei* Tikader, *Araneus* sp.



Interpretation: The lynx spiders (Oxyopidae) were found to be the most dominant group by individual numbers, followed by the wolf spiders (Lycosidae), however, considering the species richness, the long jawed spiders (Tetragnathidae) were in large number with five different species. Good agricultural practices along with habitat diversification of landscapes are imperative for enhancing the predation by rice field spiders.

Key words: Dominance, Foraging guilds, Predatory spiders, Rice, Species richness, Terai region

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Introduction

Spiders are air breathing arthropods, body divided into cephalothorax and abdomen, having eight legs and chelicerae with fangs that is used for injecting venom.Among all organisms, spiders (Order: Araneae) form the seventh largest order in terms of number of known species, after Coleoptera, Hymenoptera, Lepidoptera, Diptera, Hemiptera and Acarina. Spiders play an important role as they are exclusively predatory (Wise, 1993) and feed on a variety of available prey. They not only prey on adult insect pests but also feed on their eggs and larvae. Spiders are good friends of farmers as they control all types of pests in the crop. They play an important role in maintaining biological balance of nature and stabilizing or regulating insect populations in forest as well as in the agriculture ecosystem. Faunistic studies of different spider species from wildlife sanctuaries have been investigated by many researchers (Patal, 2003; Bhatkar, 2011; Chetia and Kalita, 2012).

Species composition of spider fauna in paddy, maize and cotton ecosystem have been explored at length by Yadav *et al.* (2016), Saranya *et al.* (2019) and Bukhari *et al.* (2012), respectively. Sahu *et al.* (1996), Vanitha *et al.* (2009) and Mathirajan and Raghupathy (2003) studied the prey preference and feeding potential of predaceous spiders in rice and cotton ecosystems. They play an important role in agroecosystem as predators, stabilizers of invader-defender equilibrium and as bio-indicators of environmental health that could be utilized for conservation purposes as well as for Integrated Pest Management Programmes (Gerlach *et al.,* 2013; Benamu, 2020). The role of spiders in the rice fields as predators of hoppers and other pests have been reported by several workers from India and abroad. Barrion *et al.* (2012) studied on spider biodiversity exploration, the first activity executed in selected areas in August 2010 yielded 10,426 specimens made up of spiderlings, subadults and adults. The composition represented 167 species under 97 genera and 19 families. Spiders represents more than 90 % of the natural enemies of brown plant hoppers living in paddy fields in Korea (Lee *et al.,* 1997). Raju *et al.* (2021) documented 23 species of spiders belonging to thirteen different families in the rice ecosystems of Telangana state of India. Similarly, a total of sixty-five species of spiders belonging to eleven families and seven foraging guilds were documented in the rice ecosystem of Kerala (Joseph and Premila, 2016).

From Mizoram state of North East India Chowdhury *et al.* (2017) reported thirty-one species of spiders representing twenty genera and ten families as polyphagous predators in rice ecosystem.During the periodic surveys carried out in the fields in Eastern Himalayan region of West Bengal, 21 species of predaceous spiders belonging to eight families were reported (Satpathi, 2004). In general, faunistic studies on spiders of cultivated rice fields in Terai region of West Bengal are comparatively few and limited. No specific extensive studies on spider faunal diversity of rice ecosystems in this region have been conducted and published. It is the first attempt from this region, to study the spider fauna, thus providing base line information for future studies on the understanding the community structure and various foraging guilds of spiders, their conservation and utilization in the rice-based cropping systems of sub-Himalayan Terai region of West Bengal.

