Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

J E Z S Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2019; 7(5): 476-481

Received: 22-07-2019
Accepted: 24-08-2019

Mithra Mohan
Department of Agricultural Entomology, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India

Melvin Mohan S
Department of Agricultural Entomology, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India

Correspondence
Mithra Mohan
Department of Agricultural Entomology, College of Agriculture, Vellayani, Thiruvananthapuram, Kerala, India

Spiders: A boon to natural pest management

Mithra Mohan and Melvin Mohan S

Abstract
Spiders, the largest group of invertebrate predators, play a significant role in controlling the pest population in natural ecosystems. Potential attributes of spiders that make them efficient bio control agents are good searching capacity, broad spectrum prey range, number of organisms consumed in a lifetime, overwintering as adult stage and adaptations to live under dearth periods. Recent trends in agriculture accentuate the need for conservation of spiders in agro ecosystems and project it as a potential candidate for natural pest control mechanism.

Keywords: Spiders, predator, agroecosystems, conservation

Introduction
Spiders are members of the phylum Arthropoda, the largest phylum of animal group in the world under the class Arachnida. Spiders are ubiquitous in distribution and invade almost every type of habitat, and are the most abundant invertebrate predators in terrestrial agro ecosystems. Nearly 47,617 species of spiders under 4,092 genera in 114 families were recorded in the world, in which 2,299 species of spiders belonging to 67 families were recorded from the biodiversity rich spots in South Asia. Around 1,442 species of spiders in 59 families are documented from different regions of India [58 [67]].
Spiders are exclusive predators of insects and play a crucial role in maintaining the prey-predator balance in agro ecosystems. Some species of spiders are characterized by construction of intricate webs that may trap their prey whereas others are active predators that ambush or hunt their prey. Spiders are considered as ideal organisms for experiments in biological sciences. They also play a significant role as biological control agents, food source and providers of venom which has been used as medicines, insecticides, etc.

Biological cycle of spiders
Eggs and egg sac
A female spider lays up to 3000 eggs and is covered with a silken sac to protect the eggs from predators. The eggs are spherical to ovoid and differ considerably in color and size. Spiderlings spent their larval stages inside the egg sac and the emerging spiderlings are very small and sexually immature but exhibit similarity to adults in body shape.
Some spiders are well known for their parental care. In the family Lycosidae, newly emerged spiderlings are attached to the abdomen of the mother for first one week in order to escape from the predators. The female of nursery web spiders (Pisauridae) build a tent like web and appends the egg sac over it so that the emerging spiderlings can stay in the nursery web for about two weeks. In some families, like Theriidae, the mother feeds her young mouth to mouth with a special substance that she regurgitates [51].

Gregarious Phase
This phase continues from days to four or five weeks. Usually, spiderlings depend on yolk as a food source but some species exclusively attack immature eggs (e.g. Clubionidae) [26].

Dispersal of spiders- Ballooning
Dispersal of spiderlings is the important stage in the spider life cycle which usually observed from the first instar stage to the third stage. Newly emerged spiderlings will mount to a highest point and secrete silk threads through its spinnerets into the air. It leads to the development of a triangular shaped parachute-like structure which equips the spiderling to disperse to distant places with the aid of wind [50].

The solitary phase
After the dispersal to new habitats, spiders start a new phase in their life cycle, the solitary phase. In this phase, they are characterized as active hunters and some feed on dead organisms [26].

Food of spider
Spiders are usually carnivorous organisms that feed on insects and sometimes they depend on other species of same group [33]. In certain situations, they consume other invertebrates *viz.,* annelids, gastropod and soil micro arthropods. Some species of large spiders even feed on small vertebrates like birds and rats [34]. Jumping spider, *Bagheera kiplingi* is an exception to the feeding habit of spiders that they solely depend on specialized leaf tips of acacia plants (beltian bodies) and nectar and are popularly known as vegetarian spiders [29].

Role of spiders in agroecosystems
Spiders were recognized as a generalist predator and were used for pest management in different parts of the world about 2000 years ago itself [61]. Spiders are also well-known for their capacity to increase predation rates and also exhibited a functional response with respect to insect pest outbreaks [12]. They are often predated on lepidopteran and hemipteran pests which act as economically important pests of major crops or as vectors of plant diseases [4].

