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# DIVERSITY OF SPIDERS AS INFLUENCED BY CULTIVATION TECHNIQUES IN RICE

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## ABSTRACT

**Field studies were carried out in wet seasons of 2014 and 2015 in rice fields of College Farm, Rajendranagar, Hyderabad to understand the abundance and biodiversity of spiders in varied rice cultivation systems. Design of the experiment was split plot with three main modules, viz., transplanted, broadcasted and drum sown rice and subtreatments under each main module included three plant protection methods viz., organic protection, farmers' practices and 'no protection' practices. Results showed that predator numbers in 'no protection' and organic protection plots of all main treatments were more than in farmers' practices indicating the impact of the chemical pesticides. A total of 22 genera of spiders belonging to 12 families were recorded which comprised of seven guilds based on their hunting strategies and microhabitats. Shannon diversity index ranged between 1.83 and 2.26 and Pielou's evenness index was 0.59-0.72 in two years of study indicating a stable ecosystem and even species distribution in rice crop at Rajendranagar. Study of the guild assemblage indicated that orb-weavers constituted 28.1% of the population, ground runners 23.51%, space web builders 18.38%, sheet-web builders 13.12%, stalkers 8.04% and ambushers made upto 0.38% of the spider population. Understanding the vertical stratification of various spider genera on the plant gave further insight into the prey preferences of these predators.**

**Key words:** Spiders, biodiversity, rice, cultivation systems, abundance, organic, farmers' practice, no protection, guilds, assemblages, diversity indices



Rice is the staple food of India and pests on the crop are a major impeding factor. Natural biological control in irrigated rice at the early crop stages can mainly be attributed to spiders (Sigsgaard, 2000). Abundant detritivores early in the season help to colonise predators in the rice fields (Settle et al., 1996). Spiders being polyphagous- can predate on alternative prey such as Collembola during fallow periods, thereby maintaining high population levels. Abundance of alternative prey in turn depend on decaying organic material available in the field (Sigsgaard, 2000). There are many environmental factors that affect species diversity. Some of these include seasonality, spatial heterogeneity, competition, predation, habitat type, environmental stability and productivity (Rosenzweig, 1995). Literature suggests that spider populations are generally affected by factors like vegetation type and structure, which in rice depend on the cultivation practices like transplantation, drum sowing and broadcasting methods and also on the plant protection measures adopted. This study assesses the impact of cultivation systems and plant protection practices and their interaction in determining spider abundance in rice crop.

## MATERIALS AND METHODS

The experiment was laid out in a split plot design in 1500 $m^2$ at the College farm, Rajendranagar for two years, *kharif* 2014 and 2015 with rice variety BPT 5204. There were three main modules, each with different establishment technique viz., transplanted rice, broadcasted and drumsown rice. The size of each module was 36 x 12 m. Under each module, three types of plant protection measures viz., organic protection, farmers' practice and 'no protection' were taken up. Recommended dosages of fertilizers were applied to all the modules and transplantation, broadcasting and drum sowing were done in the last week of July. Under organic protection, *Trichogramma japonicum* cards were pinned to the under side of the leaves @ 50,000/ha/release and six such releases were carried out starting at 35 days after transplantation. *T. chilonis* cards were also pinned to the leaves @ 50,000/ha/release and six such releases were carried out starting at 37 standard week (SMW) when leaf folder adults were noticed in the field. Pheromone traps with *Scirpophaga incertulas* lures were installed in the organic protection plots @

20 Nos./ha at 30 DAT and the lure was changed once every 22 days till 70 DAT. Two sprays of neem oil 1.0% were taken up in the organic protection plots when the stem borer crossed economic threshold level once at 36 SMW and again at 69 SMW.

In farmers' practice, carbofuran 3G granules were applied one week before pulling of nursery @500 g/ ha in the transplantation module plots. In the broadcasted and drum sown rice, carbofuran granules were applied at 30 days after sowing @25 kg/ ha. In addition, foliar sprays of chlorpyriphos @ 2.50 ml/l water were given when the pests crossed the Economic Threshold Level (ETL) once at 36 SMW and again at 69 SMW. No protection measures were taken up in the untreated control. Weekly observations on the populations of spiders were recorded in each of the treatment plots between 7.00 a.m. and 9.00 a.m. in five quadrats (1m x 1m)/ each treatment plot from 34 to 47 standard weeks coinciding with 30 days after transplantation (DAT) to 120 DAT. In each plot, a metal quadrat was placed in the four corners and in the centre to get a uniform count of the insects in that plot.

Diversity parameters of spiders were worked for the pooled data using the Biodiversity Pro 2.0 Software to find out the species richness, species diversity and Pielou's Evenness Index or equitability (Pielou, 1966) with standard formulae. Total predator density, guild composition (based on their predation habits and preying techniques- Uetz et al, 1999). Vertical stratification was computed with vertical height of the rice plant divided into five strata viz., 0-20 cm (bottom 20cm if the stem), 20-40 cm, 40-60 cm, 60-80 cm and > 80cm (crop canopy) based on the activity and foraging behaviour.