Materials and Methods

Studies on the faunistic survey of spiders were conducted in the instructional farm of Uttar Banga Krishi Viswavidyalaya, Pundibari (89°23'53" E longitude and 26°19'86" N latitude at an altitude of 43 m above the MSL), Cooch Behar, West Bengal (India) from 2019 to 2021 during both *Kharif* and *Rabi* seasons. The area of cultivation comprised irrigated double cropped fields with high cropping intensity, characterized by typical humid sub-tropical climate. To document different species of spider, a rice field was maintained by growing the variety Swarna (MTU-7029). The rice crop was sown in the 2nd week of June followed by transplanting in the 2nd week of July in *Kharif* season and 1st week of February followed by transplanting in the 1st week of March in Rabi season during 2019 to 2021 in an area of about 1 bigha (1333 sq.m.). The crop was raised under standard agronomic practices with the application of fertilizer @ 80:40:40 kg NPK ha^{-1} during *Kharif* season and 120:60:60 kg NPK ha^{-1} during *Rabi* season with a spacing of 20cm X 15cm in both *Kharif* and *Rabi* seasons of each year, respectively. To encourage the natural multiplication and growth of the spiders, no pesticide was used in the rice field. Population of spiders were recorded by following different sampling methods.

Sampling: Sampling was done in *Kharif* and Rabi seasons of 2019 to 2021 at different stages of rice growth, *i.e.,* nursery, vegetative, reproductive and maturity stages of rice at weekly interval. The following methods were used for sampling (Samu and Szinetar, 2002; Chowdhury *et al.,* 2017).

By direct counting: Twenty hills of rice plants were selected randomly from each sample plots of size 20m X 4m for direct counting of spiders and the plants were thoroughly screened at weekly interval to collect the spiders. Spiders observed on the crop canopy, from the webs in between the plants, from the webs in individual leaf folds, border weeds and field bunds were carefully collected in specimen tubes (9.0 cm x 2.5 cm) and brought to the laboratory for sorting and grouping.

Ground collection: Ground-active spiders were collected by pitfall traps. Wide mouth glass jars (6 cm diameter x 12 cm deep) were used as pitfall traps. During sampling, the jars were buried in the soil such that their rims were at level with the ground. At each site, traps were set in 3 m x 3 m grid pattern at twelve locations (6 grids within 30 m of margin and 6 grids in the centre of the fields). To each trap, 250 ml of 70 % alcohol and two drops of 5 % liquid detergent was added. At each location, traps were operated consecutively for 72 hours (= trapping session) after every week.

Foliage collection: Insect sweep nets were used at crop canopy

to collect the spiders from the foliage of rice plants. Sweeping was done at weekly interval and ten numbers of sweeps (complete sweep once in both directions) were taken for each sampling. Collection was done during early morning hours between 6 am to 9 am. Twenty spots were identified according to visual observation and sweepings were done with the help of insect net. About ten return or complete net sweepings were taken each time. Spiders of all life stages (spiderling and adult) were collected during sampling. The collected sweep nets were transferred into long polythene bags (20 cm x 12.5 cm) and brought to the laboratory. The spider specimens collected by various sampling methods were kept in collection bottles (9.0 cm x 2.5 cm) and killed by inserting a strip of cotton dipped in chloroform,then transferred separately on a white sheet of paper. Later, using a stereo zoom microscope (ZEISS Stemi 508), the spiders were sorted out and counted. The identification was done based on the available keys and literature described by Tikader (1987) and Barrion and Litsinger (1995). The unidentified samples were sent to the Zoological Survey of India, Kolkata, West Bengal (India) for their proper identification.

Preservation of spiders: Spiders killed using chloroform were preserved separately in 70 per cent ethyl alcohol in ASGI 30 ml screw cap specimen tubes and sealed using cellotape and kept in dark coloured card board boxes. Minute spider specimens and the juvenile spiders were preserved in Oudeman's solution). The preservatives were changed once at fortnightly interval to avoid the dilution of the preservative in the body fluids of the spider specimens, and the resultant contamination and damage of the specimen.

Relative abundance: The relative percentage abundance of individual species of spiders was calculated as follows:

Relative % abundance = Total no. of individual species /Total no. of all species × 100

Results and Discussion

Species richness of spider community: Double cropped irrigated rice ecosystems of sub-Himalayan Terai zone of West Bengal (India) harboured sixteen species of predaceous spiders belonging to ten genera and six families (Table 1-4). So, the species richness of rice field spiders was observed to be of moderate level. Agricultural habitats are artificially created and maintained by periodic disturbances resulting in more uniformity than most natural habitats. Agricultural ecosystems have been present for only a short evolutionary time period and hence, are likely to lack co-evolved animal communities (Samu and Szinetar, 2002). Considering communities of predatory arthropods in agricultural areas, and those of spiders in particular, it has been observed that a few dominating species also called as agrobiont species often dominate these systems (Luczak, 1979).