Spider as promising predator-Potential attributes
- Number of insects killed per unit time
- Good searching ability (especially hunting spiders)
- Predation is not species specific.
- Adaptation under conditions of food limitation
- Low metabolic rate [41]

Ecological guilds
Based on the foraging mode of the spider, they are divided in to two groups and 7 different ecological guilds [1] [62].

Web Builders - 3 Guilds
Spiders of these guilds usually construct aerial webs for capturing their prey. Walking, jumping and flying insects constitute their main prey.

Orb web weavers
Major spiders observed in the rice ecosystems. The preys were generally trapped in the sticky sites of the web and were covered with silken threads produced from the spinneret of the spider and dragged to the center of the web for feeding. The spiders recorded in this guild belong to the families *viz.*, Tetragnathidae and Araneidae.

Scattered Line Weavers
This group of spiders usually produces loose irregular webs in the shady areas. Theridiidae was recognized as the only family in this ecological guild.

Sheet Web Builders
The sheet web building spiders create closely woven sheet of irregular, adjacently spaced tangled webs. These spiders attach themselves to the web in an upside down position and feed on the trapped insects on the web. Linyphiidae and Agelenidae were the two families recorded in the guild.

Hunters- 4 guilds
The hunters recorded from the rice ecosystem include the stalkers, ambushers, ground runners and foliage runners. These spiders are invariably robust species, with elongate to cylindrical body shape and with conspicuous big eyes. They usually chase their prey, subdue it with its strength and feed on it.

Stalkers
These are diurnal spiders which jump on their prey and feed on it. The stalkers are mostly seen in upper side of the vegetation. The two families recorded are Oxyopidae and Salticidae.

Ground Runners
These spiders commonly feed on insects on the base layer of the field and rarely seen in the foliage. They jump upon its prey and mashed it using its well-developed chelicera.
e.g. Lycosidae

Ambushers
These are commonly detected in the inflorescence and exhibit a “sit-and-wait” strategy for prey capture. Some species act as predators of beneficial insects which visit the flower for pollination. e.g. Thomisidae

Foliage Runners
Whitish or brownish colored spiders which are active predators of insect pests and live in flat tubular nests constructed by rolled leaves. e.g. Miturgidae and Clubionidae.

Diversity of Spiders in Rice ecosystem in the world
The studies conducted in the agro ecosystem of Philippines identified about 51 taxa of spiders belonging to 34 genera under 16 families [5]. In China, 167 species of spiders in 28 families were reported from the rice ecosystem [68]. A survey conducted in the rice ecosystem of Bangladesh disclosed 39 species of spiders belonging to 28 genera and 10 [19].

Diversity of Spiders in Rice ecosystem in India
Studies conducted in various parts of India revealed that spiders are one of the predominant species of invertebrate predator in rice ecosystems. Thakur [64] recorded about 20 species of spiders in 12 genera and 8 families from Jammu region. The studies carried out in rice growing tracts of West Bengal led to the record of 19 species of spiders in 19 different genera under 11 families [8]. Around 19 species of spiders belonging to 15 genera under 10 families were documented from the rice ecosystems of Tamil Nadu which indicated the species abundance [21].

Important spiders in rice ecosystem
Tetragnathidae
Tetragnathidae is the predominant family of spiders observed in the rice ecosystem. These small- medium sized spiders with yellow or brown colour, usually construct weak orb webs in field or near field borders.
e.g. *Tetragnatha mandibulata*- Most common species in rice ecosystem of Central Kerala [52].
Tetragnatha listeria -Most abundant species in Kuttanad rice belts [62].
Tetragnatha javana- Most common spider observed in rice ecosystem of Tamil Nadu which was reported as the potential predator of green leaf hoppers and brown plant hoppers [27].

Prey preference and Predatory potential

Tetragnathids showed an increased preference towards green leaf hopper *Nephotettix virescens* followed by white-backed plant hopper *Sogatella furcifera*, brown plant hopper *Nilaparatha lugens*, rice stem borer *Scirpophaga incertulas* and leaf roller *Cnephalocrocis medinalis*. *Tetragnatha laboriosa* prefers gundhi bug, leaf folder and lepidopteran leaf feeders [46].