**RESULTS AND DISCUSSION**

### Abundance

In the present study a total of 45,071 spiders were collected belonging to twelve families and comprising of 22 genera and 29 species (Table 1.). Among the three major modules, abundance of spiders was found to be more in the broadcasted method of cultivation followed by the drum sown method and the transplanted method. A total of 22 genera were recorded but only 12 genera were considered as the others were in negligible numbers. Genera *Tetragnatha*,

Table 1. List of spiders and the families

| S.No. | Family | Genus | Species name |
|---|---|---|---|
| 1. | Araneidae Clerck,1757 | Genus *Neoscona* | *Neoscona mukerjei*, Tikader*, 1980* |
| | | | *Neoscona molemensis* Tikader & Bal, 1981 |
| | | Genus *Araneus* | *Araneus inustus* (L. Koch, 1871) |
| | | | *Araneus mitificus* (Simon, 1886) |
| | | Genus *Argiope* | *Argiope catenulata* Doleschall, 1859 |
| | | | *Argiope anasuja* Thorell, 1887 |
| | | | *Argiope aemula* (Walckenaer, 1841) |
| 2. | Tetragnathidae Menge, 1866 | Genus *Tetragnatha* | *Tetragnatha maxillosa* Thorell, 1895 |
| | | | *Tetragnatha versicolor* Walckenaer, 1841 |
| | | Genus *Pachygnatha* | *Pachygnatha degeeri* Sundevall, 1830 |
| | | Genus *Leucauge* | *Leucauge decorata* (Blackwall, 1864) |
| 3. | Salticidae Blackwall, 1841 | Genus *Bianor* | *Bianor* sp. |
| | | Genus *Chalcotropis* | *Chalcotropis* sp. |
| | | Genus *Mymaracnne* | *Myrmarachne* sp. |
| | | Genus *Telamonia* | *Telamonia* sp. |
| 4. | Lycosidae Sundevall, 1833 | Genus *Lycosa* | *Lycosa mackenziei* Gravely, 1924 |
| | | | *Lycosa pseudoannulata* |
| | | Genus *Pardosa* | *Pardosa sumatrana* (Thorell, 1890) |
| | | Genus *Arctosa* | *Arctosa* sp. |
| 5. | Oxyopidae Thorell, 1870 | Genus *Hamataliwa* | *Hamataliwa incompta* (Thorell, 1895) |
| | | Genus *Oxyopes* | *Oxyopes shweta* Tikader, 1970 |
| 6. | Theridiidae Sundevall, 1833 | Genus *Chrysso* | Chrysso urbasae (Tikader, 1970) |
| 7. | Thomisidae Sundevall, 1833 | Genus *Runcinia* | *Runcinia roonwali* Tikader, 1965 |
| 8. | Eutichuridae Lehtinen, 1967 | Genus *Cheiracanthium* | *Cheiracanthium danieli* Tikader, 1975 |
| | | | *Cheiracanthium melanostomum* (Thorell, 1895) |
| 9. | Sparassidae Bertkau, 1872 | Genus *Heteropoda* | *Heteropoda* sp. |
| 10. | PholcidaeC. L. Koch, 1850 | Genus *Pholcus* | *Pholcus* sp. |
| 11. | Clubionidae Wagner, 1887 | Genus *Clubiona* | *Clubiona* sp. |
| 12. | Linyphiidae Blackwall, 1859 | Genus Atypena | *Atypena formosana* (Oi) |

*Pachygnatha*, *Telamonia*, *Lycosa* and *Pardosa* were significantly abundant in the drumsown plots (36.26, 9.57, 7.09, 19.63 and 31.52 respectively), compared to the broadcasted (29.38, 7.73,6.28, 16.89 and 27.32 spiders/quadrat, respectively) and transplanted plots (28.86, 9.11, 4.46, 14.02 and 25.10 spiders/quadrat, respectively) (Table 2).

*Neoscona*, *Bianor*, *Oxyopes and Clubiona* were more in numbers (3.62, 9.01, 3.62 and 3.59 spiders/ quadrat respectively) in the broadcasted plots compared to the drumsown module (3.34, 8.69,3.34 and 3.16 spiders/quadrat, respectively) and transplanted module (1.99,8.06,1.99 and 2.82 spiders/quadrat, respectively) (Table 1). *Chrysso*, *Cheiracanthium* and *Atypena* were more in transplanted plots (42.17, 4.94 and 30.16 spiders/quadrat, respectively compared to drumsown plots (41.66, 2.89 and 28.53 spiders/quadrat, respectively and broadcasted plots with 40.82, 3.95 and 27.97 spiders/quadrat, respectively. *Cheiracanthium*, *Lycosa*, *Bianor and Clubiona* genera were significantly more in broadcasted organic plots (6.13, 5.10, 10.38 and 5.10 spiders/quadrat, respectively), while *Pachygnatha*, *Chrysso and Atypena* were to significantly more in transplanted 'no protection' plots (10.79, 48.26, 33.97 spiders/quadrat, respectively).