Satpathi (2004) had earlier enumerated twenty one species of spiders from cereal fields of the Eastern Himalayan hilly tract of West Bengal (India). The present observations are quite comparable with the earlier study of Yadav *et al.* (2016) in the adjoining Gangetic belt of Bhagalpur region of Bihar (India) which yielded sixteen species of predatory spiders belonging to six families and ten genera in rice on the same variety MTU-7029 of rice. But, opposed to the trend of spider fauna documented during current study, a large number of species of predatory spiders have been collected and documented in the rice ecosystems from other regions of India and abroad (Joseph and Premila, 2016; Joshi and Venkateshwarlu, 2016; Barrion *et al.,* 2012). Chowdhury *et al.* (2017) earlier opined that low spider diversity as compared to studies conducted outside North-east India could be attributed to the practice of monoculture prevailing in the study areas and the flooded condition of the rice fields during most of the time (Sebastian *et al.*, 2005).

In conventionally tilled rice cultivations, spider habitat is distressed by flooding and puddling before transplanting. In contrary to this, in untilled rice cultivation, the structural complexity of the spider habitats is maintained by left over plant residues. Raising high yielding cultivar by no-tillage management systems used to enhance spider assemblages through improvement of the structural complexity of the habitat and thereby providing substitute prey density (Chakraborty *et al.,* 2016). The availability of spiders in any locality depends upon the occurrence of insects prey in the area (Bristowe, 1941).

Table 1: Predaceous ground runner spider fauna in rice ecosystem of Terai zone in West Bengal

Common, Scientific name, Family	Arrangement of eyes in cephalothorax	Characteristic features
Wolf Spider, *Lycosa pseudoannulata* (Boesenberg and Strand); Lycosidae	Eyes arranged in four rows; posterior most pair largest; other 3 pairs equal in size	Moderately large; greyish brown; fork shaped median band on cephalothorax; two median yellow spots; three or four transverse yellow band posteriorly in the abdominal dorsum; mostly ground dwelling predating on leaf, plant hoppers
Wolf Spider, *Arctosa tanakai* Barrion and Litsinger; Lycosidae	Eyes arranged in three rows; posterior two rows of eyes larger, more prominent than anterior row of four eyes	Medium small; body covered with dark brown hairs; cephalothorax deep black in colour; three rows of greyish spots present on dorsum of abdomen; prefers humid atmosphere, mostly predates smaller insects like hoppers and smaller moths

Table 2: Predaceous stalker spider fauna in rice ecosystem of Terai zone in West Bengal

Common, Scientific name, Family	Arrangement of eyes in cephalothorax	Characteristic features
Lynx Spider,Oxyopes lineatipes (C.L. Koch); Oxyopidae	Eight eyes arranged in hexagonal manner; very much prominent and dark black in colour	Medium sized; yellowish orange cephalothorax and abdomen; distinct longitudinal stripes run along the cephalothorax and abdomen; legs long, slender and spinose; fast moving aggressive hunter, lives on plants and water surface, mostly predates moths of stem borers and leaf folders
Lynx Spider, *Oxyopes javanus* Thorell; Oxyopidae	Eight eyes arranged in hexagonal manner in four rows; eyes light yellowish but prominent on cephalothorax	Medium sized; straw coloured with brown cephalothorax; regular occurrence from nursery to maturity; very active feeding mostly on rice leaf and plant hoppers but sometimes smaller dipteran pests
Lynx Spider, *Oxyopes salticus* Hentz; Oxyopidae	Eight eyes of equal size arranged in hexagonal fashion; eyes dark brown and very prominent	Medium sized body; abdominal tip narrow, straw coloured body with whitish and greyish longitudinal stripes all along the body length; prefers small sized leaf and plant hoppers
Jumping Spider, *Bianor* sp.; Salticidae	Eight eyes arranged in characteristic manner; anterior median pair of eyes vertically placed and the largest	Stoutly built; body whitish grey with two brown longitudinal stripes all along the length of abdomen; cephalothorax and abdomen roundish shaped
Jumping Spider, *Hasarius adansoni* (Audouin); Salticidae	Anterior median eyes strong and powerful placed vertically in front of head, posterior lateral eyes also large and prominent	Moderately small sized, body oval shaped, robust built, brownish body, yellowish semi-circular band along the anterior margin of abdomen with two black bands longitudinally placed on the dorsum of abdomen