Tetragnatha sp. consumes an average of 14 adult BPH per day (Rao *et al.*, 1978). *T. javana* consumed 1.30 WBPH per day [32]. The feeding potential of *T. maxillosa* on *N. lugens*, *S. furcifera* and *Nephotettix* sp. to be 12.40, 15.20 and 16.60 respectively [35].

Araneidae

Araneidae is the second important family in the rice fields. These brightly coloured spiders usually construct large webs. The major genera are *Argiope* and *Neoscona*. *Argiope* species are large, yellowish- golden coloured spiders and they construct large orb webs. *Neoscona* species are small, brown coloured with fade markings on the body and create weak orb web near plants.

Prey preference and Predatory potential

Argiope sp. usually prefer gundhi bug, leaf folder and lepidopteran leaf feeders whereas *Araneus* sp. predates on leaf and plant hoppers [31] [60].

Argiope pulchella was recorded as an effective predator of BPH and it was observed to be consuming about sixteen adult BPH per day [39]. *Argiope catenulata* was recorded as a predator of grasshopper nymphs and crickets [16] whereas *Argiope anasuja* preferred leaf folders in rice [1].

Salticidae-Jumping spiders

Salticidae is another important family of spiders with large eyes and hairy body which are very active during the day time. They usually predate on caterpillars and flies [18]. Eg: *Telamonia dimidiata, Bianor carli*

Oxyopidae- Lynx spiders

The lynx spiders are strong creatures with rounded abdomen which are usually observed in the foliage. *Oxyopes* sp. predated on stem borer and leaf folders in rice ecosystem [16]. It also predates on caseworm and rice hoppers [46]. Studies conducted to identify the predatory potential of *Oxyopes javanus* revealed that it consumes about 4.80 BPH, 5.90 WBPH, and 5.20 GLH per day [27].

Lycosidae-Wolf spiders

These groups of spiders are very active and usually chase their prey. *Lycosa pseudoannulata* is considered as the most efficient predators of plant hoppers in rice ecosystem [17]. Predatory potential of *Lycosa pseudoannulata* on BPH, WBPH, and GLH was about 7.4, 6.9, and 6 respectively [27].

Pardosa pseudoannulata is another common spider which preferred hoppers, yellow stem borer, collembolans and flies [42]. *Paradosa* sp. exhibited highest preference on BPH followed by WBPH and GLH and the number of prey consumed was 14.31, 10.96 and 5.73 respectively [46]. Prey range of *P. pseudoannulata* includes leafhoppers, plant hoppers, whorl maggots, leaf folders, case worms and stem borers [23].

Vegetables

Thirty species of spiders in 9 families are observed in the vegetable ecosystem of Vellayani. *O. javanus* consumes *Amrasca biguttula biguttula*, *Aphis malvae*. and *Bemisia tabaci* and caterpillars of *Spodoptera litura*. They predated on Hemiptera, Lepidoptera and coleopteran pests in various vegetable crops [24].

Crab spider, *Thomisus* sp. feeds on caterpillar and adults of *Helicoverpa armigera* in tomato fields of Bangalore [4]. *Argiope catenulata, O. javanus and Neoscona theisi* consumes *Amrasca devastans, Aphis gossipii, B. tabaci, larva of H. armigera* and larva of *S. litura* [28].

Argiope luzona, Chrysso argyrodiformis, Hipassa pantherina, Oxyopes lineatipes, Oxyopes javanus, Peucetia viridana and *Lycosa pseudoannulata* are the important spiders present in the snakegourd and brinjal ecosystem which feed on a variety of insects like *Plusia orichalcia*, *Leucinodes orbonalis, Aphis gossypii*, *B. tabaci* and *Epilachna vigintioctopunctata* [48].

Pulses

The prevalent spiders found in redgram ecosystem were *Thomisus shivajiensis*, *Clubiona abbotti* and *Hippasa haryanesis*, which predated on lycaenid butterfly, *Lampides boeticus* [59]. They were also observed to reduce the population of *H. armigera, Clavigrella* sp. and moderately feed on *Melanagromyza obtuse* [3]. *Oxyopes shweta, Thomisus* sp. and *Saliticus* sp. predated on pod borer *Maruca testulalis* [11].