Plant protection practices influenced spider numbers greatly. 'No protection' plots registered maximum numbers of *Neoscona*, *Tetragnatha*, *Pachygnatha*, *Lycosa*, *Pardosa*, *Chrysso* and *Atypena* (1.27, 42.03, 10.44, 19.61, 29.99, 46.32 and 29.94 spiders/ quadrat, respectively, while organic protection plots registered lesser numbers of these genera (1.11, 30.48, 9.31, 16.11, 28.50, 40.86 and 28.85 spiders/quadrat, respectively and farmers' practices registered the lowest numbers indicating the vulnerability of the spiders to even neem oil and the insecticides. However, *Bianor*, *Oxyopes*, *Cheiracanthium* and *Clubiona* were found to be significantly more abundant in organic protection plots (9.64, 3.67, 4.67 and 3.64 spiders/quadrat, respectively), than in the 'no protection' plots (8.75, 3.34, 3.98 and 3.14 spiders/quadrat, respectively). The farmers' protection plots registered significantly lesser numbers of all the spider genera establishing the toxicity of insecticides to the spiders (Table 3).

A study of the interaction effects of the establishment systems and plant protection measures revealed that transplanted 'no protection', broadcasted organic protection, drumsown organic protection and Drumsown 'no protection' recorded more abundance. Transplanted 'no protection' plots recorded maximum population of

Table 2. Abundance and diversity of spiders in cultivation systems of rice

| Family | Genus | Guild | Contribution to the Guild (%) | Population of spiders (no./quadrat) | | | CD (0.05) | SEm± |
|---|---|---|---|---|---|---|---|---|
| | | | | Transplanted rice | Broadcasted rice | Drum sown rice | | |
| Araneidae | *Neoscona* | Orb weavers | 28.17 | 1.99 (3.38)[c] | 3.62 (3.05)[a] | 3.34 (3.19)[b] | 0.03 | 0.009 |
| Tetragnathidae | *Tetragnatha* | | | 28.86 (15.84)[c] | 29.38 (15.99)[b] | 36.26 (17.92)[a] | 0.57 | 0.16 |
| | *Pachygnatha* | | | 9.11 (9.03)[b] | 7.73 (8.31)[c] | 9.57 (9.19)[a] | 0.11 | 0.03 |
| Salticidae | *Bianor* | Stalkers | 8.04 | 8.06 (8.49)[c] | 9.01 (8.98)[a] | 8.69 (8.81)[b] | 0.11 | 0.03 |
| | *Telamonia* | | | 4.46 (6.29)[c] | 6.28 (7.51)[b] | 7.09 (8.08)[a] | 0.15 | 0.04 |
| | *Oxyopes* | | | 1.99 (4.06)[c] | 3.62 (5.74)[a] | 3.34 (5.53)[b] | 0.13 | 0.04 |
| Lycosidae | *Lycosa* | Ground runners | 23.51 | 14.02 (11.17)[c] | 16.89 (12.31)[b] | 19.63 (13.28)[a] | 0.11 | 0.003 |
| | *Pardosa* | | | 25.10 (16.47)[c] | 27.32 (17.25)[b] | 31.52 (18.36)[a] | 0.10 | 0.03 |
| Theridiidae | *Chrysso* | Space web builders | 18.38 | 42.17 (19.45)[a] | 40.82 (19.15)[c] | 41.66 (19.34)[b] | 0.02 | 0.005 |
| Eutichuridae | *Cheiracanthium* | Foliage runners | 8.40 | 4.94 (6.65)[a] | 3.95 (5.87)[b] | 2.89 (5.09)[c] | 0.19 | 0.06 |
| Clubionidae | *Clubiona* | | | 2.82 (5.02)[c] | 3.59 (5.62)[a] | 3.16 (5.3)[b] | 0.19 | 0.06 |
| Linyphiidae | *Atypena* | Sheet web builders | 13.12 | 30.16 (16.44)[a] | 27.97 (15.85)[c] | 28.53 (16.01)[b] | 0.37 | 0.06 |

Table 3. Abundance and diversity of spiders in plant protection methods in rice

| Family | Genus | Guild | Contribution to the Guild (%) | Population of spiders (no./quadrat) | | | CD (0.05) | SEm± |
|---|---|---|---|---|---|---|---|---|
| | | | | Organic Protection | Farmers' Practices | No Protection | | |
| Araneidae | Genus *Neoscona* | Orb weavers | 28.17 | 1.11 (3.32)$^{b}$ | 0.94 (2.91)$^{c}$ | 1.27 (3.4)$^{a}$ | 0.05 | 0.01 |
| Tetragnathidae | Genus *Tetragnatha* | | | 30.48 (16.55)$^{b}$ | 21.99 (13.78)$^{c}$ | 42.03 (19.41)$^{a}$ | 0.46 | 0.12 |
| | Genus *Pachygnatha* | | | 9.31 (9.17)$^{b}$ | 6.68 (7.67)$^{c}$ | 10.44 (9.69)$^{a}$ | 0.1 | 0.009 |
| Salticidae | Genus *Bianor* | Stalkers | 8.04 | 9.64 (9.3)$^{a}$ | 7.38 (8.12)$^{c}$ | 8.75 (8.86)$^{b}$ | 0.17 | 0.04 |
| | Genus *Oxyopes* | | | 3.67 (5.71)$^{a}$ | 1.95 (4.04)$^{c}$ | 3.34 (5.60)$^{b}$ | 0.07 | 0.02 |
| Lycosidae | Genus *Lycosa* | Groundrunners | 23.51 | 16.11 (11.98)$^{b}$ | 14.82 (11.51)$^{c}$ | 19.61 (13.27)$^{a}$ | 0.08 | 0.003 |
| | Genus *Pardosa* | | | 28.50 (17.21)$^{b}$ | 25.46 (17.38)$^{c}$ | 29.99 (17.50)$^{a}$ | 0.17 | 0.06 |
| Theridiidae | Genus *Chrysso* | Space web builders | 18.38 | 40.86 (19.18)$^{b}$ | 37.47 (18.36)$^{c}$ | 46.32 (20.41)$^{a}$ | 0.03 | 0.009 |
| Eutichuridae | Genus *Cheiracanthium* | Foliage runners | 8.40 | 4.67 (6.4)$^{a}$ | 3.14 (5.30)$^{c}$ | 3.98 (5.91)$^{b}$ | 0.13 | 0.004 |
| Clubionidae | Genus *Clubiona* | | | 3.64 (5.66)$^{a}$ | 2.79 (4.99)$^{c}$ | 3.14 (5.30)$^{b}$ | 0.14 | 0.04 |
| Linyphiidae | Genus Atypena | Sheet web Builders | 13.12 | 28.85 (16.09)$^{b}$ | 27.88 (15.82)$^{c}$ | 29.94 (16.38)$^{a}$ | 0.28 | 0.07 |