Table 3: Predaceous ambusher spider fauna in rice ecosystem of Terai zone in West Bengal

Common, Scientific name, Family	Arrangement of eyes in cephalothorax	Characteristic features
Crab Spider, *Thomisius* sp.; Thomisidae	Eyes arranged in two rows in linear fashion	Brown body with globular abdomen and cephalothorax; front pairs of legs large, predates hoppers

Furthermore, high cropping intensity of the study area (university farm) might have negatively influenced the spider population build up. Because the spider abundance and diversity are higher in abandoned fields than cultivated fields, and that species composition varies depending on field abandonment and succession (Yuki *et al.,* 2019). Maintaining cultivated fields and abandoned fields at different successional stages on temporal scale can sustain a high diversity of spiders in rice ecosystems. Fostering aquatic midge and gnat larvae through mulching, and integrating rice fields into rice-heterogeneous landscapes is likely to strengthen the biological control of pest species in rice paddies by supporting high population of spiders between cropping seasons (Radermacher *et al.,* 2020).

Grouping of rice field spiders: In this study, non-web formers and web formers broad groups were represented by eight different species of spiders each in our present study (Table 1-4). The hunting spiders were distributed over four different families, *viz.,* Lycosidae, Oxyopidae, Salticidae and Thomisidae, while the web forming spiders belonged to Tetragnathidae and Araneidae. The family Tetragnathidae or long jawed spiders showed the maximum species richness with five different species, while the family Thomisidae or crab spiders were represented only by a single species. Contrary to the present findings, spider samples collected from rice and sugarcane plots in Punjab province of Pakistan revealed Lycosidae as the most common family which was represented by nine species (Ghafoor and Mahmood, 2011).Variations in species numbers and proportion of the araneid distribution groups are attributable to varied habitat environmental factors (Yan, 1991). As a result, faunistic of rice fields spiders exhibit significant differences among regions, farmland habitats and agricultural practices (Yang *et al.,* 2018).

Foraging guilds of rice spiders: Considering the guilds in rice ecosystem, the spiders documented during the present study belonged to four functional or foraging guilds according to Uetz *et al.* (1999) namely, ground runner, stalker, ambusher (these three comprised the broad group of hunter or non-web former) and orb web weaver (of web former broad group) (Table 1-4). As functional guild, the orb web weaver group was the most diverse with eight different species signifying a stiff competition among the members of this group occupying same niche. The high species richness of orb-weaver group of spiders might be attributable to the present rice variety, *i.e.,* Swarna (MTU-7029) which is known for dense canopy, favouring this group of spiders for weaving the webs. Rice varieties with large number of tillers as well as long and broad leaves were found to harbour more orb-weaver spiders, offering conducive niche for web spinners to weave their webs (Jalaluddin *et al.,* 2000).