Oilseeds

Eighteen species of predatory spiders belonging to 16 genera in 7 families are commonly observed under oil yielding crops [44]. In groundnut, *Oxyopes salticus*, and *Misumenops* sp. occupied 85.8 to 97.7 per cent of overall population of spiders and effectively controlled the population of sesame capsule borer *Antigastra catalunalis* and *Acherontia styx* [10].

Plantation crops

In coconut, 26 species of spiders under six families were commonly observed in which *Rhene* sp. and *Cheiracanthium* sp. were reported as the predators of black-headed caterpillar *Opisina arenosella* [49]. About 117 species of spiders under 18 families were observed from the cashew plantations [13]. *Telamonia dimidiata* and *O. shweta* were recorded as the most common spiders of cashew plantation which act as predators of tea mosquito bug *Helopeltis* sp. *Argiope pulchella, Neoscona mukerjeri, Oxyopes sunandae, Nephila pilipes* were also observed to take part in keeping the pest population under control. In tea plantations, 85 species of spiders under 52 genera and 18 families were recognized from India. *Araneus mitificus*, *A. pulchella*, *Neoscona bengalensis*, *Dendrolycosa gitae*, *Thiana bhamoensis* were reported as the predominant spider fauna [45].

Fruit crops

About eleven spiders were documented from mango orchards in which *Araneus singhagadensis, Cheiracanthium danieli* and *Stegodlyphus sarasinorum* were the prevalent species which act as predators of mealy bugs [63]. The predatory potential of *Lyssomanes sikkimensis* on mango hoppers was about 0.60 to 5.20 per day [43]. *O. javanus*, *A. pulchella* and *Tetragnatha* sp. were also observed from mango ecosystem which feed on caterpillars of mango [56].

In grapevine, 27 species of spiders belonging to 14 families were recorded and the important species documented were *C. inclusum, T. dilutum, T. melanurum, Trachelas paceficus* and *Hololena dedra* which predated on grapevine leaf hopper *Erythroneura variabilis* [15]. Most common spiders in apple orchards were *Anyphaena accentuata, Clubiona brevipes, C. corticalis and C. leucaspis* which were reported as effective predators of aphids and caterpillars [26].

Flower crops

The important predatory spiders found in jasmine ecosystem were *Phidippus punjabensis, Salticus* sp., *Cheiracanthium* sp., *Pardosa* sp. and *Theridion* sp which were effective against larvae of *Nausinoe geometralis* [57].

Factors affecting spider population in an ecosystem

Ecological factors

- Soil type
- Moisture content
- Rain fall
- Temperature
- Percentage of organic matter

Direct and Indirect effect of Chemicals

- Herbicide treatments lead to destruction of habitat of spiders than by direct toxic effects [36].
- Chemical application leads to reduced prey availability
- Repellant effect of chemicals

Effect of insecticides, botanicals and microbials on spiders

Rather than direct toxicity, chemicals lead to the destruction of the habitat which negatively affects the population of spiders in agro ecosystems. Besides this, pesticide application resulted in reduction of prey availability along with consumption of poisoned prey which ultimately resulted in death of spiders [26].

Size of spray droplets also plays an important role in determining the spider population. Finer spray droplets adhered more to the webs than the coarse droplets. Usually spiders consume their web before constructing a new one resulting in the entry of these chemicals in to the spider body [47].

Experiments conducted to determine the relative toxicity of chemicals to spiders revealed that a combination of thiomethoxam and imidacloprid at a rate of 25 g ai/ ha reduced the spider population in absolute numbers [22]. But some reports highlighted that imidacloprid 0.005% was safer to spider fauna in rice ecosystem and synthetic insecticides like acephate 0.05% and quinalphos 0.05% were proved to be toxic to the spiders [1].

Broad-spectrum chemicals like dimethoate exhibited high toxicity to spiders which resulted in cent percent mortality to the lycosid *Trochosa ruricola* at concentrations below the field rates [9]. In vegetable ecosystems, avermectin was recorded as the highly toxic chemical to spiders [14]. Dimethoate at 0.05% was highly toxic to *T. mandibulata and N. mukerjei* causing cent percent mortality whereas imidacloprid 0.002% was less toxic to spiders [24].