a few genera like *Pachygnatha* (10.79 spiders/quadrat), *Pardosa* (26.52 spiders/quadrat), *Chrysso* (48.26 spiders/quadrat) and *Atypena* (33.97 spiders/quadrat). Broadcasted organic protection recorded maximum numbers of *Bianor* (10.38 spiders/quadrat), *Lycosa* (5.10 spiders/quadrat), *Pardosa* (28.74 spiders/quadrat), *Chrysso* (40.90 spiders/quadrat), *Cheiracanthium* (6.13 spiders/quadrat) and *Clubiona* (5.10 spiders/ quadrat). Drumsown organic protection plots registered maximum numbers of *Oxyopes* (4.38 spiders/quadrat), *Lycosa* (3.31 spiders/quadrat) and *Pardosa* 29.88 spiders/quadrat), while drumsown no protection plots recorded increased numbers of *Neoscona* (1.43 spiders/quadrat), *Tetragnatha* (85.76 spiders/quadrat), *Pachygnatha* (10.73 spiders/quadrat) and *Pardosa* (35.90 spiders/quadrat) (Table 4).

Tetragnathids, lycosids and salticids are active spiders and the extra space between the rows in the drumsown and broadcasted plots could have helped tetragnathids and araneids to build webs in the top canopy. According to Turnbull (1973), most webs have specific attachment and space requirements. Cherrett (1964) found that adult orb weavers in a grass land habitat needed a vertical space of at least 25-30 cm$^2$ for web placements, a factor which strongly limited those spiders to certain habitats, may be like the broadcasted and drumsown plots. Other workers also found the availability of specific structural features to limit the habitats occupied by various web builders (Duffey, 1962). Moreover, drum sown and broadcasted plots had more diversity of weeds because of the structured gaps in drum sown plots and haphazard gaps in broadcasted crop, which contributed to their growth with lesser competition from the rice crop. Other workers also reported that greater habitat complexity resulted in more abundance and diversity of spiders because structurally more diverse habitats allow a greater niche diversification and coexistence of more spider species (Langellotto and Denno, 2004; Stokmane and Spungis, 2016).

Microclimate is the main factor that accounts for spider distribution in a habitat and microclimate often correlates with the architecture of plants and complexity (Hore and Uniyal, 2008), (Buchholz, 2009). A diverse range of weeds has more to offer to the spiders in terms of resting sites, mating grounds, oviposition and overwintering substrates and protection from intraguild predation (Halaj et al, 1998). Oxbrough et al. (2005) mentioned that vegetation structure is the primary factor influencing spider communities because it is architecturally important for web builders and aids the concealment of active hunters. Previous authors found that species composition of spider assemblages (Hore and Uniyal, 2008) and spider species richness (Valverde

Table 4. Interaction effects of cultivation systems and plant protection methods on spider abundance in rice