Table 4: Predaceous orb web weaver spider fauna in rice ecosystem of Terai zone in West Bengal

Common, Scientific name, Family	Arrangement of eyes in cephalothorax	Characteristic features
Long Jawed Spider, *Tetragnatha maxillosa* Thorell; Tetragnathidae	Eight eyes arranged in two rows; posterior median & posterior lateral eyes the largest	Medium sized; abdominal dorsum fluorescent green coloured, dorsum of cephalothorax and legs brown coloured; feeding mostly on leaf and plant hoppers
Long Jawed Spider, *Tetragnatha mandibulata* Walckenaer; Tetragnathidae	Eight dark black eyes of almost equal size arranged in two rows on the anterior margin of dorsum of cephalothorax	Largest sized; member of this group possessing an extra tooth; abdomen narrow and elongated; brown coloured body; occurs regularly on rice from nursery stage to maturity stage feeding on small sized leaf and plant hoppers
Long Jawed Spider, *Tetragnatha Javana* Thorell; Tetragnathidae	Eyes homogenous, arranged in two rows	Medium sized; straw coloured, body very much narrow and elongated, cylindrical; during mid-day take shelter within crop canopy and in the morning wait in web for prey; mostly feed on hoppers
Decorated Silver Orb Spider, *Leucage decorate* Walckenaer; Tetragnathidae	Eight eyes arranged in two rows, posterior median and posterior lateral eyes as well as anterior median and lateral eyes all equal sized, dark black coloured and prominent	Medium to large sized; body oval shaped, less elongate but abdominal tip attenuated; abdominal dorsum with silvery bands, can be easily identified, dorsum of cephalothorax and legs brown coloured
Black Striped Orchard Spider, *Leucage celesbesiana* Walckenaer; Tetragnathidae	Eight dark black eyes of almost equal size arranged in two rows on anterior margin of dorsum of cephalothorax	Very colourful and distinctive, medium to large sized; abdominal dorsum white coloured with brown to black stripes; posterior end of abdomen again black coloured from dorsal side
Orb Web Spider, *Neoscona theisi* Walckenaer; Araneidae	Eyes in two rows, anterior median and posterior median eyes close, very much prominent	Small sized; greenish brown, characteristically shaped whitish markings present on the dorsum of abdomen; make circular webs and remain at centre
Orb Web Spider, *Neoscona mukerjei* Tikader; Araneidae	Eyes dark black, anterior and posterior median eyes large and prominent, lateral eyes smaller and covered with hairs	Small to medium sized; body yellowish green; cephalic region has 'V' shaped dark brown patch; abdomen sub-triangular in shape
Orb Web Spider, *Araneus* sp.; Araneidae	Eyes eight in numbers, arranged in two rows	Small to medium sized, body greenish brown in colour with whitish markings on the dorsum of abdomen

Table 5: Abundance of spider fauna in rice ecosystem of Terai zone in West Bengal (Mean of two years)

Family	Scientific name	Kharif		Rabi	
		Number/ 10 sweeps	Relative abundance %	Number/ 10 sweeps	Relative abundance %
Lycosidae	*Lycosa pseudoannulata*	51	13.78	40	13.42
	Arctosa tanakai	21	5.68	16	5.37
Oxyopidae	*Oxyopes lineatipes*	66	17.84	58	19.46
	O. javanus	34	9.19	32	10.74
	O. salticus	20	5.41	17	5.70
Tetragnathidae	*Tetragnatha maxillosa*	26	7.03	21	7.05
	T. mandibulata	20	5.41	11	3.69
	T. javana	9	2.43	5	1.68
	Leucage celesbesiana	8	2.16	6	2.01
	L. decorata	6	1.62	5	1.68
Salticidae	*Bianor* sp.	34	9.19	22	7.38
	Hasarius adansoni	16	4.32	11	3.69
Thomisidae	*Thomisius* sp.	24	6.49	20	6.71
Araneidae	*Neoscona theisi*	18	4.86	22	7.38
	N. mukerjei	11	2.97	0	0.00
	Araneus sp.	6	1.62	12	4.03
		370	100.00	298	100.00

Fig. 1: (A) *Lycosa pseudoannulata*; (B) *Arctosa tanakai*; (C) *Oxyopes lineatipes* and (D) *Oxyopes javanus.*

