DOCUMENTATION AND PREDATORY POTENTIAL OF SPIDERS IN RICE ECOSYSTEM AND IMPACT OF INSECTICIDES ON SPIDERS

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DECLARATION

I hereby declare that this thesis entitled **"Documentation and predatory potential of spiders in rice ecosystem and impact of insecticides on spiders"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Documentation and predatory potential of spiders in rice ecosystem and impact of insecticides on spiders**" is a record of research work done independently by Ms. Anis Joseph R. (2004-11-17) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Dedicated to my dear loving
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***Anis Joseph. R** (2004 - 11- 17)*

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

LIST OF ABBREVIATIONS

%	Per cent
@	At the rate of
°c	Degree Celsius
a.i	Active ingredient
CD	Critical difference
cm	Centimetre
WAT	Weeks after transplanting
SP	Soluble powder
SL	Soluble liquid
EC	Emulsifiable concentrate
et al.	And others
Fig.	Figure
g	Gram
HAS	Hours after spraying
Kg	Kilogram
m	Metre
ml	Millilitre
L	Litre
mm	Millimetre
RLR	Rice leaf roller
spp.	Species
viz.,	Namely
WAS	Weeks after spraying
BPH	Brown plant hopper
GLH	Green leaf hopper
WBPH	White backed plant hopper
ZZLH	Zig zag leaf hopper
NSKE	Neem seed kernel extract
IPM	Integrated pest management

Introduction

1. INTRODUCTION

The rice ecosystem is an indigenous system with a terrestrial and aquatic environment and these two dimensions of the rice crop account for the extremely high complexity and biodiversity. The ecological complexity in the rice fields are constituted by the arthropod species richness along with the abiotic components. Our rice fields are robust and stable even in the absence of insecticides as a result of an extremely rich web of generalist natural enemies, mainly predatory spiders. Spiders are the most omnipresent and numerous predators in both agricultural and natural ecosystems, and without them insect pest populations would become out of control. Their potential as biological control agents can only be appreciated through a greater understanding of their abundance and species composition in different ecological systems (Barrion and Litsinger, 1995).

These carnivorous arthropods are largely ignored by the general public. The great diversity in appearance and habits and many of the striking peculiarities of these solitary, predaceous animals are of extremely important for pest control and subsequent crop production. But the spiders are not usually treated as an important biological control agent, because there is so little information on the ecological role of spiders in pest control. Spiders are numerous early season predators playing an important role in natural biological control in the irrigated rice crop at the initial stage.

The drive towards a more sustainable and integrated approach to pest management has engendered a renewed interest in conservation biological control, the role of natural enemy communities and their interactions with prey. Although less abundant, the capability of the spiders to consume large number of prey insects highlights them as a more significant component of the predator complex than had previously been realized (Hardwood *et al.,* 2005).

Spiders in rice ecosystem are among the least studied arthropods and the less explored natural enemy in Kerala, their study was mainly confined to the construction of species lists and identification of the species and the dominant ones, where as the quantitative information of spiders and the knowledge about their distribution and abundance in Kerala is meager. Spiders must be given prior importance and their conservation is paramount to the success of any integrated pest management programme in rice.

Over reliance on pesticidal plant protection in rice cultivation resulted in depletion of natural enemies including spiders, thus leading to adverse effects on the environment, beneficial organisms, surface water and ultimately human ill health. The pest resurgence after insecticide application can be clearly linked to the negative effect of these toxic chemicals on the spiders. A biological pest control strategy must be developed for sustainable crop production. This could be achieved by encouraging the spiders, which are the pest's natural predators and thus managing the rice fields with due consideration for the natural environment and the living organisms. Spiders are a boon to the rice farmers.

In the developed countries like China, Korea, Japan, Philippines etc. spiders in rice fields are given prime importance and considered as a major group of biological control agents which regulate the pest complex in rice. Spiders are used effectively in the control of rice pests in South East Asia.

The spiders have ample prey capturing techniques which no other natural enemy possess. Usually the other groups of natural enemies resort to a unique mode of attack on pests and their effectiveness in pest control is less when compared to that of spiders. The webs of the spiders are a typical feature which enables them to capture the insects and all the trapped insects are not fed and thus the webs act as a natural net which sweep and trap the flying and jumping insects, the entangled insects will never escape their ultimate fate of death. Especially in a crop like paddy, these webs are like an umbrella, over the crop which do not harm the plants but prevent the pests. The hunting spiders are always alert and agile in the field, running and jumping through out the crop canopy, searching for the prey insects.

In an ever changing world, crop production is gradually switching over to organic farming and eco friendly pest management practices, emphasis on crop production and crop protection using natural and organic ways for the better subsistence of the life forms on earth, reliance on less disruptive control measures and judicious use of pesticides and chemicals, give much stress to these beneficial arthropods, especially the predatory spiders.

An old Chinese saying goes like this, "If there is a large gathering of spiders; Every thing will be satisfactory ", which mainly refers to a rice ecosystem and the spider fauna associated with it and the mechanisms of pest control by the spiders. A spider mediated IPM should be developed, giving emphasis to biological control using predatory spiders and minimal use of insecticides. In rice ecosystem the beneficial functioning of spiders is to be enhanced by maximization of spider densities and species richness.

In this context the present study was done with the following objectives.

- To document and quantify the spiders in rice ecosystem and study their species diversity.
- To assess the seasonal occurrence and abundance of spiders during the entire crop cycle.
- To evaluate the predatory efficiency of dominant spider species and to examine their hyper predation on insect natural enemies.
- To study the relative toxicity/safety of synthetic pesticides and neem formulations on the dominant spiders and to assess the impact of synthetic pesticides and neem formulations on spiders, natural enemies and pests in the field.

Review of Literature

2. REVIEW OF LITERATURE

Spiders play a major role in regulating the insect pests in the agricultural fields, as well as in natural situations. Spider communities were studied in different agro ecosystems including rice fields. However, most of these studies were limited to the identification of the spiders collected and to investigating the dominant spider species. Literature available on the documentation of spiders in rice ecosystem and their species diversity, seasonal occurrence of spiders, pests and insect natural enemies, and the prey preference and predatory potential of dominant spiders, their hyper predation on other insect natural enemies and impact of insecticides on spiders is reviewed here.

2. 1 DOCUMENTATION OF SPIDERS IN RICE ECOSYSTEM

Spiders are always present in rice fields and are considered to be the important constant mortality factor in the rice ecosystem (Okuma, 1968; Kiritani *et al.*, 1972; Kamal, 1981; Ooi, 1982). During the past two decades there had been increased interest in the utilization of these spiders as natural enemies to control and regulate the pest populations in the rice ecosystem (Chandra, 1978). Spiders have a suit of adaptations that enable them to wait out periods of low prey abundance rather than dispersing like some other groups of arthropod predators (Greenstone and Bennett, 1980). Spiders are entomophagous arthropods proffer to keep insect pests below damaging levels in rice fields and thus natural bio-control of insect pests (Riechert and Lockley, 1984; Patel, 1991; Ganeshkumar and Velusamy, 1996 a). Polyphagous predators like spiders could suppress the populations of the pests like BPH, GLH, WBPH, leaf folder and whorl maggot (Holt *et al.*, 1985; IRRI, 1985; Bhathal and Dhaliwal, 1990; Venkateshalu *et al.*, 1998). Spiders are rampant in the rice ecosystem and their active and prolific predatory activity on a wide range of prey species ensures that spiders are potent bio-control agents (Anbalagan and Narayanasamy, 1996).

2.1.1 Documentation of Spiders Around the World

Spiders played an important role as predators of numerous pests of crops. Documentation of spiders in the tropical Asian Countries showed that Thailand (60) and Malaysia (30) had the highest number of reported spider species, followed by Indonesia (24), Burma (14), Philippines (12), Sri Lanka (9), and Bangladesh (8). (Barrion and Litsinger, 1980). Barrion and Litsinger (1995) reported that nearly 350 species of spiders occurred in the rice ecosystem in South and South East Asia. About two third of them were reported from the temperate Asian countries such as Philippines, Japan (90), Taiwan (75), China (61) and Korea (32).

Xu *et al.* (1987) identified 167 species of spiders in 28 families in rice fields of China. A field investigation by Cheng (1989) showed that there were 76 species of spiders in 13 families in the paddy fields in mountaineous areas of South Zhejiang, mainly in Salticidae, Araneidae, Lycosidae, Tetragnathidae, Pisauridae, Theridiidae, Erigonidae, Clubionidae, Thomisidae, Oxyopidae and Linyphiidae. Of the arthropod predators 31.40 per cent were spiders. *Lycosa pseudoannulata* Boesenberg and Strand was found to be one of the main components of the lycosid sub community in the rice fields (Zhang, 1989 ; Shi *et al.,* 1991). Qi (1990) studied the population dynamics of spiders in the rice ecosystem of Jiangsu, China and reported that the spider fauna was composed of Erigonidae (45.60 per cent), Lycosidae (24.20 per cent), Clubionidae (10.80 per cent), Theridiidae (10.20 per cent) and others (9.20 per cent). The detailed investigations on the structure and character of spider communities of single rice cropping field by Shi *et al.* (1991) recorded 45 spider species belonging to 25 genera. The major species being *Ummeliata insecticeps* Boesenberg and Strand, *Erigonidum graminicolumn* Sundevall, *Pirata subpiraticus* Boesenberg and Strand and *P. pseudoannulata.* Li *et al.* (2002) studied the diversity of wolf spiders in paddy fields of China and documented 30 species of lycosids belonging to seven genera and the major ones being *Pirata* and *Pardosa* and the dominant species were *P. pseudoannulata* and *P. subpiraticus.* Investigations carried out by Fang *et al.* (2003) to study the community structure of predatory arthropods in a weed habitat and a neighbouring paddy field in Dasha town, Guangdong province of China, collected 55 species of spiders from the paddy fields. In another survey conducted in the rice fields of Emei, Sichuan, China, a total of 33 species of spiders belonging to 19 genera and eight families were collected, majority of the spiders belonged to Lycosidae, Araneidae, Linyphiidae and Tetragnathidae (Hua and Mei, 2004).

The Philippine rice ecosystem alone revealed the existence of vast abundance of spiders with 51 taxa comprising 34 genera under 16 families (Barrion and Litsinger, 1981 a; 1981 b). Cruz and Litsinger (1988) studied the predators in the main ratoon and second transplanted rice crops and observed that space web and hunting spiders were most abundant and prevalent than orb-web weavers in the first crop period. Heong *et al.* (1990) reported that Araneae were the major group of predators in the Philippine rice ecosystem and recorded 13 spider species, of which *P. pseudoannulata* and three species of *Tetragnatha* and Linyphiids were dominant. *Tetragnatha* sp., *Atypena formosana* Oi and *L. pseudoannulata* were collected from rice fields (Heong and Aquino, 1990). The spiders *P. pseudoannulata*, *C. formosana* and three species of *Tetragnatha* were the dominant group of natural enemies in irrigated rice fields of Philippines next to heteropteran predators (Heong *et al.,* 1991 b and 1992). In the irrigated rice fields of Philippines the most common spiders documented were *A. formosana* and *P. pseudoannulata* (Sigsgaard and Villareal, 1999).

Kamal *et al.* (1990) conducted a survey to study the abundance and diversity of spiders in and around the Bangladesh Rice Research Institute farm and collected 12 species belonging to ten genera under eight families, *L. pseudoannulata, Oxyopes javanus* Thorell, *Tetragnatha javana* Thorell and *Plexippus* sp. were more abundant. Thirty nine species of spiders belonging to 28 genera and 10 families were recorded from the paddy fields of Bangladesh (Kamal *et al.*, 1992 a). Another study conducted in Shikerpur of Jhenidah district in Bangladesh resulted in collecting twenty nine species of spiders belonging to 16 genera under ten families from rice crops, associated weedy fallow on borders, ratoons and seed beds and the dominant species were *E. javana, T. mandibulata, Oxyopes* sp., *Oxyopes shweta* Tikader and *Neoscona theisi* Walckenaer (Kamal *et al.,* 1992 b).

Survey of the spiders in rice ecosystem conducted in Tokushima prefecture, Japan brought out 70 species of spiders belonging to 13 families (Kobayashi, 1961). Murata (1995) conducted a survey to study the density of spiders and their prey in the Japanese paddy fields by sweeping method, and recorded fourteen families.

Okuma (1968) reported 63 species of spiders in paddy fields in Thailand, where as Yasumatsu and Torii (1968) reported that a spider guild of 70 species was found in Thailand rice fields. Yasumatsu *et al.* (1981) made comprehensive discoveries of predatory spiders present in the rice fields of Thailand and their numbers. Genus *Tetragnatha* was found more in paddy fields of Thailand (Vungsilabutr, 1988).

L. pseudoannulata, Tetragnatha nitens Audouin, *T. javana* and *Tetragnatha virescens* Okuma were the important predators observed in the rice fields of Mekong Delta, Vietnam (Chau, 1987).

Oraze *et al.* (1988) conducted a survey of the spiders associated with the northern California rice fields and collected more than 30,000 specimens, representing 11 families, 22 genera and 28 species. Families Araneidae, Tetragnathidae, Linyphiidae and Lycosidae dominated the spider fauna.

Bastidas and Pantoja (1993) reported that weekly sampling of Colombian rice fields with a sweep net yielded 27 species of spiders belonging to 23 genera and 11 families.

The dominant spiders in the rice fields of central Java, Indonesia were web spiders and hunting spiders (Settle, 1994). Settle *et al.* (1996) documented 765 species of spiders from the low land irrigated rice fields in Indonesia.

Paik *et al.* (1979) reported that rice fields in Korea comprised 27.96 per cent of all Korean spiders, and included 22 families, 99 genera and 175 species.

2.1.2 Documentation of Spiders in India

Spider wealth in the paddy fields in India was documented from many parts of the country. Survey on the predators of *Nilaparvata lugens* Stal. in Tamil Nadu revealed the presence of large numbers of *Tetragnatha armatissimus* Tikader (Peter, 1988). Subsequent survey by Nirmala (1990) in Coimbatore, Bhavanisagar and Annamalai recorded 14 new species of spiders. Anbalagan and Narayanasamy (1996) recorded twenty one species of spiders under 16 genera belonging to ten families from Annamalainagar, in the rice ecosystem of the Eastern coastal belt of Tamil Nadu. In another experiment in Tamil Nadu, from the three surveyed regions, a total of seventeen, fourteen and nine species of spiders were recorded from Coimbatore, Aliyarnagar and Karaikal respectively, from the cultivated rice fields and border weeds. *L. pseudoannulata, Tetragnatha* spp. and *Thomisus cherapunjeus* Tikader were found to be prevalent in all the three locations (Ganeshkumar and Velusamy, 1996 a). The predatory spider complex in the rice fields of Tamil Nadu and Pondicherry revealed that *L. pseudoannulata, Marpissa mandali* Tikader, *O. javanus, Argiope catenulata* Doleschall and *T. javana* were the most prevalent ones (Geethaviswanathan *et al.*, 1996). In the rice ecosystem of Tamil Nadu, *L. pseudoannulata, O. javanus, Pardosa sumatrana* Thorell, *Tetragnatha mandibulata* Walckenaer, *Tetragnatha maxillosa* Thorell and *T. javana* were more populated than other spiders and the population abundance and species diversity of the spiders were found directly related to the growth stages of rice plant (Anbalagan and Narayansamy, 1999). Mathirajan (2001) reported 19 species of spiders in rice ecosystem of Tamil Nadu, grouped under 15 genera belonging to ten families. Spiders were the most dominant group of predators constituting 71.20 per cent out of the total natural enemies in the rice fields at Kovur village, Kancheepuram district during Sornavari season (ERI, 2003).