| Genus | Transplanted Organic protection | Transplanted farmers' protection | Transplanted 'no protection' | Broadcasted organic protection | Broadcasted farmers' protection | Broadcasted 'no protection' | Drumsown organic protection | Drumsown farmers' practices | Drumsown 'no protection' | CD (0.05) | SEm± |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Genus *Neoscona* | 1.25 (1.15)$^{b}$ | 1.14 (1.07)$^{b}$ | 1.28 (1.16)$^{b}$ | 1.03 (1.12)$^{c}$ | 0.80 (0.94)$^{c}$ | 0.93 (0.99)$^{d}$ | 0.93 (0.99)$^{d}$ | 0.76 (0.91)$^{c}$ | 1.43 (1.24)$^{a}$ | 0.09 | 0.003 |
| Genus *Tetragnatha* | 28.88 (5.37)$^{g}$ | 15.29 (3.88)$^{i}$ | 42.42 (6.59)$^{c}$ | 30.69 (5.50)$^{f}$ | 25.90 (4.49)$^{h}$ | 37.09 (5.99)$^{d}$ | 31.88 (5.67)$^{c}$ | 47.78 (5.42)$^{b}$ | 85.76 (6.82)$^{a}$ | 0.79 | 0.15 |
| Genus *Pachygnatha* | 9.53 (3.11)$^{b}$ | 6.98 (2.64)$^{f}$ | 10.79 (3.28)$^{a}$ | 7.80 (2.93)$^{e}$ | 5.41 (2.41)$^{h}$ | 8.33 (2.97)$^{d}$ | 9.24 (3.13)$^{c}$ | 6.70 (2.64)$^{g}$ | 10.73 (3.44)$^{a}$ | 0.17 | 0.04 |
| Genus *Bianor* | 9.07 (3.01)$^{c}$ | 6.74 (2.59)$^{g}$ | 8.37 (2.89)$^{d}$ | 10.38 (3.22)$^{a}$ | 7.46 (2.73)$^{f}$ | 9.21 (3.03)$^{bc}$ | 9.48 (3.07)$^{b}$ | 7.93 (2.80)$^{e}$ | 8.66 (2.94)$^{d}$ | 0.3 | 0.006 |
| Genus *Oxyopes* | 2.36 (1.55)$^{f}$ | 0.43 (0.67)$^{h}$ | 3.18 (1.85)$^{d}$ | 3.65 (1.99)$^{b}$ | 3.06 (1.82)$^{de}$ | 3.38 (1.93)$^{c}$ | 4.38 (2.17)$^{a}$ | 1.96 (156)$^{g}$ | 2.98 (1.81)$^{e}$ | 0.13 | 0.04 |
| Genus *Lycosa* | 2.51 (1.59)$^{f}$ | 3.09 (1.75)$^{cd}$ | 2.85 (1.68)$^{de}$ | 5.10 (2.26)$^{a}$ | 2.71 (1.64)$^{ef}$ | 2.98 (1.72)$^{d}$ | 3.31 (1.82)$^{c}$ | 2.56 (1.60)$^{f}$ | 3.60 (1.89)$^{b}$ | 0.19 | 0.06 |
| Genus *Pardosa* | 26.88 (5.54)$^{c}$ | 21.92 (5.15)$^{d}$ | 26.52 (5.79)$^{abc}$ | 28.74 (5.85)$^{ab}$ | 25.67 (5.66)$^{bc}$ | 27.55 (5.73)$^{abc}$ | 29.88 (5.82)$^{ab}$ | 28.78 (5.57)$^{bc}$ | 35.90 (5.97)$^{a}$ | 0.29 | 0.47 |
| Genus *Chrysso* | 40.88 (6.39)$^{d}$ | 37.38 (6.11)$^{h}$ | 48.26 (6.95)$^{a}$ | 40.90 (6.39)$^{a}$ | 37.56 (6.13)$^{f}$ | 43.99 (6.63)$^{c}$ | 40.81 (6.39)$^{e}$ | 37.48 (6.12)$^{g}$ | 46.70 (6.83)$^{h}$ | 0.06 | 0.004 |
| Genus *Cheiracanthium* | 0.39 (0.62)$^{b}$ | 4.13 (2.03)$^{d}$ | 5.64 (2.37)$^{b}$ | 6.13 (2.47)$^{a}$ | 2.80 (1.69)$^{f}$ | 2.94 (1.71)$^{f}$ | 2.83 (1.68)$^{f}$ | 2.49 (1.58)$^{g}$ | 3.25 (1.83)$^{e}$ | 0.22 | 0.05 |
| Genus *Clubiona* | 2.51 (1.59)$^{f}$ | 3.09 (1.75)$^{cd}$ | 2.85 (1.68)$^{de}$ | 5.10 (2.26)$^{a}$ | 2.71 (1.64)$^{ef}$ | 2.98 (1.72)$^{d}$ | 3.31 (1.82)$^{c}$ | 2.56 (1.60)$^{f}$ | 3.60 (1.89)$^{b}$ | 0.24 | 0.08 |
| Genus *Atypena* | 27.81 (5.26)$^{e}$ | 28.72 (5.35)$^{d}$ | 33.97 (5.83)$^{a}$ | 29.09 (5.39)$^{cd}$ | 25.63 (5.06)$^{g}$ | 29.10 (5.44)$^{b}$ | 29.64 (5.44)$^{b}$ | 29.30 (5.41)$^{bc}$ | 26.65 (5.16)$^{f}$ | 0.49 | 0.08 |

Table 5. Diversity parameters of spiders in cultivation systems of rice

| Diversity Parameter | Transplanted rice | | | Broadcasted rice | | | Drumsown Rice | | |
|---|---|---|---|---|---|---|---|---|---|
| | Organic Protection plots | Farmers' Protection plots | No Protection plots | Organic Protection plots | Farmers' Protection plots | No Protection plots | Organic Protection plots | Farmers' Protection plots | No Protection plots |
| Species richness | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 | 22 |
| Species diversity (Shannon-Wiener index) (H') | 2.00 | 2.18 | 2.22 | 2.90 | 2.20 | 2.22 | 1.58 | 1.52 | 1.58 |
| Pielou's Evenness Index | 0.65 | 0.71 | 0.72 | 0.72 | 0.71 | 0.72 | 0.51 | 0.49 | 0.51 |
| Species density (no/quadrat) | 8.03 | 6.6 | 9.7 | 8.8 | 7.2 | 9.0 | 8.7 | 8.1 | 10.1 |

and Lobo, 2007) are significantly correlated with the structure of the vegetation. Some authors reported that plant species might have an indirect effect on spider community structure via their influence on prey abundance or diversity (Halaj et al., 1998).