Use of botanicals like neem oil, neem seed kernel extract and custard apple oil were comparatively safe to the spider population in agro ecosystems [37]. Application of neem oil and Azadirachtin were recorded as less toxic to spiders like *Distina* sp., *Marpissa* sp. and *Oxyopes* sp. [13].

Bt formulations Biotox applied at the rate of 1 kg/ha were found to be safe to spiders of Okra [30].

Effect of microbials on spiders

Fungi	Safety to spiders	Important spiders
Metarhizium anisopliae	Safe	Spiders in vegetable ecosystem [24].
Paecilomyces liilacinus	Safe	
Fusarium pallidoroseum	Safe	*Paradosa* sp., *Tetragnatha maxilosa, Oxyopes* sp. [40].
Beauveria bassiana	Pathogenic	*Tetragnatha mandibulata, C. danieli* [24].

Conservation and augmentation of spiders

- Establishment of favorable habitats for the spiders along with the artificial release of spiders in to the field. In China, straw beds were placed in fields which act as a shelter for spiders and these shelters along with spiders were transported to other places for the management of pest population in that area. This practice decreased the use of pesticides by 50 to 60 per cent [69].
- Artificial introduction of spider egg sacs in to the field along with drosophila flies. In Japan, *Drosophila* sp. were artificially released into rice fields in order to act as a food source for spiders in dearth periods [21].
- Maintaining ground cover crops in orchard which provide a habitat for spiders [41].
- Maintenance of weeds and annual flowers in the field will conserve the spiders and also maintain the micro climate in the field. e.g. The aquatic weed, *Pistia straitoides,* in rice sheltered more spider and spiderlings of *Oxyopes* sp. and *P. pseudoannulata,* which provides a suitable atmosphere for the maintenance of spiders [37].
- Addition of organic manure in to the field. It leads to the abundance of soil arthropods which act as supplementary food source for spiders [54].
- Minimum tillage will conserve the spider population [38].
- Botanicals and bio pesticides are less toxic to the spider population in the field. Use of botanicals like neem oil, neem seed kernel extract, neem seed biters, chinaberry oil and custard apple oil almost conserved the natural spider population [37].
- If there is a severe pest attack, we can depend upon some spider friendly insecticides.
- Chemical application should be judicious and limited to the periods when the spiders are inactive and in sheltered locations

List of insecticides safe to spiders

Insecticide	Dosage	Agro ecosystem
Imidacloprid 17.8 SL	0.02%	Vegetable [24]
Flubendiamide 480 SC	0.02%	Rice [53]
Chlorantraniliprole 20 SC	40 g a. i. / ha	Rice [55]
Indoxacarb 14.5 SC	72.50 g a.i./ ha	Rice [20]

Conclusion

Spiders, the generalist predators in the agro ecosystems play an important role in the management of pest population and reduce the pesticide use pattern which eventually leads to

sustainable agriculture. Besides, over wintering nature of the adults make it easier for the spiders to invade the ecosystems early in the season, so that they can subdue the pest population in a better way than other natural enemies. The increased inclination towards pesticide free products and environmental stability in the current decades led to the projection of spiders as a boon to natural pest control mechanism.