Chatterjee and Dutta (1979) presented a list of nine species of spiders that were observed preying on *N. lugens*. At Khahankal and flood prone area of West Bengal, in the summer crop, six species of spiders belonging to the families Oxyopidae, Lycosidae, Thomisidae, Argiopidae, Salticidae and Linyphiidae were collected (Nath and Sarkar, 1980). Banerji *et al.* (1993) conducted routine field sweeping for three years in West Bengal and revealed that the spider complex alone contributed about 57.98 per cent, 61.00 per cent and 55.60 per cent yearly arthropod population respectively for the three years and seven spider groups viz., *Lycosa* spp, *Atypena spp*, *Tetragnatha* spp, *Oxyopes* spp, *Phidippus* spp, *Araneus* spp, and *Thomisus* spp maintained fairly high population. In the rice growing zone of Kalyani region of West Bengal, fortnightly surveys were made to document the spiders and came out with 19 spider species representing 19 genera, 11 families and the total number being 2035 (Bhattacharyya, 2000).

In Ludhiana, a survey was conducted and 13 species of spiders were recorded preying on the delphacid, *Sogatella furcifera* Horvath, of which five species were web spinners and eight species were hunting spiders (Bhathal *et al.*, 1990). Kaur *et al.* (2001) recorded spiders under eight families from a survey in Jalandhar, in irrigated rice fields, where *Tetragnatha* and *Oxyopes* were the dominant. Shenhmar *et al.* (2001) documented spiders belonging to the families Araneidae, Clubionidae, Metidae, Oxyopidae, Salticidae, Thomisidae and Tetragnathidae from Punjab rice ecosystem.

Rao *et al.* (1978) recorded three species of predatory spiders in the dry season rice crop at Bapatla *viz., Pardosa annandalei* Gravely, *Argiope pulchella* Thorell and *Tetragnatha* sp. found operating at different vertical levels in the crop, and kept the populations of *N. lugens* under check. Gupta *et al.* (1986) documented 15 species of spiders comprising eleven genera under six families from rice fields.

Samal and Misra (1975) reported about 20 species of spiders preying on *N. lugens* on rice fields. Bhardwaj and Pawar (1987 a and 1987 b) documented the spiders in rice ecosystem in Chhattishgarh region, Madhya Pradesh for the first time and reported thirteen species in eight families. Fifteen species of spiders belonging to six families were recorded from the rice fields of Chhattishgarh, from a survey conducted by sweeping, which yielded a total of 6581 spiders (Mishra and Shrivastava, 1993).

Thakur *et al.* (1995) revealed the presence of 20 species of spider belonging to 12 genera under eight families in the rice fields of Jammu region and the predominant and common species fell under the genera *Tetragnatha, Neoscona, Oxyopes, Phidippus* and *Pardosa. Tetragnatha* spp were found in more numbers.

Pathak and Saha (1998) studied the spider fauna in the rice fields of Barak Valley Zone at Karimganj district of Assam, by weekly surveys covering the three crop seasons for three consecutive years and found that all together ten spider species belonging to six families were prevalent throughout the year. *O. shweta, Tetragnatha andamanensis* Tikader, *Pardosa* sp. were very common.

Ansari and Pawar (1992) documented the spider fauna in the paddy fields of Karnataka.

Garg *et al.* (2002) documented *P. pseudoannulata, T. maxillosa, O. javanus, A. formosana* and *A. catenulata* from the basmati rice fields of Western Uttar Pradesh.

In Kerala, Thomas *et al.* (1979) reported the occurrence of large number of spiders on rice crops in Kuttanadu (average 2/hill) and documented *Lycosa* sp., *Pholcus* sp., *M. mandali, Tetragnatha* sp., *Linyphia* sp., *Oxyopes sakuntalae* Tikader and *Argiope undata* Burlington. Regunath *et al.* (1990) recorded the presence of several spiders, *viz., T. maxillosa, P. pseudoannulata, O. javanus, Oxyopes lineatipes* C.L. Koch and *A. formosana* in the punja paddy ecosystem of Vellayani lake, Trivandrum of Southern Kerala. Nandakumar and Pramod (1998) reported that *L. pseudoannulata, Oxyopes* sp., *T. maxillosa, Phidippus* sp., *Atypena* sp., and *Araneus* sp. were found in the Kottarakkara water shed rice ecosystem of Kollam District. In the Kuttanadu rice growing tract, spiders like *Lycosa* sp., *Oxyopes* sp., *T. maxillosa* and *Atypena* sp. were present (Nalinakumari *et al.*, 1996; Ambikadevi, 1998). The arthropod populations associated with the rice growing regions of Thrissur district was quantified and analysed and found that spiders were the predominant predators at all the locations and found at a rate of 4 to 27.25 numbers (Beevi *et al.,* 2000). Meera (2000) documented nine species of spiders belonging to eight families from the rice fields of Thrissur district, both from the kole and non-kole areas. Sudhikumar and Sebastian (2001 and 2005) studied the spiders in Kuttanadu rice fields and collected spiders representing eight families, fifteen genera and 22 species. *Tetragnatha* spp, *P. pseudoannulata* and *A. formosana* were recorded from Kuttanadu and double cropped rice ecosystem of Thiruvananthapuram. *Tetragnatha* spp was the dominant predator in Thiruvananthapuram and the only spider predator observed at 30 days after transplanting in Pokkali rice fields (Premila, 2003 ; Premila *et al.*, 2003). Sebastian *et al.* (2005) conducted a survey in the irrigated rice ecosystem of central Kerala, to document the spiders associated with the paddy fields across different elevational ranges and collected 1130 individuals through visual searching, which included 92 species and 47 genera belonging to 16 families. Araenidae and Tetragnathidae were the dominant families and *T. mandibulata,* the most abundant species. Orb web weavers were dominant in all the study regions.

2.1.3 Species Diversity of Spiders in the Rice Ecosystem

2.1.3.1 Family Tetragnathidae

Among the different spider genus in the paddy fields of Thailand, *Tetragnatha* were found most abundant, and the different species included *Tetragnatha ceylonica* Cambridge, *Tetragnatha japonica* Boesenberg and Strand, *T. javana, Tetragnatha mackenziei* Gravely, *T. mandibulata, T. nitens, Tetragnatha virescens* Okuma (Okuma, 1968; Vungsilabutr, 1988). Oraze *et al.* (1988) collected *Tetragnatha elongata* Walckenaer and *Tetragnatha laboriosa* Hentz, which were found rare in the flooded rice fields of Northern California. Kamal *et al.* (1992 b) collected *Tetragnatha mandibulata bidentata* Gravely, *T. mandibulata, Tetragnatha fletcheri*

Gravely and *T. javana*, among which *T javana* and *T. mandibulata* were the common species in Bangladesh and *T mandibulata* was most abundant.

T. mandibulata was obtained from the rice fields of Madhya Pradesh and had high prevalence (Bhardwaj and Pawar, 1987 a and 1987 b). *Tetragnatha* spp were commonly found throughout the year in West Bengal (Banerji *et al.*, 1993). Thakur *et al.* (1995) reported that *T. andamanensis*, *Tetragnatha* spp, *Leucage decorata* Blackwall and L*eucage* sp. were found in more numbers in Jammu. In Tamil Nadu diverse species like *L. decorata* and *Taylorida striata* Thorell, apart from the four most abundant species *T. javana, T. mandibulata T. maxillosa* and *Tetragnatha* sp., were observed (Anbalagan and Narayanasamy, 1996 and 1999; Ganeshkumar and Velusamy, 1996 a). Of the two tetragnathids collected *viz., Tetragnatha* sp. and *T. andamanensis,* the latter one was very common in the paddy fields of Barak Valley, Assam (Pathak and Saha, 1998). Where as, in Kalyani region of West Bengal, *Tetragnatha* sp. was the rare species collected (Bhattacharyya, 2000). Kaur *et al.* (2001) reported the tetragnathids *L. decorata* and *Tetragnatha* sp. where as Shenhmar *et al.* (2001) collected diverse species of tetragnathids from Punjab rice ecosystem *viz., Leucage celebasiana* Walckenaer, *L. decorata, T. javana, T. virescens* and *Tetragnatha* sp. Mathirajan (2001) documented *T. striata, T. javana, T mandibulata* and *T. maxillosa* from Tamil Nadu. The rice fields of Kuttanad (Sudhikumar and Sebastian, 2001 and 2005) harboured *Tetragnatha listeri* Gravely, *T. fletcheri, Tetragnatha gracilis* Lucas, *T. cochinensis* and *T. mandibulata.* The most abundant species was *T. listeri.* In central Kerala, one of the dominant families observed was tetragnathidae and exhibited high diversity and the different species encountered were *Dyschiriognatha dentata* Zhu and Wen, *Leucage* sp., *Leucage bituberculata* Baert, *Leucage celebesiana* Walckenaer, *L. decorata, Leucage pondae* Tikader, *T. andamanensis, T. ceylonica, T. cochinensis, T. fletcheri, T. javana, T. mandibulata, T. maxillosa, Tetragnatha vermiformis* Emerton, *Tetragnatha* sp. and *Taylorida culta* O.P. Cambridge and among these, *T. mandibulata* was the most abundant species

(Sebastian *et al.*, 2005).

2.1.3.2 Family Araneidae

Oraze *et al.* (1988) collected *Araneus trifolium* Hentz, *Argiope aurantia* Lucas and *Argiope trifasciata* Forskal from California. Kamal *et al.* (1992 a) reported the presence of *Neoscona* sp., *N. theisi*, *Neoscona elliptica* Tikader and *Neoscona nautica* L. Koch in the rice fields of Bangladesh.

Argiope spiders were reported from the summer rice crop at Khahankal and flood prone area of West Bengal (Nath and Sarkar, 1980). *Neoscona* sp was recorded from Madhya Pradesh and Kalyani region of W. Bengal (Bhardwaj and Pawar, 1987 a; Bhattacharyya, 2000). The late colonizers in the rice crop canopy in Chinsurah were *Araneus* spp (Banerji *et al.*, 1993). In Jammu, the rice fields harboured the araneids *Neoscona* sp., *N. theisi*, *Neoscona mukerjei* Tikader, and *Araneus mitifica* Simon (Thakur *et al.*, 1995). Anbalagan and Narayanasamy (1996 and 1999) reported *A. catenulata*, *Argiope minuta* Karsh, *Cyrtophthora cicatrosa* Stoliczka, *N theisi* from Tamil Nadu. In another study in Tamil Nadu, *Neoscona* sp., *N. nautica*, *Larinia* sp., *Argiope anasuja* Thorell and *A. catenulata* were collected (Ganeshkumar and Velusamy, 1996 a). Pathak and Saha (1998) observed *Argiope pulchella* Thorell and *Neoscona* sp. from Assam. *Neoscona* sp. and *Araneus insustus* Koch were reported from Punjab (Kaur *et al.*, 2001), where as Shenhmar *et al.* (2001) recorded *A. catenulata, N. theisi* and *A. insustus* from Punjab. Mathirajan (2001) recorded the presence of *N. theisi, C. cicatrosa, A. catenulata* and *A. minuta* in Tamil Nadu . In Kuttanadu, *Cyclosa* sp., *Araneus* sp. and *Neoscona* sp. were documented (Sudhikumar and Sebastian, 2001 and 2005). Sebastian *et al.* (2005) recorded an array of araneids from rice fields of various elevational ranges in central Kerala, *viz.*, *Araneus* sp., *Araneus bilunifer* Pocock, *A. ellipticus*, *Argiope* sp., *A. aemula, A anasuja, A. catenulata, A. pulchella, Chorizopes* sp., *Cyclosa* sp., *Cyclosa bifida* Doleschall, *Cyclosa fissicauda* Simon, *Cyrtarachne* sp., *Cyrtophora* sp., *Cyrtophora citricola* Forskal, *Eriovixia* sp., *Eriovixia laglaizei* Simon, *Eriovixia excelsa* Simon, *Gasteracantha* *geminata* Fabricius, *Gibbaranea bituberculata* Walckenaer, *Neoscona* sp., *Neoscona bengalensis* Tikader & Bal, *Neoscona molemensis* Tikader & Bal, *Neoscona vigilans* Blackwall and *Zygiella* sp.

2.1.3.3 Family Salticidae

The jumping spider, *Larinia tabida* Thorell was reported from the rice fields in Philippines (Barrion and Litsinger, 1981 b). Diverse and different salticid fauna was recorded from California *viz., Habronattus klauserii* Peckham and Peckham, *Metaphidippus vitis* Cockerell, *Neon ellamae* Gertsch and Ivie, *Phidippus californicus* Peckham and Peckham, *Phidippus clarus* Keyserling, *Phidippus johnsoni* Peckham and Peckham, and *Sitticus dorsatus* Banks (Oraze *et al.,* 1988). The Bangladesh rice fields yielded the saticids, *viz., Zygoballus* sp., *Zygoballus narmadaensis* Tikader, *Zygoballus pushanensis* Tikader, *Salticus* sp., *Phidippus pateli* Tikader and *Plexippus* sp.(Kamal *et al.*, 1992 b).

The salticids *Bianor* sp., *Aelurillus* sp., *Hyllus* sp and *Thyene* sp. were collected from Chattishgarh region (Bhardwaj and Pawar, 1987 a and 1987 b). Banerji *et al.* (1993) recorded a good population of *Phidippus* sp. in West Bengal. Thakur *et al.* (1995) surveyed the Punjab rice fields and came out with the salticids *viz., Phidippus punjabensis* Tikader, *Phidippus* sp. and *Zygoballus* sp. Anbalagan and Narayanasamy (1996 and 1999) observed *Bianor* sp., *Bianor nr. angulosus* Karsh, *Bianor hotingcheihi* Schenkel from Tamil Nadu. The agile species *Phidippus* sp. and *Plexippus paykulli* Savingyny & Audouin were recorded both from Tamil Nadu and Punjab (Ganeshkumar and Velusamy, 1996 a; Shenhmar *et al.*, 2001). *Zygoballus* sp. was found in Assam (Pathak and Saha, 1998). In the Kalyani region of West Bengal, the species recorded were *Salticus ranjitus* Tikader, *Aelurillus* sp., *Bianor* sp., *Hyllus* sp., *Thyene* sp. and *Marpissa* sp., (Bhattacharyya, 2000). Kaur *et al.* (2001) observed the active movement of salticids in paddy fields of Punjab. Mathirajan (2001) recorded *B. nr angulosus* and *B. hotingchiehi* from Tamil Nadu. Salticid spiders were collected from Kuttanadu (Sudhikumar and Sebastian, 2001 and

2005). The salticids recorded from central Kerala were *Bavia* sp., *Bianor* sp., *Hasarius adansoni* Audouin, *Hyllus* sp., *Myrmarachne orientalis* Tikader, *Phintella* sp., *Phintella vitatta* C. L. Koch, *Plexippus* sp., *P. paykulli, Plexippus petersi* Karsch, *Telamonia* sp. , *Telamonia dimidiata* Simon, *Thiania* sp., and *Thyene* sp. (Sebastian *et al.*, 2005).

2.1.3.4 Family Lycosidae

Oraze *et al.* (1988) bought out some diversified species in Californian rice fields *viz., Alopecosa kochi* Keyserling, *Pardosa ramulosa* McCook and *Pirata piraticus* Clerck, among them semi aquatic *P. ramulosa* and *P. piraticus* were the most common species observed in the field. Kamal *et al.* (1992 a and b) reported *Lycosa* sp., *Lycosa mackenziei* Gravely, *Pardosa* sp., *Pardosa sumatrana* Thorell, *Pardosa birmanica* Simon and *P. annandelai* from the paddy fields in Bangladesh.