*Chrysso*, *Cheiracanthium* and *Atypena* live close to the water level and transplanted plots had more water depths maintained throughout the growth period compared to drum sown and broadcasted plots. Moreover, these three species are foliage dwellers and form tiny sheet webs or sac webs and the closely spaced hills in the transplanted crop could have suited their existence. Shading in the plots also might help these shade loving genera. Entling et al. (2007) also reported that spider communities show relationship to shading and moisture. Interactive effects of the main and subtreatments were also significant for most of the spider genera considered. Not only are the insecticides lethal to the spiders but to their prey as well, like the chironomids and detrivores as well, which also form an important part of the spider diet. Similar result was reported by Ghosh (2013) who found that the two synthetic insecticides methomyl and profenophos were harmful and caused significant killing of spiders in bhendi.

Takada et al. (2014) reported that spider density and species richness were more in winter flooded naturally grown rice fields than in conventional systems, both before and after insecticide applications. They suggested that the spider density and species richness in naturally grown rice was affected by the biomass of chironomids and other Nematocera but did not include any factors of habitat complexity, such as mean rice height or weed density. These two groups of prey increased both spider density and species richness. Girish (2011) observed that the survived spider population in azadirachtin treatments was at par with untreated check, after three days of spray. Sekh et al. (2007) suggested that flubendiamide 480 SC was safe to important natural enemies associated with rice leaf folder and yellow stem borer. Karthikeyan et al. (2008) found that spinosad 45 SC @ 54 g.a.i./ha was safe to spiders, which predominate the predatory fauna of rice ecosystem, while emamectin benzoate, bifenthrin, profenophos, chlorfenpyr, thiacloprid, indoxacarb and ranaypyr treatments supported significantly low spider population. The lower spider population in emamectin benzoate and profenophos might be due to the acaricidal properties. (Girish, 2011). The spider populations decreased by 39.4% at 3 days after application of deltamethrin 25% at 10 and 12.5 g a.i./ha (Sontakke and Dash, 2000).

**Species richness, diversity and evenness**

**Species richness:** A wide diversity of spiders of twelve families, twenty two genera and twenty nine species was observed in the present study. Species richness was 22 spiders (genera) belonging to 12 families *viz*., Araneidae (*Neoscona*, *Araneus*, *Argiope*), Clubionidae (*Clubiona*) Eutichuridae (*Cheiracanthium*), Linyphiidae (*Atypena*), Lycosidae (*Lycosa* and *Arctosa*), Oxyopidae (*Hamataliwa* and *Oxyopes*), Pholcidae (*Pholcus*), Salticidae (*Bianor*, *Chalcotropis*, *Mymarachne*, *Telamonia)*, Sparassidae (*Heteropoda*), Tetragnathidae (*Tetragnatha*, *Pachygnatha* and *Leucauge)* Theridiicae (*Chrysso*), Thomisidae (*Runcinia*) (Table 4).

Similar studies on spider species richness in different establishment methods of rice were carried out by Girish et al. (2015), who reported the occurrence of six families viz., Lycosidae, Tetgragnathidae, Araneidae, Salticidae, Miturgidae and Oxyopidae.

**Species diversity:** Species diversity or Shannon-Wiener index (H') of pooled data of two years was the highest (Table 5) in 'no protection' plots of transplanted rice (2.9) and the least in farmers practice plots of drumsown rice (1.52). Diversity was found to be more in the transplanted and broadcasted rice plots, while the drum sown plots registered less. This indicated that crop structure in transplanted and broadcasted plots supported more spider diversity. Structurally complex crops, providing a wider assortment of resources, would be predicted to support a more diverse spider assemblage, thus increasing the chances of the 'best' match between spiders and insect pests (Sudhikumar et al. 2005) and transplanted and broadcasted rice plots could have offered a complex structure for spiders.

A higher diversity implied better more chances of natural control but this also depends on prey density, architecture of the vegetation, crop stage, season and many other factors. A higher Shannon Wiener index indicated a more diversity of spiders and this meant lesser competition between the species for the food resources as spider genera vary with each other in terms of food preferences. Such a variation helps keep up the chances of enhanced natural control. A diverse community indicates more complicated food chain, better flow of energy between the various trophic levels and enhanced stability. Similar results were reported by Tahir and Butt (2009) who found non-significant differences between diversity (df=3, 15; F= 2.69; P= 0.109) and evenness (df= 3, 15; F= 13.36; P= 0.177) among four differently managed rice fields viz., organic field, herbicide treated field, reduced input field and tilled field.