Reference

1. Anis JR. Documentation and predatory potential of spiders in rice ecosystem and impact of insecticides on spiders. M. Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 2007, 170.
2. Ansari MA, Pawar AD. Prospectus for biocontrol of fruit borer, *Heliothis armigera* (Hubner) (Lepidoptera: Noctuidae) on tomato in Bangalore. Journal of Insect Science. 1980; 4:41-43.
3. Arrora PK, Monga K. Predacious spiders of pigeon pea pests and their extent of feeding. Uttar Pradesh Journal of Zoology. 1993; 13(1):81-82.
4. Bardwell CJ, Averill LA. Spiders and their prey in Massachusetts cranberry bogs. Journal of Arachnology. 1997; 25:31-41.
5. Barrion AT, Listinger JA. The spider fauna of Philippine rice agro ecosystems. Phillipines Entomolgist. 1981; 5:139-166.
6. Bhat PS, Srikumar KK, Raviprasad TN *et al*. Seasonal diversity and status of spiders (Arachnida: Araneae) in cashew ecosystem. World Applied Sciences Journal. 2013; 22(6):763-770.
7. Bhathal JS, Dhaliwal GS. Feeding efficiency of natural enemies of white backed plant hopper, *Sogatella furcifera* (Horvath). Indian Journal of Entomology. 1990; 52(2):223-225.
8. Bhattacharyya S. Biodiversity of spiders in the rice- field of Kalyani, West Bengal, India. Research journal of chemistry and Environment. 2000; 4(2):75.
9. Birnie L, Shaw K, Pye B, Denholm I *et al*. Considerations with the use of multiple dose bioassays for assessing pesticide effects on non-target arthropods. In: Proceedings, Brighton Crop Protection Conference on Pests and Diseases, 16-19 November, Brighton, UK, 1998, pp. 291-296.
10. Biswas GC, Kabir SMH, Das GP *et al*. Insect pests of sesame, *Sesame indicum* Linn in Bangladesh, their succession and natural enemies. Indian Journal of Entomology. 2001; 63(2):117-124.
11. Borah BK, Dutta SK. Natural enemies of legume pod borer *Maruca testulalis* Geyer in Jorhat, Assam. Insect Environment. 2001; 7:113-114.
12. Breene RG, Sterling WL, Nyffeler M *et al*. Efficacy of spider and ant predators on the cotton flea hopper (Hemiptera: Miridae). Entomophaga. 1990; 35:393-401.
13. Chakraborti S. Neem based management approaches for mustard insect pests. Journal of Entomological Research. 2001; 25(3):213-220.
14. Cheng XF, Liao C, Han WY, Fen ZJ *et al*. Studies on the effectiveness of avermectin to *Plutella xylostella* and its effects to farmland community structure of pests and their natural enemies. Acta Agricultural Zhejiangensis. 2000; 12:92-96.
15. Costello MJ, Daane KM. Spider (Araneae) species composition and seasonal abundance in San Joaquin Valley grape vineyards. Environmental Entomology. 1995; 24(4):823-831.
16. Garg DK, Kumar P, Single RN, Pathak M *et al*. Role of parasitoid *Trichogramma japonicum* and other natural enemies in the management of yellow stem borer and leaf folder in Basamati rice. Indian Journal of Entomology. 2002; 64(2):117-123.
17. Heong KL, Aquino GB, Barrion AT *et al*. Arthropod community structures of rice ecosystems in the Philippines. Bulletin of Entomological Research. 1991; 8(4):407-416.
18. Jackson RR, Pollard SD. Predatory Behavior of jumping spiders. Annual Review of Entomology. 1996; 41:287-308.
19. Kamal NQ, Karim RANM, Alam S *et al*. Spider fauna of paddy in Bangladesh. Journal of Insect Science. 1992; 5(2):175-177.
20. Karthick KS, Kandibane M, Kumar K *et al*. Effect of newer insecticides to natural enemies in the coastal rice ecosystem of Karaikal district, Union Territory of Puducherry. Asian Journal of Biological Sciences. 2015; 10(1):39-42.
21. Kobayashi S. The effect of *Drosophila* release on the spider population in a paddy field. Applied Entomology and Zoology. 1975; 10:268-274.
22. Krishnaiah NV, Prasad ASR, Lingaiah T, Kumar KM *et al*. Utilization of thiomethoxam and imidacloprid for the management of insect pest complex in rice. Indian Journal of Plant Protection. 2003; 31(1):51-55.
23. Lu Zhong-Xian, Villareal S, Yu xiao-Ping KL, Cui HU *et al*. Biodiversity and dynamics of Plant hoppers and their natural enemies in rice fields with different nitrogen regimes. Rice Science. 2006; 13(3):218-226.
24. Manu MP. Major spiders in vegetable ecosystem and their predatory potential. M. Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 2005, 104.
25. Marc P. Intraspecific predation in *Clubiona corticalis* (Walckenaer, 1802) (Araneae, Clubionidae): a spider bred for its interest in biological control. Memoirs of Queensland Museum. 2005; 33(2):607-614.
26. Marc P, Canard A, Ysnel F *et al*. Spiders (Araneae) useful for pest limitation and bio indication. Agriculture Ecosystem and Environment. 1999; 74:229-273.
27. Mathirajan VG. Diversity and predatory potential of spiders in cotton and rice ecosystem applied with thiamethoxam. Ph.D. thesis, Tamilnadu Agricultural University, Coimbatore, 2001, 92.
28. Mathirajan VG, Reghupathy A. Prey preference and predatory potential of spiders in cotton ecosystem. Entomon. 2003; 28:9-14.
29. Meehan CJ, Olson EJ Curry RL. Exploitation of the Pseudomyrmex–Acacia mutualism by a predominantly vegetarian jumping spider (*Bagheera kiplingi*). 93rd ESA Annual Meeting. 21 August, 2008.
30. Mishra NC, Mishra SN. Impact of biopesticides on insect pests and defenders of okra. Indian Journal of Plant Protection. 2002; 30:99-101.
31. Nanadakumar C, Pramodkumar MS. Survey of natural enemies in a rice ecosystem. Insect Environment. 1998; 4(1):16.
32. Nirmala R. Studies on predatory spiders, their potential prey and competitors: relationship between size and frequency. Oecologia. 1990; 55:130-136.
33. Nyffeler M. Prey selection of spiders in the field. Journal