Lycosid spiders were most abundant in the summer crop of the flood prone area of West Bengal (Nath and Sarkar, 1980). *P. pseudoannulata, Arctosa* sp. and *Pardosa* sp., were the common lycosids found in the Chhattishgarh region (Bhardwaj and Pawar, 1987 a; 1987 b). *Lycosa* spp were highly abundant in the Chinsurah region (Banerji *et al.*, 1993). In Jammu, the rice fields harboured *Pardosa minutus* Tikader & Malhotra, *P. annandalei* and *P. birmanica* (Thakur *et al.*, 1995). *Lycosa geotubalis* Tikader & Malhotra and *P. pseudoannulata* were observed in Tamil Nadu (Ganeshkumar and Velusamy, 1996 a). The population fluctuation of lycosids in rice fields of Tamil Nadu *viz., Hippasa* sp., *P. pseudoannulata* and *P. sumatrana* was studied (Anbalagan and Narayanasamy, 1996 and 1999). Bhattacharyya (2000) recorded *Arctosa* sp. and *Pardosa* sp. from Kalyani region, in West Bengal. Kaur *et al.* (2001) reported the abundance of *P. pseudoannulata* in the Punjab rice ecosystem. Mathirajan (2001) observed *P. sumatrana, Hippasa* sp. and *P. pseudoannulata* from Tamil Nadu. Sudhikumar and Sebastian (2001) observed *Pardosa* sp. in Kuttanad paddy growing regions. In Central Kerala, the rice fields harboured diverse species of lycosids, *viz., Hippasa* sp., *Lycosa* sp., Lycosa *tista* Tikader, *Pardosa* sp., *P. pseudoannulata,* *P. minuta, P. sumatrana* (Sebastian *et al.,* 2005). In the Kuttanadu rice tracts *Evippa* sp., *Hippasa* sp. and *Pardosa* sp. represented lycosidae (Sudhikumar and Sebastian, 2005).

2.1.3.5 Family Oxyopidae

Oraze *et al.* (1988) reported that *Oxyopes salticus* Hentz was the rare species obtained from California rice fields. In Bangladesh, the oxyopid fauna collected were *Oxyopes* sp., *O. shweta* and *Oxyopes ratnae* Tikader (Kamal *et al.,* 1992 a).

Oxyopids were collected from the Khahankal region of West Bengal and also from Madhya Pradesh (Nath and Sarkar, 1980; Bhardwaj and Pawar, 1987 b). In Chinsurah, the lynx spider, *Oxyopes* sp. was found in good numbers (Banerji *et al.,* 1993). Thakur *et al.* (1995) observed *Oxyopes* sp. and *O. shweta* in Punjab. From Tamil Nadu the oxyopids *viz., O. javanus, Oxyopes rufisternum* Tikader and *Peucetia viridana* Stoliczka were recorded (Ganeshkumar and Velusamy, 1996 a; Anbalagan and Narayanasamy, 1996). Pathak and Saha (1998) recorded *Oxyopes* sp. and *O. shweta* from Assam. Oxyopids were collected from the rice fields of Kalyani region, Punjab and Kuttanad (Bhattacharyya, 2000; Kaur *et al.,* 2001; Sudhikumar and Sebastian, 2001). High population of the lynx spider, *O. javanus* was reported from Tamil Nadu (Mathirajan, 2001) and Punjab (Shenhmar *et al.,* 2001). Sebastian *et al.* (2005) collected *Oxyopes* sp., *Oxyopes ashae* Gajbe, *Oxyopes bharatae* Gajbe, *Oxyopes sakuntalae* Tikader, *O. shweta, Oxyopes sitae* Tikader, *Oxyopes sunandae* Tikader, *Peucetia* sp. and *P. viridana* from central Kerala.

2.1.3.6 Family Thomisidae

Oraze *et al.* (1988) reported an indigenous species of Thomisidae *viz., Xysticus californicus* Keyserling from the rice fields of California. Kamal *et al.* (1992 a and b) recorded *Thomisus* sp. and *Thomisus cherapunjeus* Tikader from Bangladesh.

Thomisid spiders were collected from the Khahankal and flood prone area of West Bengal (Nath and Sarkar, 1980). *Runcinia* sp. and *Thomisus* sp. were obtained from the paddy ecosystem of Chhattishgarh (Bhardwaj and Pawar, 1987 b). In the Chinsurah region and in Jammu *Thomisus* spp. were collected (Banerji *et al.*, 1993; Thakur *et al.*, 1995). Ganeshkumar and Velusamy (1996 a) reported *Thomisus beautifularis* Basu, *T. cherapunjeus* and *T. pugilis* and Anbalagan and Narayanasamy (1996 and 1999) collected *Phlegra* sp. and *Runcinia* nr *albostriata* Böesenberg & Strand from Tamil Nadu rice ecosystem. In the paddy fields of Kalyani region, the thomisid fauna included *Xysticus* sp. and *Runcinia* sp. (Bhattacharyya, 2000). Kaur *et al.* (2001) collected *R. albostriata* and *Thomisus okinawensis* Strand from the rice ecosystem of Punjab. A similar study in Punjab, brought out newer species *viz., Runcinia sangasanga* Bores, *R.. albostriata, Runcinia* sp. and *Thomisus* sp. (Shenhmar *et al.,* 2001). Mathirajan (2001) observed *R. nr. albostriata* from Tamil Nadu. Sebastian *et al.* (2005) reported the presence of *Thomisus* sp. and *T. andamanensis* from Central Kerala.

2.1.3.7 Other Families

Clubiona japonicola Böesenberg & Strand (Clubionidae) were reported from the rice fields in Philippines (Barrion and Litsinger, 1981 b). Oraze *et al.* (1988) documented *Dysdera crocata* C.L.Koch (Dysderidae), *Drassyllus insularis* Banks, *Drassyllus saphes* Chamberlin, *Micaria* sp., *Trachyzelotes iyonneti* Audouin, *Urozelotes rusticus* L.Koch, *Zelotes puritanus* Chamberlin (Gnaphosidae), *Tibellus oblongus* Walckenaer, *Tricholathys saltona* Chamberlin (Dictynidae) and linyphiid and erigonid spiders from the flooded rice fields in Northern California. In the paddy fields of Bangladesh, the rice spider fauna included *Uloborus* sp., and *Uloborus danolius* Tikader (Uloboridae), *Theridion* sp.(Theridiidae) and *Cheiracanthium* sp. (Clubionidae) (Kamal *et al.*, 1992 a).

Spiders belonging to family Linyphiidae were collected from the summer crop at Khahankal and flood prone area of West Bengal (Nath and Sarkar, 1980). Bhardwaj and Pawar (1987 b) observed a uloborid, *Uloboriid* sp. and *Eusparassid* sp. (Eusparassidae) from Chhattishgarh region. Banerji *et al.* (1993) reported the presence of *Atypena* sp., (Linyphiidae) from Chinsurah region, West Bengal. Thakur *et al.* (1995) recorded *Cheiracanthium* sp., *Cheiracanthium trivialis* Thorell (Clubionidae) and *Stegodyphus sarsinoram* Karsch (Eresidae) from the rice fields of Jammu. The spider fauna in the rice fields of Tamil Nadu included *Clubiona nr drassodes* Cambridge (Clubionidae), *Dolomedes* sp. (Pissauridae), *Philodromus* sp. (Philodromidae) (Anbalagan and Narayanasamy, 1996 and 1999). Ganeshkumar and Velusamy (1996 a) recorded *C. japonicola* (Clubionidae) from Tamil Nadu. Pathak and Saha (1998) reported *Theridion* sp. (Theridiidae) from the rice ecosystem of Assam. The rice fields of Kalyani, harboured *Ischnocolus* sp. (Theraphosidae), *Sparassus* sp., (Aparassidae), *Gnaphosa* sp. (Gnaphosidae), *Uloborid* sp. (Uloboridae) and *Eusparassid* sp. (Eusparassidae) (Bhattacharyya, 2000). In the Punjab rice fields, *Erigone* sp. (Linyphiidae) was found (Kaur *et al.*, 2001) and *Clubiona* sp. (Clubionidae) was reported by Shenhmar *et al.*, (2001). Sudhikumar and Sebastian (2001) observed spiders belonging to family Theridiidae - *Diptera* sp. and *Theridion* sp. and Linyphiidae from Kuttanadu region. Mathirajan (2001) obtained *C. nr. drassodes* (Clubionidae), *Philodromus* sp. (Philodromidae), *Dolomedes* sp. (Pissauridae) from Tamil Nadu rice fields. Sudhikumar *et al.* (2004) reported a rare comb footed spider, *Trigonobothrys martinae* Roberts (Theridiidae) for the first time from Kuttanadu rice growing regions. Genus *Phycosoma* (Therdiidae) was also recorded from Kuttanadu (Sudhikumar and Sebastian, 2005). Sebastian *et al.* (2005) documented *Clubiona* sp. and *C. drassodes* (Clubionidae), *S. sarasinorum* (Eresidae), *Pritha* sp. (Filistatidae), *Gnaphosa* sp. (Gnaphosidae), *Hersilia savigyni* Lucas (Hersiliidae), *Linyphia* sp. (Linyphiidae), *Cheiracanthium melanostomum* Thorell (Miturgidae), *Heteropoda venatoria* Linnaeus (Sparassidae), *Achaearanea* sp., *Achaearanea durgae* Tikader, *Argyrodes* sp., *Chrysso argyrodiformis* Yaginuma, *Dipoena sp.*, *Phycosoma martinae* Roberts, *Theridion* sp. and *Theridula* sp. (Theridiidae), *Uloborus* sp. and *U. danolius* (Uloboridae) from the different rice fields across various elevational areas in Central Kerala.

2.2 SEASONAL OCCURRENCE OF ARTHROPODS

The paddy agro ecosystem, man - modified environment, is an integrated water dependent system, which include rice plants, arthropods and plants other than rice (FAO, 1977; Kiritani, 1977). Heinrichs and Miller (1991) reported that arthropod predators were the most abundant life forms in rice fields. This rich community consisted largely of spiders, and contributed to keep insect pest species below damaging levels.

Approximately about one to seven spiders per rice plant hill was found to inhabit the rice fields of Japan (Kobayashi, 1961). Spiders were highly abundant in rice fields preying on a wide array of insect pests (Barrion, 1980). Space - web and hunting spiders were the most abundant in the first crop and were more prevalent than orb - web spiders than the second crop. Hunting spiders, dominated by *L. pseudoannulata* maintained a high population (Cruz and Litsinger, 1986). Spiders were the most abundant predators of rice insect pests in Chhattishgarh region, Madhya Pradesh and among them *T. mandibulata* showed high prevalence and *L . pseudoannulata* had moderate prevalence (Bhardwaj and Pawar, 1987 b). Chau (1987) reported that the wolf spider, *L . pseudoannulata,* occurred throughout the crop cycle and the peak period was at tillering. Cheng (1989) observed that spiders were highly abundant in the Zheijiang province and constituted 31.40 per cent. Irrigated rice fields had richer and more diverse spider fauna and the abundance and diversity of spiders were related to the growth stage of rice (Kamal *et al.,* 1990). Qi (1990) reported that there were 73.10 to 93.50 spiders and 325.50 to 543.20 spiders per 100 hills each at transplanting and grain filling stage respectively in Jiangsu, China. The abundance of spiders in rice fields depended on the total phytophages like homopterans (Heong *et al.,* 1991 a and b and 1992). Catling and Islam (1993) recorded the abundance of spiders with respect to flooding of rice fields. Spider populations built up rapidly in the pre-flooded field with highest numbers occurring before flooding. Thakur *et al.*

(1995) reported that *Tetragnatha* spp were maximum in number, where as spiders under the families Thomisidae, Clubionidae and Eresidae were found in lesser numbers. Murata (1995) reported that tetragnathid spiders were the most abundant followed by thomisids and clubionids in the Japanese rice fields. The spider density fluctuated quite synchronously with the densities of plant and leaf hoppers. The spider densities were higher in the sustainable cultivated field than in the customary cultivated field. Kraker *et al.* (1999) reported that *P. pseudoannulata* and *Tetragnatha* spp were the most common spiders in the Philippine rice fields both in terms of incidence and abundance. Bhaskar (1999) found out that the abundance of spiders were not restricted by the confines of the plant canopy and plant morphology, but depended on the population of prey insects and *P. pseudoannulata* was observed throughout the crop period. Abundance of spiders was significantly positively correlated with the weed biomass in rice fields (Afun *et al.*, 1999). Meera (2000) reported that both in the kole and non-kole areas spiders were the most abundant predators and the total number ranged between 101 to 375. Sigsgaard (2000) reported that orb weaving spiders were the most abundant spiders in rice fields assessed across the cropping season, with *Tetragnatha* spp being the single most common genus in the South East Asian Countries. Sigsgaard and Villareal (2001) observed that a significant linear relation was observed between tiller number per hill and the spider density. Chander (2001) reported that spider population increased and decreased with the abundance of prey insects.

Population densities of spiders decreased greatly after rice harvest because of disruption of their habitats and hence conservation of these beneficial forms during crop free periods is important to ensure adequate numbers to recolonize the fields when the crop is established (Shepard *et al.*, 1989). Thakur *et al.* (1995) noticed that the spider population increased gradually with the growth of rice plants and almost doubled from August to September in Jammu. Sigsgaard and Villareal (1999) observed that spiders appeared in the field shortly after crop establishment during the early vegetative stage. The population of spiders reached a maximum level at about the maximum tillering stage and then stabilized or decreased slowly towards maturity (Kraker *et al.,* 1999). The occurrence of spider species in different regions of rice ecosystem differed greatly, but the population abundance and species diversity of the spiders were found directly related to the growth stage of rice plant (Anbalagan and Narayanasamy, 1999). Mathirajan (2001) observed *P. pseudoannulata, P. sumatrana, C. nr drassodes, O. javanus, R. nr drassodes* and *N. theisi* in the rice nursery. Xiaoping *et al.* (2002) observed that, after transplanting of rice seedlings, spiders moved into the rice fields in large numbers from the adjacent weed habitat and majority of them moved back into these habitats before harvesting of rice, and the population of spiders decreased when the crop reached maturity. Lekha (2003) reported that highest populations of spiders were observed at the reproductive phase of the crop.

Heong *et al.* (1991 b) studied the arthropod community associated with the irrigated rice fields and reported that phytophages and predators were predominant in all sites. Gupta and Pawar (1993) studied the biological wealth in the rice ecosystem. Settle (1994) explained that, on an average, one hectare of paddy field may have up to five to seven million parasitoids, predators and neutrals. The neutrals were the early inhabitants followed by predators, and thus the rice fields were more stable and resilient to influxes of rice pests because of the development of predators early in the season, before pest population develops. Settle *et al.* (1996) reported that the populations of the detritus feeding and plankton feeding insects reached a peak and declined in the first third of the season.

Minsheng (1997) conducted field surveys in China and observed the species richness of herbivorous insects, predatory insects, spiders and total species in the community varied with each field type because of the environmental variables and fluctuated with various growth stages of rice crop. But the rice ecosystem was very rich in natural enemies of insect pests (Panda, 2001). Nalinakumari and Hebsybai (2002) observed that the population of beneficials was high at the early stages of the crop and showed a declining trend after the vegetative phase.

Bhaskar (1999) reported that the correlation between the minimum temperature and the populations of *L. pseudoannulata* and *T. maxillosa* was negative.