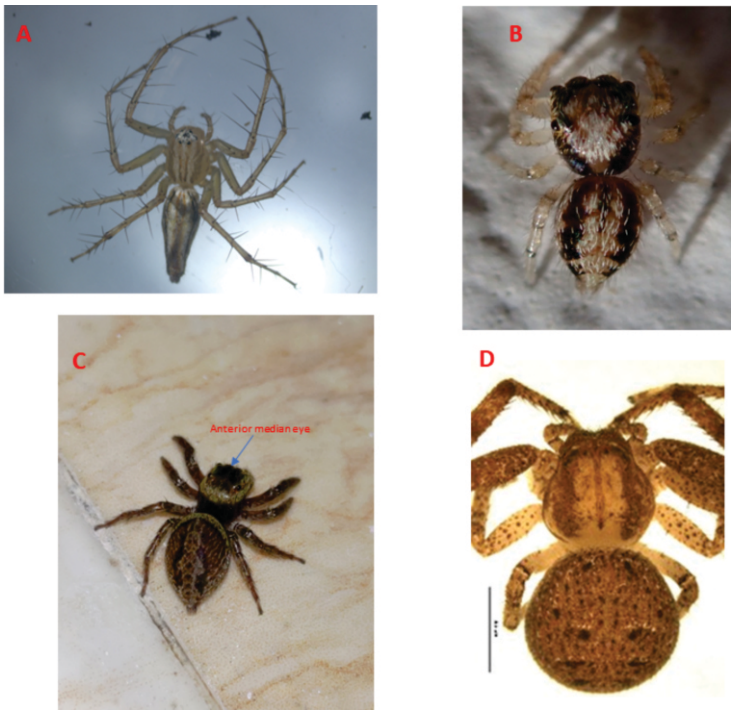

Fig. 2: (A) *Oxyopes salticus*; (B) *Bianor sp.*; (C) *Hasarius adansoni* and (D) *Thomisius* sp.

Abundance of rice spiders on individual number basis: The lynx spiders (Oxyopidae) were found to be the most dominant group by individual numbers, followed by wolf spiders (Lycosidae) (Table 5). Species wise, *Oxyopes lineatipes* was most abundantly found in field both during kharif and rabi season. The dominance of non web forming lynx and wolf spiders is attributable to unique agroecological conditions, farm land habitats and cultivation practices of this zone. Use of agricultural chemicals are also important factors affecting the community ecology of rice field spiders. Spiders are more sensitive than other pests to certain

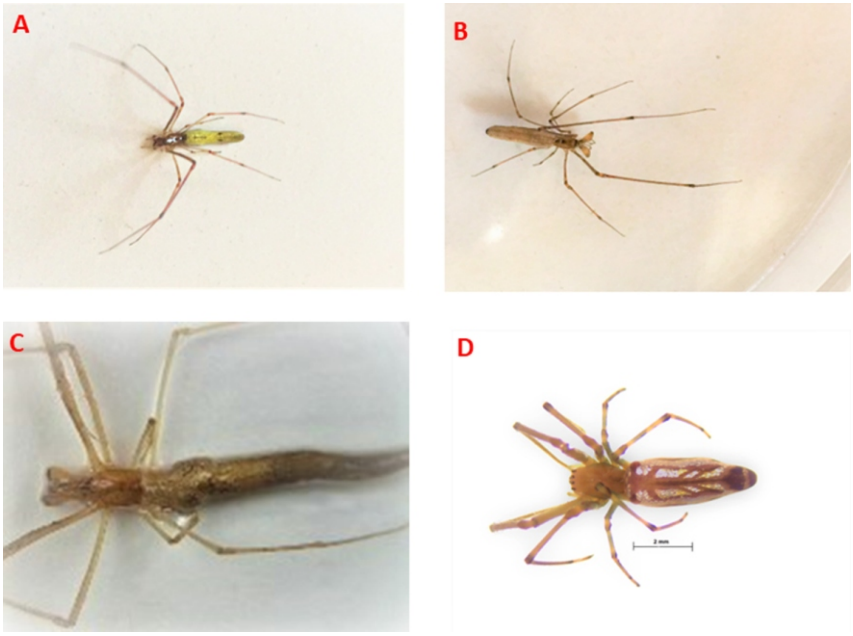

Fig. 3: (A) *Tetragnatha maxillosa*; (B) *Tetragnatha mandibulata*; (C) *Tetragnatha javana* and (D) *Leucage decorata.*