Pekár and Kocourek (2004) reported that insecticides seemed to destroy spider diversity, however, Prieto-Benitz and Mendez (2011) reported no loss of spider diversity due to insecticides. Sudhikumar (2007) found that the Shannon diversity index of spiders, richness index and evenness index did not differ significantly between *kharif* and *rabi* seasons. A diverse group of spiders might be effective in biological control because they differ in hunting strategies, prey and habitat preference and activity/periods. Spiders exhibit both functional and numerical responses to prey densities. By virtue of these density dependent responses, as well as polyphagy, spider populations in agrosystems are stable (Sarma et al., 2013). Diversity parameters indicated a very stable rice ecosystem in the study area. Similar results were reported by Zhang et al. (2013) on diversity indices of organic rice in China. Sebastian et al. (2005) collected spiders representing 16 families, 47 genera and 92 species from the rice fields of Kuttanad, Kerala. Bhuvad et al. (2011) recorded 526 individuals, 14 genera and 29 species belonging to seven families with a Shannon diversity index of 2.73 in rice crop in the Konkan region.

**Pielou's Evenness Index:** Pielou's Evenness Index ranged from 0.59 to 0.73 between treatments. A higher evenness index indicates a very even community as in the present study and pooled data indicated higher and on par evenness indices in transplanted (0.65, 0.71 and 0.72, respectively in organically protected, farmers' practices and unprotected plots), while in broadcasted rice plots evenness indices in organically protected, farmers' practices and unprotected transplanted rice plots were 0.72, 0.71 and 0.72, respectively. Lower indices of 0.51, 0.49 and 0.51 prevailed in the organically protected, farmers' practices and unprotected drumsown rice plots, respectively.

**Species density**

Pooled data on spider density was 8.03, 6.6, 9.7 respectively in the organically protected, farmers' practices and unprotected transplanted rice plots, while it was 8.8, 7.2 and 9.0 in the organically protected, farmers' practices and unprotected broadcasted rice plots, respectively and it was 8.7, 8.1 and 10.1 in the organically protected, farmers' practices and unprotected drum sown rice plots, respectively. Evenness and number of species influence the Shannon-Wiener index in any ecosystem.

**Guild structure**

Spider genera collected were classified into seven categories on the basis of mode of predation or attack on the prey (Uetz et al., 1999). Contribution of each type of guild to the total spider population in the rice ecosystem was worked out and the results are presented in Fig. 1.

Many workers worked on the guild of rice spiders in various parts of the country. Mathew et al., (2014) reported 17 families of spiders on rice crop in Kuttanad rice ecosystem and 28% of them belonged to stalkers category, 26% to orb weavers, 13% were ground runners, 11% were spaceweb builders, 10% ambushers, 7% foliage runners and 5% were sheet web builders. Chapke (2012) made a study on spider diversity in agroecosystem of Vidharbha region, Maharashtra collecting spiders representing 11 families, 30 genera and 65 species and reported that the Salticidae constituted 37% and Araneidae, Thombicidae 14% each, respectively while Lycosidae and Clubionidae constituted 10% and 7% of the total collection.

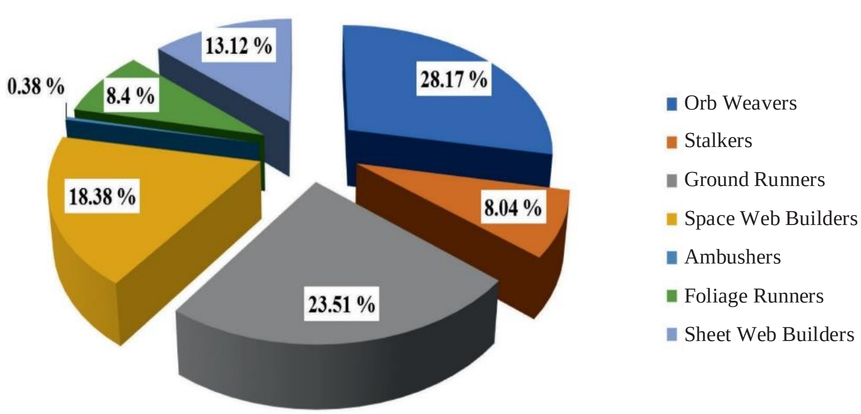


Fig. 1. Guild composition of spiders in rice ecosystem

Spiders can be grouped into specific functional groups based on the relative distribution and predatory methods (Bultman et al., 1982). Describing spider diversity in terms of these groups allows greater insights into how habitat differences may be reflected in life history strategies (Lee and Kim, 2001). Spiders are mostly generalists and their diversity and abundance in a crop depends on many factors like spacing, micro and macroclimate, season and time of the day, and their foraging strategy. Changes in the vegetation structure of the habitat influence species composition (Mathew et al., 2014)- dense and compact canopy as in the case of rice crop. Structural complexity might determine the guild composition of a crop spider fauna and indirectly influence the level of herbivore damage (Young and Edwards, 1990).