2.3 PREDATORY EFFICIENCY OF SPIDERS IN RICE ECOSYSTEM

2.3.1 Prey Preference

Spiders were generalist predators which could consume a sizeable proportion of insect pests. Kang and Kiritani (1975) observed that during winter, the over wintering populations of *Nephotettix cincticeps* Uhler could be reduced to half due to the efficient predation of *L. pseudoannulata*. In IRRI rice fields, *L. pseudoannulata* was considered to be the most important predator of BPH (IRRI, 1973; Dyck and Orlido, 1977). The functional responses of the females of *L. pseudoannulata* in searching the BPH were more efficient than GLH (IRRI, 1978). *L. pseudoannulata* was the major regulator of BPH populations and there existed a strong correlation between *L. pseudoannulata* density and peak population of brown plant hopper (Kenmore *et al.,* 1984; Kaushik *et al.,* 1986; Zhou and Chen, 1986). *L. pseudoannulata* was one of the effective predator of rice plant hoppers, and the most important factor of mortality of *S. furcifera* (Bhardwaj and Pawar, 1986; Salim and Heinrichs, 1986a). Heong *et al.* (1991 a) reported that *L. pseudoannulata* fed mostly plant and leaf hoppers and both male and females showed significant preference for BPH. *L. pseudoannulata* was a sit-and-wait hunter that did not actively seek out prey and searched more efficiently for BPH, than for GLH and BPH was the most preferred prey (Heong and Rubia, 1989). Morrill and Rubia (1990) observed the mode of prey capture by *P. pseudoannulata,* by hiding under water for one to thirteen minutes for hunting the most preferred diet, BPH. Rubia *et al.* (1990) reported that *P. pseudoannulata,* mostly preferred hoppers, yellow stem borer moths, collembolans and flies. But *Pardosa* had a distinct preference for *N. lugens* than *S. furcifera* and *N*ephotettix *virescens* Distant (Nirmala, 1990; Ganeshkumar, 1994). *L. pseudoannulata* was one of the most prolific predators of rice hoppers in the field (Heong and Rubia, 1990; Ganeshkumar and

Velusamy, 1995; Mathirajan and Regupathy, 2003). Nandakumar and Pramod (1998) reported that *P. pseudoannulata* preferred stem borer, leaf and plant hoppers. *Pardosa* preferred *N. lugens* (41.04%) to *S. furcifera* (30.79%) and *N. virescens* (14.05%) and preferred significantly more leaf folders (37.24%) followed by stem borer (34.60%) and case worm (29.70%) (Samiayyan and Chandrasekharan, 1998.a). Bhaskar (1999) observed that the population of *P. pseudoannulata* showed significant positive correlation with the population of *N. lugens*. *L. pseudoannulata* was the predominant spider in rice fields and had got high pest killing capacity and preferred moving prey, mostly hoppers (Panda, 2001).

Salticids were the most voraceous predators followed by lycosids and oxyopids (Samal and Misra, 1975). The green lynx spider, *Oxyopes* sp. showed no significant feeding preference, but there was a trend for the more active type of prey to be taken (Riechert and Gillespie, 1983; Guillebeau and All, 1989). While the diet of salticids seem to be biased especially towards caterpillars and flies (Jackson and Pollard, 1996). Where as when adults of *O. javanus* were offered a choice of preys, they preferred adults of *N. lugens* (Ganeshkumar and Velusamy, 1996 b). Nandakumar and Pramod (1998) reported that *Oxyopes* sp. predated on stem borer and leaf folders, *Araneus* sp. preferred leaf and plant hoppers, *Phidippus* sp. preferred GLH and *T. maxillosa* on leaf hoppers, moths and flies. *Tetragnatha préferred* significantly more *N. virescens* (16.81 %) to *S. furcifera* (11.08%) and *N. lugens* (10.44%) and stem borer (29.60%) and leaf folder (29.07%), while *Oxyopes* had a greater preference for *N virescens* (39.23%) followed by *S. furcifera* (19.19%) and *N. lugens* (14.40%) and preferred more of case worm (35.17%) followed by leaf folder (19.72%) and showed a lesser preference to stem borer moths (19.51%) (Samiayyan and Chandrasekharan, 1998 a). Garg *et al.* (2002) observed that *A. catenulata* preferred the grass hopper nymphs and crickets. Although *O. javanus* and *T. javana* showed greater preference to *N. lugens,* than *S. furcifera* and *N. virescens, T. javana* was an efficient predator followed by *O. javanus* and between sexes of spiders, the female was more efficient than the male (Mathirajan and Regupathy, 2003). Sivakumar *et al.* (2003) evaluated the prey range and prey preference of *Argiope* sp., *T. laboriosa, Neoscona* sp., *Phidippus* sp. and *Clubiona* sp. and reported that the major insect pests in rice like gundhi bug, leaf folder and lepidopteran leaf feeders were the preferred prey.

Chatterjee and Dutta (1979) presented a list of nine spiders as predators of *N. lugens*. In another report from IRRI (1980), spiders appeared to be the most important predators of WBPH nymphs and adults. Spiders had higher host finding ability and capacity to consume greater number of prey than other paddy field inhabiting predators and could kill a sizeable number of pests per unit time (Kamal, 1981; Heong and Rubia, 1990; Ganeshkumar and Velusamy, 1995). A significant positive correlation was found between the dynamic changes in the population of spiders and *N. lugens* (Cheng, 1989). The predatory spiders in rice fields were the major natural enemies of *N. lugens* (Gupta and Pawar, 1989). Kamal *et al.* (1992 b) reported that spiders fed on hoppers, dipterans and lepidopterans in paddy. Catling and Islam (1993) suggested that, although spiders fed on a wide array of rice pests, they were the most significant group of borer predators, and spiders regulated the population of rice yellow stem borer, *Scirpophaga incertulas* Walker. The spiders showed a positive effect of predation on *N. lugens* (Wu *et al.*, 1993).

2.3.2 Predatory Potential

The feeding potential of spiders depended on the availability of prey insects. *Lycosa* sp. fed on brown plant hoppers and green leaf hoppers in a ratio of 5: 2 (Kiritani *et al.*, 1972). Sassaba *et al.* (1973) found the feeding rate of *Lycosa* on BPH to be higher during day than at night and observed that *P. pseudoannulata* killed BPH @ 2 per day. Rao *et al.* (1978) observed *P. annandalei* feeding on BPH at the rate of 18 adults per day. The predation rates of *Lycosa* in the laboratory was 3.08 and 4.28 adult BPH for the second and fourth instar spiderlings, while 13.52 and 11.48 adult BPH for adult female and adult male spiders respectively (Chiu, 1979). Where as the female *L. pseudoannulata* killed significantly more hoppers (9 BPH per day) than the males (5 BPH per day) and killed 1.5 WBPH per day (IRRI, 1980). The feeding activity of *L. pseudoannulata* on WBPH was 5.9 hoppers per day and it caused 27 % WBPH mortality (Salim and Heinrichs, 1986 b). In another experiment by Chau (1987), *L. pseudoannulata* had the highest predatory capacity on BPH, *i.e.*, 8.5. Nirmala (1990) observed the rate of predation by female and male *P. pseudoannulata* as 9.16 and 5.07 adult WBPH per day, respectively. The predatory spider *Lycosa* sp. consumed relatively higher populations of GLH, BPH and WBPH and predatory potential was higher when caged together on resistant cultivars than on susceptible ones (Kalode *et al.*,1990 ; Ganeshkumar and Velusamy, 1996 b). Samiayyan and Chandrasekharan (1998 a) reported that *Pardosa* sp. had the highest predatory potential on BPH (14.31) followed by WBPH (10.96) and GLH (5.73). *Pardosa* sp. was significantly superior and prey upon twice the number of plant and leaf hoppers than the other spiders (Ganeshkumar, 1994; Kamal *et al.*, 1992 b). Bhaskar (1999) observed the predation rates of *P. pseudoannulata* at lower prey density of *N. lugens* to be 37.24 per cent and at higher prey density 41.50 per cent, where as Panda (2001) recorded the predation of the same spider on *S. furcifera* to be 70.60 per cent to 75 per cent. Mathirajan (2001) studied the extent of predation by *L. pseudoannulata* on BPH, WBPH and GLH as 7.40, 6.90 and 6.00 per day respectively and the predatory potential of female was more than male, 1.20, 1.30 and 1.20 times in *L. pseudoannulata* on BPH, GLH and WBPH respectively. Where as Premila (2003) estimated the feeding potential of *L. pseudoannulata* on *N. lugens, S. furcifera* and *Nephotettix* spp to be 26.60, 22.20 and 17.00 in seven days respectively.

Oxyopes sp. killed BPH more efficiently (3 BPH per day) than *Tetragnatha* sp. and *Argiope* sp. (IRRI, 1976). *A. pulchella* and *Tetragnatha sutherlandi* Gravely were effective predators of BPH and *A. pulchella* and *Tetragnatha* sp. consumed on an average 16 and 14 adult BPH per day, respectively (Rao *et al.*, 1978). Where as *O. javanus* killed 2.3 WBPH per day while *A. catenulata* and *T. japonica* consumed one WBPH per day (IRRI, 1980) and *Tetragnatha* sp. consumed 6.10 BPH (Chau, 1987). Lynx spiders consumed about one prey per day, and almost all the hunting spiders fed at the same rate (Edgar, 1970; Schaefer, 1974; Nyffeler *et al.*, 1987). *T. javana* consumed 1.30 and 0.57 WBPH per day (Nirmala, 1990). According to Bhathal and Dhaliwal (1990) *Salticus scenicus* Clerck was found to be the most efficient predator of *S. furcifera* consuming 4.95 nymphs per day, which caught its prey by jumping, where as *O. pandae* and *P. birmanica* consumed 3.67 nymphs each and *Thomisus* sp., *N. nautica* and *Casnoidea indica* Thunberg consumed 3.45, 2.55 and 1.18 nymphs per day, respectively. Samiayyan and Chandrasekharan (1998 a) reported that *Tetragnatha* and *Oxyopes* sp. consumed more of GLH, 5.69 and 7.29 respectively and their potential against WBPH and BPH was almost equal (3.78 to 4.53). Mathirajan (2001) studied the extent of predation by *O. javanus* and *T. javana* as 4.80 and 6.20 BPH, 4.70 and 5.90 WBPH and 3.50 and 5.20 GLH per day, respectively. Premila (2003) estimated the feeding potential of *T. maxillosa* on *N. lugens, S. furcifera* and *Nephotettix* spp to be 12.40, 15.20 and 16.60 in seven days, respectively.

When the spiders were highly abundant, the dominant species could control 81 per cent of rice leaf hoppers (Yasumatsu and Torii, 1968). Nyffeler *et al.* (1987) observed the spiders taking prey ranging between 0.10 and 1.10 times their own body size. In rice fields, the number of *N. lugens* consumed by dominant predatory spiders during the booting, tasselling, milking and maturation stages of rice were 11, 11, 13 and 10 respectively (Yuan *et al.*, 2003).

2.3.3 Hyper Predation of Spiders

Spiders fed on all groups of insects. When ten *L. pseudoannulata* were caged together, they were cannibalistic and had 24 per cent mortality. The spider killed 60 per cent of *Cyrtorhinus lividipennis* Reuter when caged with ten *C. lividipennis, S. octomaculata* and *Paederus fuscipes* Curtis. Except for the spiders, no other predators in rice fields are cannibalistic. When one *L. pseudoannulata* was caged with ten *C. lividipennis* and ten WBPH, *C. lividipennis* had 41 per cent morality and WBPH had only 27 per cent

(Salim and Heinrichs, 1986a). *L. pseudoannulata* killed three mirids per day (IRRI, 1987) and 5.22 adult mirids per day (Rajendran, 1987). Heong *et al.* (1989) found that *L. pseudoannulata* preyed on beneficial species in the rice ecosystem, such as *C. lividipennis* and hymenopteran parasitoids and both male and female spiders attacked all stages of mirid bugs equally. An adult spider could consume as many as 22 mirids a day. Rubia *et al.* (1990) observed that *L. pseudoannulata* feed on predatory mirid bug, *C.lividipennis*. When *N. lugens and C. lividipennis* were provided as mixed diet to *P. pseudoannulata,* the attack rate was greater and handling time shorter for *C. lividipennis* (Heong *et al.*, 1991 a).

Green lynx spiders consumed all stages of the predatory bug *Geocoris* spp and spiders at a rate of one or two a day (Guillebeau and All, 1989). Adult of *O. javanus* were found to feed readily on nymphs and adults of *C. lividipennis* (Ganeshkumar and Velusamy, 1996 b). Okuyama (2002) studied the role of direct and indirect interaction in intraguild predation of two salticid spiders, *Phidippus audax* Hentz. and *Phidippus octopunctatus* Hentz. and found that *P. audax* readily consumed *P. octopunctatus.*

Most entomophagous predators like spiders, were general feeders and often preyed upon one another (Guillebeau and All, 1989). Way and Heong (1994) found that intraguild predation and cannibalism were thought to help spider survival when prey was scarce. Sunderland (1999) observed that although hyper predation may disrupt biological control occasionally, the wide range of competitive interactions between natural enemies promoted diversity and stability of the natural enemy community and generates a robust basis for pest control.

2.4 EFFECT OF SYNTHETIC INSECTICIDES AND NEEM FORMULATIONS ON SPIDERS

2.4.1 Impact on Individual Spiders

Synthetic insecticides

Chiu and Cheng (1976) recorded the safety of acephate to *L. pseudoannulata.*

Ku and Wang (1981) found that acephate was toxic to the non-target organisms, especially spiders. Fabellar and Heinrichs (1984) reported that acephate was the least toxic to *L. pseudoannulata* and was not a stomach poison through ingestion of the treated *N. lugens*. *L. pseudoannulata* tolerated insecticide treatments and continued its predatory activity (Chu *et al.*, 1976). Acephate reduced the growth and predation of the spiders (Thang *et al.*, 1987). Ganeshkumar and Velusamy (1996 c) observed low mortality of *L. pseudoannulata* and *O. javanus* on treatment with acephate and was found safe to *L. pseudoannulata, T. javana* and *O. javanus.* Also found that acephate had higher LC_{50} values to *O. javanus* and *A. catenulata* (Ganeshkumar and Velusamy, 1997 and 2000). Gopan (2004) reported that acephate was safe to spiders.

Imidacloprid caused no deleterious effect on spiders (Mao and Liang, 1995; Katole and Patil, 2000; Satheesan *et al.,* 2002). Imidacloprid at 0.20 kg ai ha^{-1} was safe to spiders and quite promising (Panda and Mishra, 1998). Imidacloprid of 100 ml ha^{-1} and 400 ml ha^{-1} was found toxic to predatory spiders (Manjunatha and Shivanna, 2001). The number of *N. virescens* adults consumed by *P. pseudoannulata* which was exposed to imidacloprid treated rice seedlings for the last 24 hours before experiment was significantly lower than that on untreated ones (Widiarta *et al.*, 2001). Krishnaiah *et al.* (2003) found that a combination of thiamethoxam and imidacloprid 25 g ai / ha reduced the spider predators in absolute numbers. Imidacloprid alone adversely affected the population of spiders at different growth stages (Lekha, 2003). But, Kannan *et al.* (2004) reported that imidacloprid was safe to *O. javanus, A. minuta, L. pseudoannulata, T. javana, N. theisi* and *P. viridana.*

Among the different tested insecticides, triazophos was one of the most poisonous insecticide to spiders (Babu *et al*., 2002).

When granules, dusts and E.C. formulations of quinalphos was sprayed for BPH control, the dust of the insecticide provided maximum mortality of the spider complex (62.50 per cent) where as the lowest mortality was recorded in the granules (33.45 per cent). Quinalphos dust caused highest spider mortality (71.25 per cent)

(Mandal and Somchoudhury, 1994).

The safety and toxicity of the chemical pesticides used for pest management in rice for spiders was studied by Reissig *et al.* (1982). Fagan *et al.* (1998) observed that insecticide treatment did not reduce wolf spider density. Where as populations of spiders were heavily affected by insecticide applications and had more significant toxic effects on spiders (Arida *et al.*, 1997).

Neem formulations

Botanicals, especially neem products were usually harmless to the spiders. Saxena *et al.* (1983) studied the safety of neem products to spiders in rice ecosystem and neem oil was the least toxic and not affected the spider population even at the highest dose tested, *i.e.*, 50g/ spider. Raguraman and Rajasekaran (1996) found that better recolonization of the predatory wolf spider, *L. pseudoannulata* was observed in case of treatment with neem oil 3 per cent. Also application of neem oil appeared to be quite safe to predatory spiders like *Distina* sp., *Marpissa* sp., *Oxyopes* sp. and *O. pandae* (Chakraborti, 2001). Neem at 3 ml / L and 5 ml/ L concentrations were found to be relatively safe to spiders (Babu *et al.*, 2002).

NSKE was safe to spiders (Latha *et al.*, 1994 ; Chakraborti, 2001) and better recolonization of spiders occurred when treated with NSKE 5 per cent (Raguraman and Rajasekaran, 1996).