Fig. 4: (A) *Leucauge celebasiana*; (B) *Neoscona theisi*; (C) *Neoscona mukerjei* and (D) *Araneus* sp.

pesticides, such as synthetic pyrethroids like cypermethrin and deltamethrin, organophosphates like dimethoate and malathion, and carbamates like carbaryl (Maloney *et al.,* 2003). The effect of chemical pesticides on web forming spiders is even greater than the non-web formers (Wang *et al.,* 2001). So, integration of different approaches, including increasing habitat diversity, landscape configuration complexity, crop rotation, adding non-crop components in the fields, management of water and fertilizer, and other agricultural cultivation practices are imperative to increase the species richness and diversity of predaceous

spiders and to provide favourable conditions for the growth and reproduction of the dominant spider species.

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References

Barrion, A.T. and J.A. Litsinger: Riceland spiders of South and South East Asia. CAB. International U.K., 60 pages (1995).

Barrion, A.T., S.S. Villareal, J.L.A. Catindig, D. Cai, Q.H. Yuan and K.L. Heong: The spider fauna in the rice agricultural landscape of Hainan Island, China: Composition, abundance and feeding structure. *Asia Life Sci.,* **21**, 625-651 (2012).

Benamu, M A.: The importance of spider diversity in agroecosystems and the effect of pesticides. *Glob. J. Ecol.,* **5**, 60-61(2020).

Bhatkar, N.V.: Spider diversity in the Wan sanctuary of Melghat Tiger Reserve. *Indian J. Trop.Biodivers.,* **4**, 31–38 (2011).

Bristowe, W.S.: The Comity of Spiders. Volume II, The Ray Society, London, 560 pages (1941).

Bukhari, M., A. Mohamed, M.M. Naeem, K. Rehman, Shehla and Leeb: Occurrence and distribution of araneid fauna trapped from cotton fields of district Faisalabad, Pakistan. *World Appl. Sci. J.,* **19**, 714–718 (2012).

Chakraborty, K., M.N. Moitra, A.K. Sanyal and P.C. Rath: Important natural enemies of paddy insect pests in the Upper Gangetic plains of West Bengal, India. *Int. J. Plant, Animal Env. Sci.,* **6**, 35-40 (2016).

Chetia, P. and D.K. Kalita: Diversity and distribution of spiders from gibbon wildlife sanctuary, Assam, India. *Asian J. Conserv. Biol.,* **1**, 5–15 (2012).

Chowdhury, S., T. Boopathi, A. Chakraborty, P.P. Sontakke, T. Paul, D. Bhattacharjee, J.K. Dey and J. Bhattacharjee: Diversity of predatory spider and their species composition in rice ecosystem in Kolasib district of Mizoram. *Innov. Farm.,* **2**, 12-18 (2017).

Ghafoor, A. and A. Mahmood: Population dynamics of the Araneid fauna from district Gujranwala, Pakistan. *J. Anim. Plant Sci.,* **21**, 812-816 (2011).

Gerlach, J., M. Samways and J. Pryke: Terrestrial invertebrates as bioindicators: An overview of available taxonomic groups. *J. Inse. Conserv.,* **17**, 831-850 (2013).

Jalaluddin S.M., R. Mohan, R. Velusamy and S. Sadakathulla: Predatory spider behaviour in rice varieties under sodic soil conditions. *Entomon.,* **25**, 347-349. (2000).

Joshi J.S. and M. Venkateshwarlu: Spiders as biological pest control in rice fields of Dakshina Kannada district. *Int. J. Curr. Res.,* **8**, 42749-42751 (2016).

Joseph, Anis R. and K.S. Premila: A study on the richness of spider fauna in rice ecosystem. *J. Entomol. Zool. Stud.,* **4**, 425-430 (2016).

Lee, J.H., K.H. Kim and U.T. Lim: Arthropod community in small rice fields associated with different planting methods in Suwon and Icheon. *Kor. J. Appl. Entomol.,* **36**, 55- 66 (1997).