**Vertical stratification**

Most of the Tetragnathidae and Araneidae build webs in the top canopy of the crop and wait for prey like adults of stem borer, leaf folder adults, green leaf hopper, Diptera, dragonflies and damsel flies flying at heights of the rice canopy (Table 6). Eutichuridae and Sparassidae were found in the 60-80 cm of the plant height preying upon lepidopteran adults or grasshoppers, adult flies, wasps while Clubionidae, Pholcidae and Thomisidae were found to thrive on the 40-60 cm stratum of the rice plant. They preferred to feed on leafhoppers and brown plant hoppers and other small insects or coccinellids. Oxyopids were observed to be moving actively in the 20-60 cm stratum, stalking their prey which mainly consisted of hymenopterans, small dipterans and small adult moths. Thomisids especially are ambushers and adept at pouncing upon quick moving leaf hoppers and coccinellids like *Scymnus* sp. They wait behind the flowers and leapt upon honey bees or butterflies which alight on the panicle to suck the nectar from flowers.

Table 6. Vertical stratification of spiders in rice

| S. No. | Family | Genus | Stratum observed (height in cm of crop canopy from the base) (cm) |
|---|---|---|---|
| 1. | Araneidae | *Neoscona* | 20 |
| | | *Araneus* | >80 |
| | | *Argiope* | 80 |
| 2. | Tetragnathidae | *Tetragnatha* | 80 |
| | | *Pachygnatha* | >20 |
| | | *Leucauge* | >80 |
| 3. | Salticidae | *Bianor* | 20-40 |
| | | *Chalcotropis* | 20-40 |
| | | *Mymarachne* | 20-40 |
| | | *Telamonia* | 20-40 |
| 4. | Lycosidae | *Lycosa* | <20 |
| | | *Pardosa* | <20 |
| | | *Arctosa* | <20 |
| 5. | Oxyopidae | *Hamataliwa* | <20 |
| | | *Oxyopes* | 40-60 |
| 6. | Theridiidae | *Chrysso* | <20 |
| 7. | Thomisidae | *Runcinia* | 40-60 |
| 8. | Eutichuridae | *Cheiracanthium* | 60-80 |
| 9. | Sparassidae | *Heteropoda* | 60-80 |
| 10. | Pholcidae | *Pholcus* | 40-60 |
| 11. | Clubionidae | *Clubiona* | 40-60 |
| 12. | Linyphiidae | Atypena | 20-40 |

Sheetweb spiders of Linyphiidae and jumping spiders of Salticidae were seen at the penultimate stratum 20-40 cm where the former built small webs to trap prey but the latter were stalkers and could jump upon a wide range of insects like hoppers, wasps, flies, moths and butterflies. Theridiids and Lycosids (*Pardosa* sp.) were observed in the 0-20cm stratum chasing their prey which consisted of water dwelling insects also at times as they lived close to the ground. Genera of these families Linyphiidae and Theridiidae (*Atypena* and *Chrysso*) were found in more abundance in the present study.

In the present study, the spider community displayed good evenness and stability. Communities that exhibit more even numbers of individuals within the total number of species present might be closer to a state of equilibrium than those in which the numbers of individuals is not that even. Because the energy flow within ecological systems is constantly changing, consistent patterns of evenness within a given community could be equated with community stability.

Most of the Tetragnathidae and Araneidae build webs in the top canopy of the crop and wait for prey like adults of stem borer, leaf folder adults, green leaf hopper, Diptera, dragonflies, damsel flies flying at heights of the rice canopy. Sebastian et al. (2005) attributed the dominance of tetragnathid spiders in the rice ecosystem of central Kerala to the wet habitat which is congenial for this family.

Deviation in the spider species found at the base of the plant and collected from the canopy of the plant was due to the difference in position of their habitation in the paddy field. (Mathew et al., 2014). This indicated that the position of spider genera depended on the placement of the prey, possibility of finding it and structure of the vegetation. The web building and plant wandering spiders rely on vegetation for some part of their lives, either for finding food, building retreats or for web building (Mathew et al., 2014). These also reported more web building and plant dwelling spiders like the present study than ground dwellers. Hence, the diversity of spiders depends on the structural complexity of the vegetation to a large extent.

Complexity of the structure of vegetation again depended on the method of establishment of the crop; plants in the transplanted plots were more uniformly spaced compared to the plots where rice was sown by drum sown and broadcasted methods. The drum sown and broadcasted plots had wider spacing and this could have led to better aeration between the hills which supported lower pest levels and subsequently lesser populations of spiders were recorded in those plots. Dense and compact vegetation provides shade and humidity which are appropriate conditions, especially for small spiders of Linyphiidae and Theridiidae (Mathew et al., 2014) and genera of these families (*Atypena* and *Chrysso*) were found in more abundance in the present study. These spiders, exposed to loss of water more than larger ones, find hiding places in numerous, tiny spaces of such habitats (Duffey, 1962). Baur et al. (1966) opined that community of spiders or other invertebrates are mainly organized as a function of the structural complexity of the environments.

The present study focused on the diversity of spiders in rice ecosystem that showed enormous scope for natural control in rice in the absence of impeding forces like the indiscriminate use of agricultural chemicals, which have long term effects on the biology, fecundity and behavior of these valuable predators. Our results demonstrated that there is a strong relationship between cultivation systems, plant protection measures and the abundance and diversity of spiders in rice crop. A huge diversity of twelve families, 22 genera and 29 species were observed in the study area, which if conserved would help suppress pests in a natural way with no ill-effects to the environment.

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