Lakshmi *et al.* (1998) reported that neem gold at 0.50 per cent and neemax at 20 per cent were safe to spider predators. The application of azadirachtin was quite safe to predatory spiders like *Distina* sp., *Marpissa* sp., *Oxyopes* sp. and *O. pandae* (Chakraborti, 2001). Dhaliwal *et al.* (2001) evaluated the neem formulations directly against *T. javana* by directly treating them with neem azal one per cent and the mortality of spiders varied from 13 - 30 per cent among different concentrations of neem azal after 24 hours. After 48 hours, mortality of spiders increased to 16-43 per cent among neem formulations. Spiders devoured about 15-21 per cent WBPH nymphs after 24 hours in different neem treatments and it increased to 20-26 per cent after 48 hours. Gopan (2004) found that azadirachtin was relatively safe to spiders.

Though there was an initial reduction in the number of *L. pseudoannulata* in neem treated plots, recolonization was better (Mohan *et al.*,1991). Neem products did not affect the population of *O. javanus* (TNAU, 1992). Babu *et al.* (1995) observed that neem formulations were quite effective against insect pests of rice and very safe to the spiders. The greater populations of natural enemies like spiders and mirid bugs occurred following application with neem formulations (Dash *et al.*,1996). Neem products did not harm the spiders (Samiayyan and Chandrasekharan, 1998 b). Neem products were less toxic to *L. pseudoannulata, T. maxillosa* and *A. catenulata* (Dash *et al.,* 2001).

2.4.2 Effect on Field Population

Synthetic insecticides

The chemical control of pests decreased the population density of spiders in rice fields (Yasumatsu and Torii, 1968; Madsen and Madsen, 1982; Kim, 1992; Yoon, 1997). Thomas *et al.* (1979) observed that six days after insecticide application during an outbreak of BPH, both spider and plant hopper populations were lesser than on untreated rice and the population of spiders and pests increased again two weeks after treatment, where as during the next crop season when insecticide application was negligible, spider populations were large and plant hopper populations were small. The spider populations were consistently reduced in the insecticide treated plots (Reissig *et al.,* 1982). Hunting spiders tend to suffer more damage than web builders, while the active hunters suffered more than less active ones (Bostanian *et al.,* 1984). There was a 50 per cent reduction in the attack rate of the spiders caused in the insecticidal treated plots and had a negative effect on the rice field spiders and resulted in a three-fold increase in BPH population (Holt *et al.,* 1985; Lee *et al.,* 1993; Bae *et al.,* 1994). Also Lee *et al.* (1993) found that the reduction of spider populations in rice fields after insecticide applications, was not because the spiders were killed by the insecticides but because their prey were killed and it was observed that the density of hunters was higher than that of web builders in the period after insecticide application and during the recovery period the active hunters played an important role in rebuilding the spider densities. Cuong *et al.* (1997) and Garg *et al.* (2002) observed that in insecticide free plots predatory spiders of *N. lugens* were generally higher. Pest resurgence after insecticide spraying was due to the negative impact of insecticides on spiders and other natural enemies (Sigsgaard, 2000). There were higher levels of predatory spiders in natural bio control plots when compared to insecticide treated plots and the population levels were significantly higher *i.e.,* 2.6 - 13.6 / 25 hills and 8.4 - 18.6 / 25 hills (Katti *et al.*, 2000). Most of the spiders in rice fields seem to evacuate the field after the application of insecticides and moved back into the field later (Lee and Kim, 2001). At Kovur village, occurrence of wide range of spiders encountered during *Sornavari* 2002 was due to the absence of insecticidal application in the fields for the past six years (ERI, 2003). At one day after application of azadirachtin 0.004 per cent and imidacloprid 0.005 per cent the population of spiders recorded was 5.66 and 7.92, respectively and acephate 0.05 per cent (8.64) was found to be comparatively safe when compared to control (10.66), where as five days after spraying, all were relatively safe (Gopan, 2004). Rong *et al.* (2004) reported that when triazophos was sprayed reduction of the population density of spiders resulted in increased survival of plant hoppers.

Neem formulations

The spider population became low in the neem sprayed rice fields, but better recolonisation was observed (Mohan *et al.*, 1991). When neem oil 3 per cent and NSKE 5 per cent was sprayed in the field, the count of predatory spiders was reduced by 20 per cent in the NSKE treated plots and 43.50 per cent in the neem oil treated plots during Kharif season and 60 per cent in NSKE, 27. 40 per cent in neem oil in the rabi season (Shukla and Kaushik, 1994). Samiayyan and Chandrasekharan (1998 b) reported that ten days after spraying NSKE 5 per cent, significantly higher number of spiders (9.63 / 20 hills) was recorded and was equal to neem oil 3 per cent (9.39 / 20 hills). Dash *et al.* (2001) found that plots receiving neem sprays harboured more population of spiders than in an insecticide treated plots. In the neem based pesticide application, higher number of spiders were harboured (Bora *et al.,* 2004). Rajeswaran *et al.* (2005) reported that the use of neem products enhanced the spider populations in rice fields.

Materials and Methods

3. MATERIALS AND METHODS

Survey was conducted in the Upaniyur padasekharam of Kalliyoor panchayat of Thiruvananthapuram district to quantify and document the spiders in rice ecosystem. The prey preference, predatory potential and hyper predation of the dominant spiders in rice ecosystem was evaluated in the laboratory in the College of Agriculture, Vellayani. The hyper predation of spiders on insect natural enemies was assessed. The safety and /or toxicity of synthetic insecticides and neem formulations to the dominant spiders were tested in the laboratory and in the field.

3. 1 DOCUMENTATION OF SPIDERS IN RICE ECOSYSTEM

A random survey was conducted in the Upaniyur padasekharam, an extensive rice growing area in Kalliyoor panchayat of Thiruvananthapuram district to collect the spiders associated with the rice crop and to study the habitat and abundance of the spiders.

3.1.1 Collection of Spiders

Sweep net method

A standard sweep net of 1.5 meter long was used to sweep the spiders from the crop canopy, adopting the method suggested by Reissig *et al.* (1986) and Bayot *et al.*, 1990. The collections of the sweep net were transferred into long polythene bags and brought to the laboratory. The specimens of each polythene bag were killed by inserting a strip of cotton dipped in chloroform and transferred separately on a white sheet of paper and using a stereo microscope, the spiders were sorted out, separated, counted and preserved for identification. The spiders were observed and studied in the laboratory using the microscope, sorted and grouped according to the external appearance, colour, size and shape, and each groups were counted separately and recorded, which were identified later.

By direct count

Twenty hills of rice plants were selected randomly from the one cent plot for direct counting of spiders and the plants were searched thoroughly to collect the spiders. Spiders observed on the crop canopy, base and mid of the plants, from the webs in between the plants, from the webs in individual leaf folds, from water, border weeds and field bunds were carefully collected in specimen tubes and brought to the laboratory and sorted and grouped.

3.1.2 Preservation of Spiders

Spiders were killed using chloroform and the grouped specimens were preserved separately in 70 per cent ethyl alcohol (70 parts of 100 per cent alcohol + 30 parts of distilled water) in ASGI 30 ml screw cap specimen tubes and in 250 ml wide mouthed bottles and sealed using cello tape and kept in dark coloured card board boxes for identification. The very small spider specimens and the juvenile spiders were preserved in Oudeman's fluid (85 parts of 70 per cent alcohol + 5 parts of glycerine + 8 parts of glacial acetic acid + 2 parts distilled water). The preservatives were changed once in fortnightly intervals to avoid the dilution of the preservative in the body fluids of the spider specimens and the resultant contamination and damage of the specimen.

3.1.3 Identification of Spiders

The spiders collected from the rice ecosystem were got identified by Dr. P. A. Sebastian, Reader and Mr. A. V. Sudhikumar, Ph. D. Student, Division of Arachnology, Department of Zoology, Sacred Heart College, Thevara, Cochin, Kerala, India.

3.2 SEASONAL OCCURRENCE OF ARTHROPODS IN RICE ECOSYSTEM

The extensive rice fields in the Kalliyoor panchayat of Thiruvananthapuram district was selected for surveying the seasonal occurrence of spiders, pests and insect natural enemies. Based on area of cultivation, variety used and mode of cropping, ten locations were selected at random. From each location three plots of one cent each were demarkated. Population of spiders, pests, insect natural enemies and neutrals were assessed at weekly intervals from one week after transplanting and continued until harvesting of the crop for two cropping seasons during the Virippu and Mundakan seasons of 2005- '06 (July – Nov, 2005 and Dec 2005 – April 2006). Ten net sweeps were made as five double stroke sweeps from each plot.

3.2.1 Collection of Spiders, Pests, Insect natural enemies and Neutrals

Sweep net method

The sweeping of spiders, pests, insect natural enemies and neutrals was done as explained in 3.1.1. The collections of the sweep net were transferred into long polythene bags and numbered them according to the location and plot selected and marked the date of collection, and brought to the laboratory. The samples collected from the thirty plots on each sampling weeks were examined separately. All the arthropods collected by net sweeps were transferred in to long polythene bags and were killed by inserting a chloroform dipped cotton strip without touching the sides of the polythene bag and separated and grouped as phytophages, entomophages and neutrals based on the taxonomic characters. Each group of spiders, pests, insect natural enemies and neutrals obtained in each week were counted separately and recorded. The population of spiders, pests, insect natural enemies and neutrals collected during the sampling weeks from each plot were counted and pooled the observations of the thirty plots and recorded as an individual observation against each week.

3.2.2 Meteorological Observations

The daily weather parameters like morning and evening relative humidity (RH) , maximum and minimum temperature (T), rainfall and number of rainy days existed during the crop period were measured and recorded from the Department of Agricultural Meteorology, College of Agriculture, Vellayani, Thiruvananthapuram, and studied the correlation of these weather parameters with the total population of spiders.

3. 3 PREDATORY EFFICIENCY OF DOMINANT SPIDERS

From the spiders documented in the rice ecosystem, ten abundant mostly represented, and dominant spiders were selected, *viz., T. mandibulata, T. maxillosa, O. javanus, P. viridana, P. pseudoannulata, A. anasuja, Neoscona rumpfi* Tikader & Biswas, *T. dimidiata, Bianor carli* Reimoser and *Thomisus projectus* Tikader were tested for their prey range, prey preference and predatory potential in the laboratory.

3.3.1 Raising of Paddy Plants

Paddy seedlings of twenty one days old which were ready to be transplanted to the main field were planted in clay pots of 15 cm diameter, filled with clayey soil obtained from the puddled rice fields. The holes in the clay pots were plugged with cement so as to maintain a puddled condition in the pots for the luxurious growth of the seedlings. Two seedlings per pot were planted and maintained as per the package of practices recommendations of Kerala Agricultural University (KAU, 2002). Fifty days after planting, when the plants started active tillering, each pot with the plants were covered with a cylindrical mylar film cage of one meter length and 20 cm diameter and the upper portion was covered with a muslin cloth. The cages were provided with a cloth lined window for releasing the prey insects and predators, and this was used for conducting the various laboratory experiments.

3.3.2 Maintenance of Field Population of Spiders and Culturing of Prey Insects

The selected dominant spiders were collected from the plots in ten locations maintained for the survey and documentation. Fully grown adult spiders of same size and sex were sorted out from the sweep net samples obtained from the plots and used. Also a rice field of about 200 m^2 was maintained in the

Instructional farm, College of Agriculture, Vellayani, and planted with seedlings of rice variety, Jyothi, for collection of spider predators for the experiment, as listed in 3. 3 and also their prey insects, for maintaining the stock culture. The crop was maintained as per the package of practices recommendations of Kerala Agricultural University (KAU, 2002) without adopting any plant protection measures.

3.3.3 Evaluation of Prey Preference

The pests observed in the rice ecosystem during the survey were tested for their preference for feeding by the adults of the ten dominant spiders in the rice ecosystem. The adults of the spiders, as listed in 3.3, of same age, size and sex were selected and pre-starved for 24 hours and then released individually into the caged potted plants. The experiment was conducted in completely randomized block design (CRD), with five replications each. The pests of each group *viz.*, hoppers, bugs, lepidopterans, orthopterans and coleopterans in the rice field were provided as a mixed diet to the caged spiders. The relative preference for various prey insects of each group was determined by providing the chosen prey insects of each group as a mixed diet by providing ten numbers each of the individual prey insects and observed for seven days. A white sheet of paper was kept over the pot to cover the open end of the pot to prevent the falling of the insects in to water in the pots and to count the predated prey insects easily and separately. Observations were taken daily and continued for seven days and the prey insects were replenished daily to maintain uniform prey number. The cumulative mean of one day's observation was worked out and expressed as the relative preference of each spider.

Hoppers

The nymphs and the adults of the hoppers *viz., N. lugens, Nephotettix* spp., *Cofana spectra* Distant, *S. furcifera* and *Recilia dorsalis* Motschulsky were subjected to the prey preference experiment and provided ten prey each as a mixed diet. The experiment was conducted as explained in 3.3.3.

Bugs

Both the nymphs and adults of *Leptocorisa acuta* Thunberg, *Scotinophara* spp. and *Menida histrio* Fabricius were provided @ ten insects of each species as a mixed diet for evaluating the prey preference of the spiders among the bugs. The experiment was carried out as detailed in 3.3.3.

Lepidopterans

The adults of *S. incertulas*, larvae and moths of *Cnaphalocrocis medinalis* Guenee, *Parapoynx stagnalis* Guenee and *Melanitis leda-ismene* Cramer were used to test the prey preference among the lepidopterans and ten numbers per species was provided from each prey insects and supplied as a mixed diet. The experiment was done as given under 3.3.3.

Grass hoppers

Three orthopteran prey insects were evaluated for their relative preference by providing ten prey insects each from the species *viz.*, nymphs and adults of *Oxya chinensis* Thunberg and nymphs of *Conocephalus pallidus* Redt.. The experiment was conducted as detailed in 3.3.3.

Beetles

To assess the prey preference among the coleopteran pests the adults of *Leptispa pygmaea* Baly, *Haltica cyanea* Web., *Dicladispa armigera* Olivier and *Oides affinis* J. were supplied @ ten numbers each of the prey species as mixed diet. The experiment was carried out as explained in 3.3.3.

3.3.4 Evaluation of Predatory Potential

Based on the prey preference of the spiders, the pests were provided individually to the caged spiders at the rate of twenty numbers each and recorded the feeding potential for every 24 hours and continued for seven days and replenished the prey insects to maintain the prey density uniformly. The cumulative mean of one day's feeding was worked out and expressed as the feeding efficiency of each spider. The experiment was conducted as described in 3.3.3.

3.3.5 Evaluation of Hyper Predation of Spiders

The ten dominant spiders as explained in 3.3. were used for assessing their hyper predatory activity on the insect predators and parasitoids in the rice field. The experiment was carried out in a similar way as given in 3.3.3. The required insect natural enemies were collected from the rice fields maintained (3.3.2). The observations were taken after every 24 hrs, and continued for seven days as detailed under 3.3.4 and expressed as the mean number of insect natural enemy consumed in one day by each spider.

Insect predators

The hyper predation of the ten selected spiders on the insect predators in the rice ecosystem *viz., Agriocnemis* spp., *C. lividipennis* , *Metioche vitatticollis* Stl., grubs and adults of *Micraspis* spp. were evaluated as given under 3.3.4.

Parasitoids

Six commonly occurring hymenopteran parasitoids in the rice fields were used to evaluate the hyper predation of spiders on the parasitoids. Because of the mortality of the parasitoids within five days the experiment was carried out for five days and the observations were taken as detailed under 3.3.4.

3.4 EFFECT OF INSECTICIDES AND NEEM FORMULATIONS ON THE SPIDERS IN RICE ECOSYSTEM

3.4.1 Laboratory Evaluation

The chemical insecticides and the neem products used for the control of pests of rice as given in Table 1 were evaluated for their relative safety and toxicity to the dominant spiders *viz., T. mandibulata, T. maxillosa, O. javanus, P. viridana, P. pseudoannulata, A. anasuja, N. rumpfi, T. dimidiata, B. carli* and *T. projectus* at their recommended doses.