Luczak J.: Spiders in agrocoenoses. *Pol. Ecol. Stud.,* **5**, 151-200 (1979).

Maloney, D., F.A. Drummond and R. Alford: Spider predation in agroecosystems: can spiders effectively control pest populations? Technical Bulletin 190, Maine Agricultural and Forest Experiment Station, The University of Maine, Orono, 32 pages (2003).

Mathirajan, V.G. and A. Raghupathy: Prey preference and predatory potential of spider in cotton ecosystem. *J. Entomon.,* **28**, 9–14 (2003).

Radermacher, N., T.R. Hartke, S. Villareal and S. Scheu: Spiders in rice-paddy ecosystems shift from aquatic to terrestrial prey and use carbon pools of different origin. *Oecologia*, **192**, 801-812 (2020).

Raju, A., S.J. Rahman, S.M.A.S. Rahman, R. Jagadeeshwar and S.N. Reddy: Identification, documentation and relative abundance of predatory spider fauna in rice ecosystem of Telangana state. *Pharm. Innov. J.,* **10**, 704-711 (2021).

Patal, B.H.: A preliminary list of spiders with descriptions of three new species from Parambikulan wildlife sanctuary, Kerala. *Zoos' Print J.,* **18**, 1207–1212 (2003).

Sahu, S., R. Singh and P. Kumar: Host preference and feeding potential of spiders predaceous in insect pest of rice. *J. Entomol. Res.,* **20**, 145–150 (1996).

Saranya, V.S.L., K. Samiayyan and M.S. Prema: Diversity of predatory spider fauna in maize ecosystem. *J. Biol. Cont.,* **33**, 27-35 (2019).

Satpathi, C.R.: Predacious spiders of crop pests. Capital Publishing Company, New Delhi, 188 pages (2004).

Samu, F. and C. Szinetar: On the nature of agrobiont spiders. *J. Arachnol.,* **30**, 389 – 402 (2002).

Sebastian, P.A., M.J. Mathew, S.B. Pathummal, J. Joseph and H.C. Biju: The spider fauna of the irrigated rice ecosystem in the Central Kerala, Inrua. *J. Arachnol.,* **33**, 247-255 (2005).

Tikader, B.K.: Handbook of Indian Spiders. Calcutta, India: Zoological Survey of India, 251 pages (1987).

Uetz, G.W., J. Halaj and A.B. Cady: Guild structure of spiders in major crops. *J. Arachnol.,* **27**, 270-280 (1999).

Vanitha, K., P. Sivasubramaniyan, Z. Kavitharagavan, C. Vijayaraghavan and K. Samiayyan: Prey preference, cross predation and impact of some cultural practices on spider and their abundance in cotton. *Karnataka J. Agric. Sci.,* **22**, 548–551(2009).

Wang, Z., B.P. Zeng, H.M. Yan and H.Q. Wang: Comparative study on similarity of the dominant spider families of rice field community in IPM and chemical control field. *Chinese Agric. Sci. Bull.,* **17**, 9-26 (2001).

Wise, D.H.: Spiders in Ecological Webs. Cambridge Univ. Press, London, 342 pages (1993).

Yadav, M., T.N. Goswami, Anil and S.N. Ray: Species composition of spider-fauna in paddy ecosystem throughout the cropping period at Sabour, Bihar, India. *Ecol. Environ.Conserv.,* **22**, 719-722 (2016).

Yan, H.M.: Community ecology spiders in rice field in southwest China. *Acta Scientiarum Naturalium Universitatis Normalis Hunanensis*, *Changsha*, **11**, 78-83 (1991).

Yang, H., P. Yuande, T. Jianxiang, W. Juan, W. Baoyang, X. Chunliang and W. Zhi: Rice field spiders in China: A review of the literature. *J. Econ. Entomol.,* **111**, 53-64 (2018).

Yuki, G.B., K. Tanaka and K. Yoshinobu: Changes in spider diversity and community structure along abandonment and vegetation succession in rice paddy ecosystems. *Ecol. Eng.,* **127**, 235-244 (2019).