of Arachnology. 1999; 27:317-324.
34. Nyffeler M, Symondson WOC. Spiders and harvestmen as gastropod predators. Ecological Entomology. 2001; 26:617-628.
35. Premila KS. Major Predators in rice ecosystems and their potential in rice pest management. Ph. D. thesis, Kerala Agricultural University, Thrissur, 2003, 200.
36. Raatikainen M, Huhta V. On the spider fauna of Finnish oat fields. Annales Zoologici Fennici. 1968; 5:254-261.
37. Rajendran R. Studies on the predatory spiders in rice ecosystem. Ph. D. thesis. Tamilnadu Agricultural University, Coimbatore, 1987, 160.
38. Rajeswaran J, Duraimurugan P, Shanmugam PS *et al*. Role of spiders in agriculture and horticulture ecosystem. Journal of Food Agriculture and Environment. 2005; 3(4):147-152.
39. Rao NB, Narayanan KL, Krishnamurthy S, Rao BH *et al*. *Paradosa annandalei*, a predatory spider of the brown plant hopper. International rice Research Newsletter. 1978; 3(1):13.
40. Reji Rani OP. Production and evaluation of the fungus *Fusarium palidoroseum* (Cooke) Saac.as a bio pesticide against pea aphid *Aphis craccivora* Koch. Ph. D. thesis, Kerala Agricultural University, Thrissur, 2001, 200.
41. Riechert SE, Lockley T. Spiders as biological control agent. Annual Review of Entomology. 1984; 29:299-320.
42. Rubia EG, Almazan LP, Heong KL *et al*. Predation of yellow stem borer (YSB) moths by wolfspider. International Rice Research. Newsletter. 1990; 15(5):22.
43. Sadana GL, Goel NK. A new species of spider of the genus *Oxyopes latreille* from India. Entomon. 1995; 20(1):71-73.
44. Sadana GL, Meenakumari. Predatory potential of the Lyssomanid spider, *Lyssomanes sikkimensis* Tikader on the mango hopper, *Idioscopus clypealis* (Lethierry). Entomon. 1991; 16:283-285.
45. Saha S, Roy TK, Raychaudhuri D *et al*. Survey on spider faunal diversity of Darjeeling tea plantations. Munis Entomology and Zoology journal. 2016; 11(2):622-635.
46. Samiayyan K, Chandrasekharan B. Prey potential and preference of three rice dwelling spiders. Madras Agricultural Journal. 1998; 85(7-9):427-429.
47. Samu F, Mathews GA, Lake D, Vollrath F *et al*. Spider webs are efficient collectors of agrochemical spray. Pesticide Science. 1992; 36:47-51.
48. Sankari A, Thiyagesan K. Population and predatory potency of spiders in brinjal and snakegourd. Journal of Biopesticide, 3(1), 28-32.
49. Sathiamma B, Jayapal SP, Pillai GB *et al*. The observations on spiders (Order: Araneae) predacious on the coconut leaf eating caterpillar *Opisina arenosella* Wlk. in Kerala: Occurrence and seasonal abundance. Entomon. 1987; 12(2):175-178.
50. Schneider JM, Roos J, Lubin Y, Henschel JR *et al*. Dispersal of *Stegodyphus dumicola* (Araneae, Eresidae): They do balloon after all. Journal of Arachnology. 2001; 29(1):114-116.
51. Sebastian PA, Peter KV. Spiders of India. University press, Hyderabad, 2009, 614.
52. Sebastian PA, Mathew MJ, Beevi PS, Joseph J, Biju CR *et al*. The spider fauna of the irrigated rice ecosystem in Central Kerala, India, across different elevational ranges. The Journal of Arachnology. 2005; 33:247-255.