Table-1 List of synthetic insecticides and neem based botanical formulations tested against rice field spiders.

Sl. No.	Common Name	Trade Name	Concentration used	Company
I	**Chemical Insecticides**			
1	Acephate	Asataf 75 SP	0.05%	Rallis Tata Enterprise
2	Imidacloprid	Confidor 200SL	0.005%	Bayer (India) Ltd.
3	Triazophos	Hostathion 40EC	0.05%	Agro Evo India Ltd.
.4	Quinalphos	Ekalux 25EC	0.05%	Novartis India Ltd.
II	**Neem Formulations**			
1	Azadirachtin	Neem Azal T/S	0.004%	E.I.D Parry (India) Ltd.
2	Neem Oil		2%	
3	NSKE		5%	Preparation

3.4.1.1 Preparation of spray solution

The spray solution of the pesticides and botanicals for the experiment was prepared by adding 0.5g, 0.125ml, 0.5ml, 1ml, 1ml, 10ml and 50g of acephate, imidacloprid, triazophos, quinalphos, azadirachtin, neem oil and neem seed kernels separately in 500 ml of water, respectively to prepare the required concentration of the chemicals for the experiment.

3.4.1.2 Toxicity evaluation

Two techniques were employed for testing the toxicity of the chemicals used for the experiment, *viz.*, Topical application on spiders and release of spiders on sprayed plants. The test plants for the experiment were raised as given in 3.3.1. The spiders were collected from the field maintained as described in 3.3.2.

Topical application on spiders

The experiment was conducted in CRD with five replications. Ten adult spiders of each species, of same size were chosen and kept inside 90 mm petri dishes. The spray solution was uniformly sprayed upon each spiders using an atomizer. After ten minutes, when the spray solution was dried, the treated spiders were released into the cages set for the experiment as explained in 3.3.1. Prey insects *viz., N. lugens, Nephotettix* spp., *S. furcifera, R. dorsalis, C. spectra, S. incertulas , C. medinalis, N. depunctalis* and *M. leda-ismene* were also supplied to the spiders at ten numbers each. The mortality of the spiders was recorded after every 24 hours and continued for seven days. Prey insects were replenished regularly. Spiders sprayed with water alone were kept as the control.

Release of spiders on sprayed plants

The pesticide solution was sprayed on to the paddy plants raised for the experiment, until the droplets rolled down, *i.e.,* just enough to wet the foliage and this was exposed to air for ten minutes to dry and placed inside the cage. Ten adult spiders of each species were released separately in to the cages, along with prey insects as mentioned in 3.4.1.2. Five replications were maintained for each spider species. Mortality of the spiders were recorded after every 24 hours for seven days and the prey insects were replenished daily. Plants sprayed with water alone was kept as control.

3.4.2 Field Evaluation

The synthetic chemicals and neem products recommended for the control of pests of rice were evaluated for their relative safety / toxicity to rice dwelling spiders, insect natural enemies and pests. The field trial was conducted in the Upaniyur padasekharam of Kalliyoor panchayat in the farmer's field. The experiment was done during the Mundakan season of 2005-'06. The rice variety selected for the trial was ' Jyothi'. The crop was raised and maintained as per the package of practices recommendations of the KAU (2002).

3.4.2.1 Design and Lay out

Design	: RBD
Treatments	: 8
Replications	: 3
Plot size	: 5m x 4m
Total number of plots	: 24

3.4.2.2 Treatments involved

T_1 : Acephate 0.05 per cent

T_2 : Imidacloprid 0.005 per cent

T_3 : Triazophos 0.05 per cent

T_4 : Quinalphos 0.05 per cent (insecticide check)

T_5 : Azadirachtin 0.004 per cent

T_6 : Neem oil 2 per cent

T_7 : Neem Seed Kernel Extract 5 per cent

T_8 : Control (unsprayed)

3.4.2.3 Pre – count of arthropods

The pre – count on the population of spiders, pests and insect natural enemies was taken to assess the status of the spiders, pests and insect natural enemies in an unsprayed field before spraying. This was done by sweeping as described in 3.1.2.1.

3.4.2.4 Application of treatments

The field was laid out as per the statistical design employed for the experiment as given in 3.4.2.1 and only one spraying was given. Spraying was done in the early morning hours during the maximum tillering stage (MTS) of the crop. The necessary quantity of spray solution was prepared and sprayed using a high volume knapsack sprayer. Plastic sacs stitched together and tied on to poles served as wind screen between two plots to avoid the air drift of pesticide droplets while spraying. The control plot was maintained with out any spraying.

3.4.2.5 Preparation of spray solutions

Acephate

Acephate 0.05 per cent was prepared by mixing six gram of the insecticide in three litres of water.

Imidacloprid

0.75 ml of the insecticide was dissolved in three litres of water to prepare imidacloprid 0.005 per cent.

Triazophos

To prepare triazophos 0.05 per cent , three ml of the insecticide was dissolved in three litres of water.

Quinalphos

Quinalphos 0.05 per cent was obtained by dissolving six ml of the formulation in three litres of water.

Azadirachtin

The botanical pesticide was prepared by mixing six ml of neem azal in three litres of water.

Neem Oil

Sliced ordinary washing soap (15 grams) was dissolved thoroughly in 500 ml of luke warm water to prepare the soap solution. Sixty ml of Neem Oil was taken in a bucket and the soap solution was added to that by continuous agitation and 2.50 litres of water was added into that mixture and stirred thoroughly to prepare two per cent neem oil emulsion.

Neem Seed Kernel Extract (NSKE)

250 gram neem seed kernels were ground to obtain a coarse powder and this was tied in a muslin cloth and dipped in a bucket containing two litres of water, and kept overnight for 24 hours. The next day the cloth bag was thoroughly squeezed to extract the whole contents completely. Fifteen grams of washing soap was sliced and dissolved in one litre of luke warm water and this was added into the neem seed kernel extract and mixed properly and stirred well to obtain 5 per cent neem seed kernel extract.

3.4.2.6 Observations on the population of spiders, pests and insect natural enemies

The population of spiders, pests and insect natural enemies were recorded at one, three, five, seven, ten and fifteen days after spraying the insecticides. This was assessed by sweeping the treated plots using a sweep net as mentioned in 3.2.1. Three replicated samples were taken, each with ten net sweeps and the mean population was recorded. The recolonization of spiders after pesticide application was closely observed and recorded.

3.5 STATISTICAL ANALYSIS

The data generated from the experiments were tabulated and analysed using suitable statistical tools (Panse and Sukhatme, 1967).

Results

4. RESULTS

Spiders are dextrous predators with skilful prey capturing abilities capable of curbing the generous growth of pests in the field. Results of the study conducted to document the diversity of spiders in rice ecosystem, their seasonal abundance, predatory efficiency of the dominant spiders and the relative safety of insecticides and botanicals to them are presented in Tables 2 - 23.

4. 1 DOCUMENTATION OF SPIDERS IN RICE ECOSYSTEM

Random survey conducted in the rice fields of Upaniyur Padasekharam in the Kalliyoor panchayat of Thiruvananthapuram district proved that rice fields harbour a multitude of spiders. Both hunters and web builders were prevalent in the field. Sixty five spiders belonging to seven guilds and eleven families were recorded (Table 2).

4.1.1 Web Builders

The web builders comprised of three guilds *viz.,* orb web weavers, scattered line weavers and sheet web builders. Different types of aerial webs were spun by these spiders for trapping their prey. Walking, jumping and flying insects constituted their main prey.

4.1.1.1 Orb Web Weavers

The orb web weavers consisting of 27 species of spiders were the major web builders in the rice ecosystem. The spiders built orb webs, a two dimensional snare, for prey capture. When an insect became entangled in the lines, it was seized, trussed with silk and carried to the hub in the web. The spiders recorded in the guild belonged to the families Tetragnathidae and Araneidae.

Tetragnathidae

Tetragnathidae was the predominant family in the rice ecosystem. Most of the tetragnathids recorded were small to medium sized, elongated spiders, colour of which ranged from flourescent green to straw yellow and brown. These long jawed spiders built weak orb webs in between paddy plants or on border weeds or field bunds and always remained near their webs. They rested on individual leaves in an elongated posture. When disturbed, they dropped on to the surface of water, over which they strode like aquatic bugs. Two genera were recorded. *Tetragnatha* was characterized by elongate and tapering abdomen and *Dyschiriognatha* with rounded globose abdomen. *Tetragnatha* was the dominant genera. The species of spiders in the family included *Tetragnatha mandibulata* Walckenaer, *Tetragnatha maxillosa* Thorell, *Tetragnatha javana* Thorell, *Tetragnatha viridorufa* Gravely, *Tetragnatha vermiformis* Emerton, *Tetragnatha andamanensis* Tikader, *Tetragnatha fletcheri* Gravely, *Tetragnatha cochinensis* Gravely, *Tetragnatha* spp., *Dyschiriognatha dentata* Zhu & Wen and *Dyschiriognatha* sp (Plates 1 & 2). *T. mandibulata* was the predominant species recorded followed by *T. maxillosa.* The females of *T. mandibulata* were dominant than the males. *T. mandibulata* was the largest and robust among the different species and possessed an extra tooth. *T. maxillosa* occurred regularly in the field and its promarginal guide tooth and the first largest tooth were widely separated.

T. mandibulata , *T. maxillosa* , *T. javana* and *T. viridorufa* were observed in the field during the nursery, vegetative, reproductive and maturity stages of the crop regularly. They were seen on border weeds, field bunds, individual plants and within the crop canopy. *T. vermiformis* was found occurring regularly during the vegetative, reproductive and ripening stages of the crop. The spider was observed on border weeds, field bunds, individual plants and crop canopy. *T. andamanensis* was a frequently seen species during the vegetative, reproductive and maturity stages in the border weeds, field bunds, individual plants and crop canopy. *T. fletcheri* was occasionally seen during the vegetative, reproductive and maturity stages from the border weeds, individual plants and crop canopy. *T. cochinensis* was observed occasionally on the border weeds, field bunds, individual plants and crop canopy during the nursery, vegetative, reproductive and maturity stages of the crop. *Tetragnatha* spp. were occasionally collected during the

Table 2 Spiders documented from the rice fields of Kalliyoor panchayat of Thiruvananthapuram district, their guild structure, crop stage and frequency of occurrence and habitat.

Sl No.	Spider species	Occurrence		Habitat
		Crop Stage	Frequency	
A	**Web Builders**			
I	**Orb Web Weavers**			
a	**Family Tetragnathidae**			
1	*Tetragnatha mandibulata* Walckenaer	N,V,F,M	RE	BW,FB,PP,CC
2	*Tetragnatha maxillosa* Thorell	N,V,F,M	RE	BW,FB,PP,CC
3	*Tetragnatha javana* Thorell	N,V,F,M	RE	BW,FB,PP,CC
4	*Tetragnatha viridorufa* Gravely	N,V,F,M	RE	BW,FB,PP,CC
5	*Tetragnatha vermiformis* Emerton	V,F,M	RE	BW,FB,PP,CC
6	*Tetragnatha andamanensis* Tikader	V,F,M	F	BW,FB,PP,CC
7	*Tetragnatha fletcheri* Gravely	V,F,M	O	BW,PP,CC
8	*Tetragnatha cochinensis* Gravely	N,V,F,M	O	BW,FB,PP,CC
9	*Tetragnatha* spp.	V,F,M	O	BW,FB,PP,CC
10	*Dyschiriognatha dentata* Zhu& Wen	V,F,M	O	PP,CC
11	*Dyschiriognatha* sp.	V,F,M	R	PP,CC
b	**Family Araneidae**			
12	*Argiope anasuja* Thorell	V,F,M	RE	BW,FB,PP,CC
13	*Argiope aemula* Walckenaer	V,M	O	BW,PP,CC
14	*Argiope catenulata* Doleschall	V,F,M	O	BW,FB,PP,CC
15	*Argiope pulchella* Thorell	V,F,M	O	BW,PP,CC
16	*Neoscona rumpfi* Tikader&Biswas	N,V,F,M	RE	BW,FB,PP,CC
17	*Neoscona bengalensis* Tikader&Bal	V,F,M	O	BW,PP,CC
18	*Neoscona mukerjei* Tikader	V,F,M	O	BW,PP,CC
19	*Neoscona* spp.	V,M	O	BW,PP,CC
20	*Araneus ellipticus* Tikader&Bal	V,F,M	F	BW,FB,PP,CC
21	*Araneus* spp.	V,M	O	PP,CC
22	*Eriovixia laglaizei* Simon	V,F,M	O	BW,FB,PP,CC

23	*Eriovixia* sp.	V	R	CC
24	*Larinia* sp.	V,M	O	PP,CC
25	*Cyrtarachne keralaensis* Sunil&Sebastian	V,F,M	O	PP,CC
26	*Cyrtophora citricola* Forskal	V,M	R	CC
27	*Gasteracantha geminata* Fabricius	M	R	CC
II	**Scattered Line Weavers**			
c	**Family Theridiidae**			
28	*Theridion* spp.	N,V,F,M	RE	BW,FB,PP,CC
III	**Sheet Web Builders**			
d	**Family Linyphiidae**			
29	*Linyphia* spp.	V,M	R	PP,CC
e	**Family Agelenidae**			
30	*Agelena* sp.	V	R	PP,CC
B	**Hunters**			
IV	**Stalkers**			
f	**Family Salticidae**			
31	*Telamonia dimidiata* Simon	V,F,M	RE	PP,CC
32	*Bianor carli* Reimoser	V,M	RE	FB,CC
33	*Bianor* sp.	V	O	CC
34	*Plexippus paykulli* Savingyny&Audouin	V,F,M	O	BW,FB,PP,CC
35	*Plexippus* sp.	V,M	O	CC
36	*Bavia kairali* Samson&Sebastian	V,M	O	BW,FB,CC
37	*Thiania bhamoensis* Thorell	V	O	CC
38	*Epeus indicus* Proszynski	V,F,M	O	BW,FB,CC
39	*Carhottus vidus* C.L.Koch	V	O	CC
40	*Carhottus* sp.	V,M	O	FB,CC
41	*Hyllus semicupreus* Simon	N,V,M	O	BW,FB,CC
42	*Hyllus* sp.	V,M	O	BW,FB,CC
43	*Myrmarachne plataleoides* O.P. Cambridge	V,M	O	BW,FB,CC
44	*Myrmarachne* sp.	V	R	CC
g	**Family Oxyopidae**			
45	*Oxyopes javanus* Thorell	N,V,F,M.	RE	BW,FB,PP,CC

46	*Oxyopes shweta* Tikader	V,F,M	RE	BW,PP,CC
47	*Oxyopes sunandae* Tikader	V,M	F	PP,CC
48	*Peucetia viridiana* Stoliczka	V,F,M	RE	BW,FB,PP,CC
V	**Ground Runners**			
h	**Family Lycosidae**			
49	*Pardosa pseudoannulata* Boesenberg&Strand	V,F,M	RE	BW,FB,PP.CC
50	*Pardosa sumatrana* Thorell	V,F,M	F	FB,PP,CC
51	*Pardosa amkhaensis* Tikader&Malhotra	V,M	O	CC
52	*Pardosa* spp.	V	F	CC
53	*Lycosa tista* Tikader	V,M	F	CC
54	*Lycosa* spp.	V,F,M	F	BW,CC
VI	**Ambushers**			
i	**Family Thomisidae**			
55	*Thomisus projectus* Tikader	V,F,M	RE	BW,FB,PP,CC
56	*Thomisus pugilis* Stoliczka	V,F,M	O	BW,FB,PP,CC
57	*Thomisus* sp.	F,M	R	PP,CC
58	*Misumena* sp.	V,F,M	O	BW,FB,CC
59	*Runcinia* sp.	F,M	O	BW,CC
60	*Xysticus* sp.	F,M	O	BW,CC
VII	**Foliage Runners**			
j	**Family Miturgidae**			
61	*Cheiracanthium danieli* Tikader	V,F,M	O	CC
62	*Cheiracanthium melanostomum* Thorell	V,F	O	BW, PP,CC
63	*Cheiracanthium* sp.	V	O	CC
k	**Family Clubionidae**			
64	*Matidia* sp.	V,F	O	CC
65	*Clubiona* sp.	V,F,M	O	BW,FB,CC

RE : Regular F : Frequent O : Occasional R : Rare
N :Nursery V :Vegetative F :Reproductive M : Maturity
FB: Field Bunds BW: Border Weeds CC : Crop Canopy PP : Individual plant

T. mandibulata

T. maxillosa

T. javana

T. viridorufa

T. vermiformis

T. andamanensis

Plate 1. Tetragnathids in rice ecosystem

T. fletcheri

T. cochinensis

Tetragnatha sp.

Tetragnatha sp.

D. dentata

Dyschiriognatha sp.

Plate 2. Tetragnathids in rice ecosystem

A. anasuja

A. aemula

A. catenulata

A. pulchella

N. rumpfi

N. bengalensis

Plate 3. Araenids in rice ecosystem

N. mukerjei

Neoscona sp.

A. ellipticus

Araneus sp.

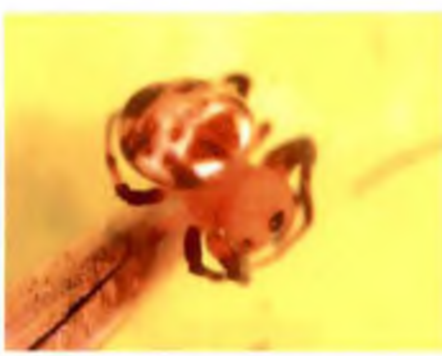
Araneus sp.

E. laglaizei

Plate 4. Araenids in rice ecosystem

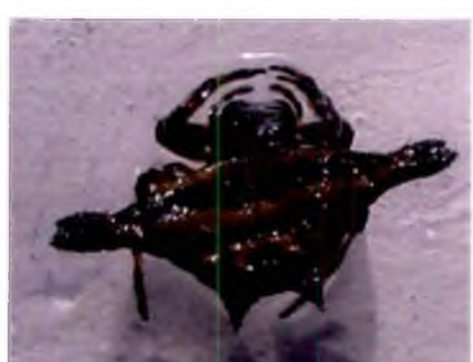
Eriovixia sp.

Larinia sp.



C. keralaensis

C. citricola



G. geminata

Plate 5. Araenids in rice ecosystem

Theridion sp.

Linyphia sp.

Agelena sp.

Plate 6. Scattered line weavers and sheet web builders in rice ecosystem

Male *T. dimidiata* Female

B. carli

Bianor sp.

P. paykulli

Plexippus sp.

Plate 7. Salticids in rice ecosystem

B. kairali

T. bhamoensis

E. indicus

C. vidus

Carhottus sp.

H. semicupreus

Plate 8. Salticids in rice ecosystem

Hyllus sp.

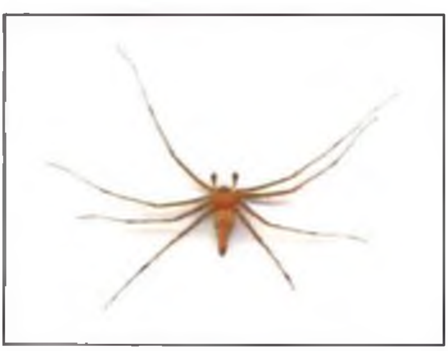
M. plataleoides

Myrmarachne sp.

Plate 9. Salticids in rice ecosystem

Adult *O. javanus* Juvenile

O. shweta

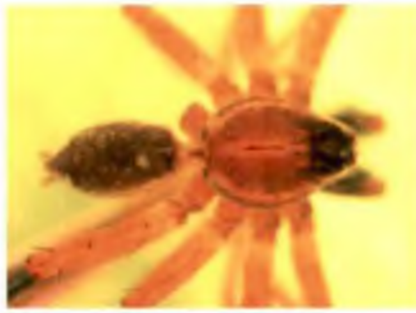


O. sunandae

P. viridana

Plate 10. Oxyopids in rice ecosystem

P. pseudoannulata



P. sumatrana

P. amkhaensis

Pardosa sp.

Pardosa sp.

L. tista

Lycosa sp.

Lycosa sp.

Plate 11. Lycosids in rice ecosystem

T. projectus

T. pugilis

Thomisus sp.

Misumena sp.

Misumena sp.

Runcinia sp.

Xysticus sp.

Plate 12. Thomisids in rice ecosystem

C. danieli

C. melanostomum

Cheiracanthium sp.

Matida sp.

Clubiona sp.

Plate 13. Foliage runners in rice ecosystem

vegetative, reproductive and maturity stages from the border weeds, field bunds, individual plants and crop canopy. *D. dentata* was occasionally recorded from the crop canopy and individual plants during the vegetative, reproductive and maturity stages of the crop. *Dyschiriognatha* sp. was found rarely during the vegetative, reproductive and maturity stages of the crop on the crop canopy and individual plants.

Araneidae

Araneidae was the second abundant family collected from the rice fields. These conspicuous creatures were brightly coloured and made large webs. The araneids built orb webs either in between the plants or just above the crop canopy. Eight genera and sixteen species were recorded in the family. The major genera were *Argiope* and *Neoscona*. *Argiope* species were large sized, brightly coloured and built a three dimensional snare where as *Neoscona* species were small sized, mostly brown coloured with dull markings and built a weak orb web. The species recorded were *Argiope anasuja* Thorell, *Argiope aemula* Walckenaer, *Argiope catenulata* Doleschall, *Argiope pulchella* Thorell, *Neoscona rumpfi* Tikader & Biswas, *Neoscona bengalensis* Tikader & Bal, *Neoscona mukerjei* Tikader , *Neoscona* spp., *Araneus ellipticus* Tikader & Bal, *Araneus* spp., *Eriovixia laglaizei* Simon, *Eriovixia* sp., *Larinia* sp., *Cyrtarachne keralaensis* Sunil & Sebastian, *Cyrtophora citricola* Forskål and *Gasteracantha geminata* Fabricius (Plates-3, 4 & 5). *A. anasuja* and *N. rumpfi* were the two dominant species. Both the spiders were found during vegetative, reproductive and maturity stages regularly and occupied almost all habitats in the rice fields, like field bunds, border weeds, individual plants and from within the crop canopy. *N rumpfi* was also recorded during the nursery stage of the crop. *A. anasuja* was bright red and grey coloured with yellow stripes in the abdomen with a flat cephalothorax clothed with thick layer of short white hairs, long legs and variably shaped abdomen. *N. rumpfi* was yellowish brown coloured, clothed with long white hairs in the cephalic area, and abdomen is sub-ovate to sub-triangular, longer than wide, dorsum with an inverted christmas tree like folium of brown and chalk white bands. *A. ellipticus* occured frequently during the vegetative, reproductive and maturity stages of the crop and was obtained from border weeds, field bunds, individual plants and within the crop canopy. *Araneus* spp. and *A. aemula* were present occasionally during vegetative and maturity stage of the crop and was collected from within the crop canopy and individual plants except *A. aemula* , also found in the border weeds. *A. catenulata, A. pulchella, N. bengalensis, N. mukerjei, Neoscona* spp. and *E. laglaizei* were obtained during the vegetative, reproductive and maturity stages of the crop occasionally from field bunds, border weeds, individual plants and within the crop canopy. *Eriovixia* sp. was rare in the field and collected from the crop canopy. *Larinia* sp. was observed during vegetative and maturity stages occasionally from within the crop canopy and individual plant and *C. keralaensis* was occasionally collected during vegetative, reproductive and maturity stages from within the crop canopy and individual plant. *C. citricola* and *G. geminata* were rare in the field during the vegetative and maturity stages and collected from the crop canopy.

4.1.1.2 Scattered Line Weavers

The scattered line weavers spun loose, irregular webs in dark places. The only family recorded in the guild was Theridiidae.

Theridiidae

The spiders were small sized thick set spiders, creamy white coloured with globose abdomen and long thin legs also called as comb footed or cob web spiders. They hung upside down from the dry threads of irregular maze webs. Only a single species was recorded in the family, *viz., Theridion* spp., (Plate-6) which was found in large numbers through out the crop period from nursery to the maturity stages. It was seen in diverse habitats like field bunds, border weeds, and individual plants and in the crop canopy.

4.1.1.3 Sheet Web Builders

The sheet web building spiders spun closely woven sheet of irregularly tangled loose and thin spaced webs. The spiders were observed clinging upside down beneath the blanket, upon which flying and jumping insects were trapped. Linyphiidae and Agelenidae were the two families recorded in the guild.

Linyphiidae

The linyphiids were small spiders which preferred shady and hidden places. The family contributed only a single genus with a single species, *Linyphia* spp. which occurred rarely during the vegetative and maturity stages of the crop (Plate-6). It was observed from the crop canopy and on individual plants.

Agelenidae

Agelenidae was one of the least represented families with a single species *viz.*, *Agelena* sp (Plate-6). Occurrence of these flesh coloured, large sized spiders were rare and found only during the vegetative stage of the crop. It was collected from the crop canopy and from loose webs spun on individual plants.

4.1.2 Hunters

The hunters recorded from the rice ecosystem included the stalkers, ambushers, ground runners and foliage runners. These spiders are generally strong bold creatures, with elongate and cylindrical bodies propelled by stout legs of moderate length. Most of them were big eyed. They caught prey by pursuing and overpowering them with strength, speed and alertness.

4.1.2.1 Stalkers

The stalkers were generally observed running over vegetation with great agility. They were mostly active during day time. Two families were recorded in the guild.

Salticidae

The family salticidae was another dominant family in the rice field. These jumping spiders were big eyed, diurnal, with hairy bodies. The family recorded nine genera with fourteen species. The different species recorded were *Telamonia dimidiata* Simon, *Bianor carli* Reimoser, *Bianor* sp., *Plexippus paykulli* Savingyny & Audouin , *Plexippus* sp., *Bavia kairali* Samson & Sebastian, *Thiania bhamoensis* Thorell, *Epeus indicus* Proszynski, *Carhottus vidus* C.L.Koch, *Carhottus* sp., *Hyllus semicupreus* Simon, *Hyllus* sp., *Myrmarachne plataleoides* O.P. Cambridge and *Myrmarachne* sp (Plates- 7, 8 & 9). *T. dimidiata* and *B. carli* were the dominant species among the salticids. *T. dimidiata* was moderately large, beautifully coloured, males with reddish brown and snowy white stripes and females with yellow and white long stripes. *T. dimidiata* was observed in the field during vegetative, reproductive and maturity stages regularly and were mostly collected from individual thick, white, viscid silk retreats in rice plants and from the crop canopy. *B. carli* occured frequently during vegetative and maturity stages and were collected from the crop canopy and field bunds. *Bianor* sp. was recorded occasionally during vegetative stage from the crop canopy. *P. paykulli* was present in the field during vegetative, reproductive and maturity stages occasionally and obtained from the field bunds, border weeds, individual plants and the crop canopy. *Plexippus* sp. was found occasionally during vegetative and maturity stages and *T. bhamoenisis* and *C. vidus* were observed occasionally during the vegetative stage only and were obtained from the crop canopy alone. *B. kairali* was observed during the vegetative and maturity stages of the crop occasionally from the field bunds, border weeds and within the crop canopy. *E. indicus* was recorded during the vegetative, reproductive and maturity stages occasionally from field bunds, border weeds and within the crop canopy. *Carhottus* sp. was found occasionally during vegetative and maturity stages in field bunds and crop canopy. *H. semicupreus*, *Hyllus* sp. and *M. plataleoides* were occasionally seen during the vegetative and maturity stages of the crop from field bunds, border weeds and within the crop canopy except *H. semicupreus* which was also found in nursery stage of the crop. *Myrmarachne* sp. was found rarely and only during the vegetative stage from the crop canopy.

Oxyopidae

The lynx spiders were strongly built, with a high, oval cephalothorax and rounded abdomen tapering to a point behind. Their legs were thin, long and armed with long black spines. All the legs were of the same length. The family comprised two genera, *viz., Oxyopes* and *Peucetia.* Four species of spiders *viz., Oxyopes javanus* Thorell, *Peucetia viridana* Stoliczka, *Oxyopes shweta* Tikader and *Oxyopes sunandae* Tikader were recorded (Plate-10). *O. javanus* and *P. viridana* were the dominant species among them. *O. javanus* was straw coloured with brown cephalothorax and eight eyes arranged in four rows. *P. viridana* was beautifully coloured with bright transparent green variegated with rows of small red and yellow spots. *O. javanus* occurred regularly in the field during the nursery, vegetative, reproductive and maturity stages on the field bunds, border weeds, individual plants and within the crop canopy. *P. viridana* and *O. shweta* too were present in the field regularly during the vegetative, reproductive and maturity stages and obtained from the border weeds, individual plant and with in the crop canopy. *O. sunandae* was found during vegetative and maturity stages frequently and found in individual plants and with in the crop canopy.

4.1.2.2 Ground Runners

These spiders were two clawed and were seen moving on soil and vegetation. The front legs were directed forwards. The spider was observed to pounce upon its prey and holding the body in its strong front legs, crushed it with its stout chelicera.

Lycosidae

The members of this family usually known as wolf spiders were good hunters, and chased their prey. The cuticle was clothed with simple or squamose hairs, which helped them to swim through water in the paddy fields and thus moved from one plant to another. The females enclosed the eggs in a carefully moulded subspherical bag and attached the sac to their spinnerets and dragged it around with her wherever she went. The family Lycosidae recorded six species of spiders. *Pardosa* and *Lycosa* were the two genera obtained, of which *Pardosa* was predominant. The different species observed were *Pardosa pseudoannulata* Böesenberg & Strand, *Pardosa sumatrana* Throell, *Pardosa amkhaensis* Tikader & Malhotra, *Pardosa* sp., *Lycosa tista* Tikader and *Lycosa* sp. (Plate-11). Among these, *P. pseudoannulata* was dominant. The spider was medium large sized, greyish brown coloured, with a fork shaped median band on cephalothorax, two median yellow spots and three or four transverse yellow bands posteriorly in the abdominal dorsum. It was abundant in the field throughout the crop period, during vegetative, reproductive and maturity stages and were observed from field bund, border weeds, individual plant, within the crop canopy. *P. sumatrana* was encountered frequently during vegetative, reproductive and maturity stages from field bunds, individual plant and with in the crop canopy. *P. pseudoannulata* and *P. sumatrana* were found resting at the base of the paddy plants. *P. amkhaensis* was recorded during vegetative and maturity stages occasionally from within the crop canopy. *Pardosa* sp. recorded its presence occasionally during vegetative stage from the crop canopy alone. *L . tista* and *Lycosa* sp. were encountered frequently during vegetative and maturity stages from the crop canopy, except the latter which was found during reproductive stage and collected from border weeds also.

4.1.2.3 Ambushers

The ambushers or crab spiders were mostly found in and among the inflorescence. They ran swiftly and pursued the prey.

Thomisidae

The thomisid spiders had a flattened body and were formidable creatures which attacked insects and other spiders much larger than themselves and exhibited camouflaged prey capture. Four genera and six species of ambushers were observed during the study period, they were *Thomisus projectus* Tikader, *Misumena* sp., *Thomisus pugilis* Stoliczka, *Thomisus* sp., *Runcinia* sp. and *Xysticus* sp. (Plate -12). *T. projectus* was the dominant spider, pearly white with eyes small and laterally projected large horn like protuberances on the head and exhibited vigour and good prey capturing abilities, and longevity. *T. projectus* was encountered regularly during vegetative, reproductive and maturity stages from field bunds, border weeds, and individual plant and within the crop canopy. *Misumena* sp. and *T. pugilis* appeared occasionally collected during vegetative, reproductive and maturity stages on the field bunds, border weeds and within the crop canopy except *T. pugilis* which was also found in creamy white silken retreats in individual leaves on plants. *Thomisus* sp. was rarely observed during flowering and maturity stages from with in crop canopy and individually in webs made on twisted leaves. *Runcinia* sp. and *Xysticus* sp. were present occasionally during the flowering and maturity stages of paddy. They were seen both on border weeds and within crop canopy.