53. Sekh K, Nair N, Gosh SK, Somachoudhary AK *et al*. Evaluation of flubendiamide 480 SC against stem borer and leaf folder of rice and effect on their natural enemies. Pestology. 2007; 31:32-34.
54. Settle WH, Ariawan H, Astuti TE, Cahyana W, Hakim LA, Hindayana D *et al*. Management of tropical rice pests through conservation of generalist natural enemies and alternative prey. Ecology. 1996; 77:1975-1988.
55. Shanwei B, Bengui X, Fang L *et al*. Control effectiveness of chlorantraniliprole on *Cnaphalocrocis medinalis* and evaluation of its safety to beneficial arthropods in the rice fields. Oryza. 2009; 7:144-157.
56. Shivamurthy. Population dynamics and management of shoot webber and hoppers infesting mango using safer molecules. M. Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 2016, 133.
57. Shukla GK, Sandhu GS. New records of natural enemies of jasmine leaf–web worm in India. Bulletin of Entomology. 1983; 24(2):135-136.
58. Silwal M, Molur S. Checklist of spiders (Arachinida: Araneae) of South Asia including the 2006 update of Indian spider checklist. Zoo's print Journal, 2007, 22(2).
59. Singh J, Mavi GS. A spider as predator of *Lambides boeticus* (Linn) (Lepidoptera: Lycaenidae), Punjab, India. Journal of Bombay Natural History Society. 1984; 81(2):501.
60. Sivakumar S, Baral K, Dasgupta MK *et al*. Role of bioagents in integrated control of some insect pests of rice. Journal of Interacademicia. 2003; 71:79-86.
61. Sparks AN, Ables JR, Jones RL *et al*. Notes on biological control of stem bores in corn, sugarcane and rice in the People's Republic of China. In: Biological control of pest in China. Washington, D. C, US Department of Agriculture, 1982, 193-215.
62. Sudhikumar AV. Studies on the taxonomy and bionomics of some predaceous spiders on insect pests of rice agrosystem in Kuttanad, Kerala. Ph. D thesis. Mahatma Gandhi University, Kochi, Kerala, 2007, 230.
63. Tandon PL, Lal B. Predatory spiders associated with insect pests of mango in India. Bulletin of Entomology. 1983; 24(2):144-147.
64. Thakur JN, Singh JP, Verma OP, Diwakarr MC *et al*. Spider fauna in rice ecosystem of Jammu. Journal of Biological Control. 1995; 9(2):125-127.
65. Van Den Berg AM, Dippenaar-schoeman AS, Schoonbee HJ *et al*. The effect of two pesticides on spiders in South Africa cotton fields. Phytophylactica. 1990; 22:435-441.
66. Wise DH. Spiders in Ecological Webs. Cambridge University Press, Cambridge, UK, 1993, 209.
67. World Catalog Spider. Natural History Museum Bern, version, 2018. 15.5. http://wsc.nmbe.ch.
68. Xu JS, Chen ZF, Hu RL *et al*. A study of spiders in paddy fields in Zheijang Province and their utilization. Natural enemies insects. 1987; 9(3):140-144.
69. Zhao J, Liu F, Chen W *et al*. Preliminary studies of the life history of *Misumenops tricuspidatus* and its control of cotton pests. Acta Ecologica Sinica. 1993; 26(3):255-266.