4.1.2.4 Foliage Runners

These vagrants had long legs with well developed claw tufts and were good climbers, mostly whitish or brownish coloured. They lived in flat tubular nests, open at both ends, rolled in leaves or under bark. The plant hunters observed belonged to the families Miturgidae and Clubionidae.

Miturgidae

Cheiracanthium was the only genus recorded under this family, with three species *viz., Cheiracanthium danieli* Tikader, *Cheiracanthium melanostomum* Thorell, and *Cheiracanthium* sp (Plate-13). *C. danieli* was the dominant among the three and was seen occasionally during the vegetative, reproductive and maturity stages of the crop from with in the crop canopy. *C. melanostomum* was collected occasionally during vegetative and reproductive stages from border weeds, individual plant and within the crop canopy. *Cheiracanthium* sp. was found during vegetative stage occasionally from the crop canopy.

Clubionidae

Clubionids are two clawed hunting spiders, usually seen in plants in rolled leaves. Two species *viz., Matidia* sp. and *Clubiona* sp. represented the family Clubionidae (Plate-13). *Matidia* sp. was recorded occasionally during vegetative and reproductive stages from with in the crop canopy. *Clubiona* sp. was collected during the vegetative, reproductive and maturity stages occasionally from field bund, border weeds and within the crop canopy.

4. 2 SEASONAL OCCURRENCE OF SPIDERS, PESTS, INSECT NATURAL ENEMIES AND NEUTRALS

The population of spiders, pests, insect natural enemies and neutrals in the rice fields expressed as number per ten sweeps is presented in Tables 3 – 6.

4. 2. 1 Virippu Season

Spiders

Data on the occurrence of spiders in different crop stages are given in Table 3. Among the eleven families of spiders recorded from the rice fields, six families *viz.,* Tetragnathidae, Araneidae, Salticidae, Lycosidae, Oxyopidae and Thomisidae were more populated. The mean population of spiders in the various families ranged from 0.29 - 2.43. Significantly higher mean population of spiders was recorded in Tetragnathidae (2.43), followed by Araneidae (1.19) and Salticidae (0.92) which were on par. Lycosidae (0.83) and Oxyopidae (0.78) recorded lower numbers which were on par. Comparatively low mean population was recorded in the family Thomisidae, 0.40 spiders and 0.29 spiders by the other minor families, which were on par.

The mean population of spiders recorded at weekly intervals ranged from 0.08 - 1.68. During the early vegetative stage the mean population was low, being 0.08, 0.28 and 0.71, during one, two and three weeks after transplanting. During the later half of the vegetative stage the mean population recorded was 1.04 and 1.36 four and

Table 3 Occurrence of spiders in different stages of crop in the rice fields of Kalliyoor panchayat during Virippu season

Spider families	Weeks After Transplanting (number per ten sweeps)																Mean
	Vegetative stage						Reproductive stage					Maturity stage					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Tetragnathidae	0.40	0.73	2.43	3.10	3.97	4.30	4.10	4.00	3.37	2.70	2.03	1.70	1.73	1.53	1.43	1.33	2.43
Araenidae	0	0.30	0.77	1.23	1.47	1.87	1.33	2.03	2.17	2.57	1.70	1.33	1.17	0.67	0.23	0.13	1.19
Salticidae	0.03	0.23	0.37	0.63	0.90	0.77	1.13	1.23	1.60	2.17	2.50	1.80	0.53	0.43	0.23	0.10	0.92
Lycosidae	0	0.23	0.43	0.73	0.90	1.10	0.90	0.80	1.30	1.57	1.47	1.33	1.23	0.73	0.47	0.10	0.83
Oxyopidae	0.10	0.37	0.60	0.77	1.37	1.63	2.17	1.47	1.37	0.90	0.93	0.40	0.27	0.10	0	0	0.78
Thomisidae	0	0	0.17	0.43	0.70	0.53	0.33	0.53	0.83	1.07	0.60	0.50	0.20	0.27	0.17	0	0.40
Others	0	0.10	0.23	0.37	0.20	0.50	0.13	0.30	0.43	0.80	0.63	0.33	0.27	0.17	0.17	0.07	0.29
Mean	0.08	0.28	0.71	1.04	1.36	1.53	1.44	1.48	1.58	1.68	1.41	1.06	0.77	0.56	0.39	0.25	

C.D. (0.05) Spider families: (0.180)
C.D. (0.05) Weeks : (0.272)
C.D. (0.05) Treatments : (0.720)

five weeks after transplanting which increased to 1.53 in sixth week. Higher mean population of spiders was recorded in the reproductive stage. The mean population recorded at seven, eight, nine, ten and eleven weeks after transplanting were 1.44, 1.48, 1.58, 1.68 and 1.41 spiders, respectively and were on par. At maturity stage of the crop the mean population of spiders started decreasing slowly and was observed to be 1.06, 0.77, 0.56, 0.39 and 0.25 on the twelfth, thirteenth, fourteenth, fifteenth and sixteenth weeks after transplanting, respectively.

The population of the tetragnathids during the virippu season, ranged between 0.40 - 4.30 spiders. The population of the spider was significantly low during the early vegetative stage being 0.40 and 0.73, one and two weeks after transplanting. The population increased to 2.43 during the third week and 3.10 during the fourth week and were statistically on par. Significantly high population of tetragnathids was recorded during the later vegetative stage and early reproductive stage, being 3.97, 4.30, 4.10 and 4.00 during fifth, sixth, seventh and eighth weeks, respectively. The population decreased during the later reproductive stage to 3.37, 2.70 and 2.03 on the ninth, tenth and eleventh weeks, respectively. During the maturity stage, the population was still lower being 1.70, 1.73, 1.53, 1.43 and 1.33 during the twelfth, thirteenth, fourteenth, fifteenth and sixteenth weeks, respectively.

The weekly population of Araneidae in the rice field ranged from 0.13 - 2.57 spiders. One week after transplanting no araneids were encountered in the field. The population of araneids recorded two and three weeks after transplanting were relatively low and was 0.30 and 0.77, respectively which were on par. At four, five and six weeks after transplanting when the crop was at maximum tillering stage, the number of araneids increased to 1.23, 1.47 and 1.87, respectively and were on par. The reproductive stage of the crop harboured the higher population of araneids. The early reproductive stage recorded 1.33 spiders on seven weeks after transplanting, where as the eighth, ninth and tenth weeks recorded moderately high population of 2.03, 2.17 and 2.57 araneids, respectively and were on par. The population started declining during the later half of the reproductive stage, the number of spiders recorded at eleven weeks of transplanting being 1.70. During the maturity stage of the crop the number of araneids recorded was 1.33 (twelfth) and 1.17 (thirteenth), respectively and were on par. When the crop neared harvest, at fourteen, fifteen and sixteen weeks after transplanting, the araneids observed were 0.67, 0.23 and 0.13, respectively and were on par.

The family Salticidae recorded a population in the range of 0.03 - 2.50. The population of salticids recorded during the vegetative stage of the crop at one, two, three and four weeks after transplanting ranged between 0.03 - 0.63 and were on par. The later half of the vegetative stage recorded 0.90 and 0.77 salticids on five and six weeks after transplanting, which were on par with the population of the spider during seventh (1.13) and eighth (1.23) weeks. The population of salticids built up on ninth and tenth weeks during reproductive stage which recorded 1.60 and 2.17 spiders and were on par. The highest population of 2.50 salticids was observed during the eleventh week. During the maturity stage, at twelve weeks after transplanting relatively higher population of 1.80 spiders was seen, where as thirteen, fourteen, fifteen and sixteen weeks after transplanting only low population of the spiders in the range of 0.10 - 0.53 was recorded.

The population of Lycosidae in rice ecosystem ranged from 0.10 - 1.57 spiders. One week after transplanting, no lycosids were encountered in the field. The population of lycosids observed during two, three, four and five weeks after transplanting were 0.23, 0.43, 0.73 and 0.90, respectively and were on par. The population increased to 1.10 spiders at six weeks after transplanting and then slowly decreased during the early reproductive stage to 0.90 and 0.80 spiders at seven and eight weeks after transplanting, respectively. In the later reproductive stage the population of lycosids increased to 1.30, 1.57 and 1.47 spiders during the nine, ten and eleven weeks, respectively which were on par with the population of lycosids observed during the early half of the maturity stage at twelve (1.33) and thirteen

(1.23) weeks after transplanting. During the later half of the maturity stage when the crop neared harvest the population recorded was 0.73 (fourteenth), 0.47 (fifteenth) and 0.10 (sixteenth week) spiders, respectively and were on par.

The oxyopids in rice fields during virippu season ranged from 0.10 - 2.17. The population of the spider was significantly low during the vegetative stage being 0.10, 0.37, 0.60 and 0.77, at one, two, three and four weeks after transplanting, respectively and were on par. The population increased to 1.37 during the fifth week and 1.63 during the sixth week and were on par. Significantly higher population of oxyopids was recorded during the early reproductive stage being 2.17 and 1.47 spiders at seven and eight weeks after transplanting. The population of the spiders observed at nine, ten and eleven weeks after transplanting were 1.37, 0.90 and 0.93, respectively and were on par. The maturity stage observed very low population of oxyopids , the population recorded being 0.40, 0.27 and 0.10 spiders at twelve, thirteen and fourteen weeks after transplanting, respectively and were on par. During the last two weeks just before harvest, when the crop was at senescence stage, at fifteen and sixteen weeks no oxyopids were encountered in the field.

Among the six major families, Thomisidae was the least populated, the mean number of spiders recorded ranging from 0.17 - 1.07. In the first and second weeks after transplanting, no thomisids were recorded from the field. Low population was observed during three, four, five and six weeks after transplanting being 0.17, 0.43, 0.70 and 0.53, respectively and were on par. During the reproductive stage the population of thomisids ranged between 0.33 – 0.60 and were on par. In the maturity stage the population of thomisids were comparatively low and ranged from 0.17 - 0.50 spiders and were on par. At sixteen weeks after transplanting no thomisids were observed in the field.

The population of the other spiders *viz.,* Clubionidae, Linyphiidae, Agelenidae, Theridiidae and Miturgidae was also very low. One week after transplanting no spiders representing these minor families were recorded. The population of the minor families were very low during the vegetative stage and ranged from 0.10 - 0.50 spiders and were on par. In the reproductive stage relatively higher population was recorded and ranged between 0.13 - 0.80. During the maturity stage of the crop the other families recorded very low population ranging from 0.07 – 0.33 spiders and were on par.

Pests, insect natural enemies and neutrals

The data on the population of pests, insect natural enemies and neutrals in the rice fields of Kalliyoor Panchayat during the Virippu presented in Table 4 indicated that the mean population of insect natural enemies (14.03) in rice fields was significantly higher than the mean population of hoppers (12.79) which was the dominant group of pests, followed by the bugs (7.77) and neutrals (6.94). The mean population of lepidopteran pests (6.10), was on par with the other groups of pests (6.01).

Regarding the distribution of pests, insect natural enemies and neutrals over the different weeks of crop growth, the weekly mean population of insects ranged between 1.39 - 11.99. During the early vegetative stage the mean population of insects was 1.39, 3.34 and 6.70 at one, two and three weeks after transplanting, where as the second half of the vegetative stage recorded higher mean populations, 9.02 and 11.08 at fourth and fifth weeks, and the highest during the sixth week (11.99). The reproductive stage of the crop recorded almost uniform mean population of insects, 11.09, 11.63, 11.82, 10.68 and 10.73 insects, seven, eight, nine, ten and eleven weeks after transplanting, respectively. The maturity stage showed almost a similar trend as that of the reproductive stage and recorded 11.02 and 10.02 insects during the twelfth and thirteenth weeks. During the fag end of the maturity stage the mean population of insects declined significantly to 8.83, 8.01 and 5.71 during fourteen, fifteen and sixteen weeks after transplanting.

Among the pests, hoppers were the dominant group, with a population ranging from 0.33 - 27.70 hoppers during the cropping season. A significant increase in the

Table 4 Population of pests, insect natural enemies and neutrals in the rice fields of Kalliyoor panchayat during the Virippu season

Insects	Weeks After Transplanting (number per ten sweeps)																Mean
	Vegetative stage						Reproductive stage					Maturity stage					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Pests																	
Hoppers	0.33	3.87	6.80	8.80	13.10	14.90	18.60	22.67	27.70	24.77	16.40	12.60	10.87	10.33	7.23	5.60	12.79
Bugs	0	0.07	0.57	1.97	3.87	6.17	9.97	11.50	15.30	11.87	8.27	13.60	13.43	11.23	9.63	6.93	7.77
Lepidopterans	1.03	3.83	5.60	6.00	6.20	8.40	9.63	10.93	8.60	7.63	6.23	6.00	5.27	4.00	4.47	3.77	6.10
Others	0.60	0.60	2.77	2.47	2.00	2.80	1.07	3.40	3.03	2.57	11.80	11.50	13.07	12.83	14.60	11.10	6.01
Natural enemies	3.37	6.90	11.93	17.10	20.97	23.07	15.93	13.37	10.63	14.13	19.43	20.87	16.27	13.37	10.93	6.27	14.03
Neutrals	3.03	4.77	12.53	17.80	20.33	16.63	11.37	7.90	5.63	3.10	2.27	1.57	1.23	1.20	1.17	0.57	6.94
Mean	1.39	3.34	6.70	9.02	11.08	11.99	11.09	11.63	11.82	10.68	10.73	11.02	10.02	8.83	8.01	5.71	

C.D (0.05) Insects : (0.380)
C.D (0.05) Weeks : (0.620)
C.D (0.05) Treatments : (1.519)

population of the hoppers during the vegetative stage, the population being 0.33, 3.87, 6.80 and 8.80 on first, second, third and four weeks respectively, after transplanting. During maximum tillering, the population of hoppers recorded was 13.10 and 14.90 at fifth and sixth weeks after transplanting. When the crop was at the reproductive stage the hopper population was significantly higher being 18.60 and 22.67, seven and eight weeks after transplanting. The highest population of 27.70 was recorded during the ninth week, followed by 24.77 and 16.40 in the tenth and eleventh weeks, respectively. The population of hoppers were significantly low during the maturity stage and ranged between 5.60 - 12.60.

The population of bugs ranged from 0.07 - 15.30 through out the crop period. No bugs were found residing on the newly transplanted crop, one week after transplanting. The bugs were found in relatively lower numbers during the vegetative stage, the population ranging between 0.07 - 1.97. The late vegetative season recorded a significant increase in the population of the bugs being 3.87 and 6.17, five and six weeks after transplanting. The reproductive stage recorded higher number of bugs, the population being 9.97, 11.50 on seventh and eighth weeks. The highest population (15.30) was recorded on ninth week, and it differed significantly from the population of the bugs recorded during the different weeks. A decrease in the population was noticed during the late reproductive stage, ten (11.87) and eleven (8.27) weeks after transplanting. During the maturity stage, the population again built up to 13.60, 13.43 and 11.23 , twelve, thirteen and fourteen weeks after transplanting, respectively. There was a subsequent decline during the end stage of the crop, 9.63 and 6.93, fifteen and sixteen weeks after transplanting.

Lepidopteran pests in the rice field during the crop season ranged from 1.03 - 10.93 per week. The population of lepidopterans was comparatively low in the vegetative stage, being 1.03 and 3.83, one and two weeks after transplanting later the population increased to 5.60, 6.00, 6.20 and 8.40, three, four, five and six weeks after transplanting, respectively. The reproductive stage of the crop harboured more lepidopterans, the highest being 10.93 recorded during eighth week and it was on par with the population recorded during the seventh week (9.63). The population of lepidopterans were 8.60, 7.63 and 6.23 during the late reproductive stage, at nine, ten and eleven weeks after transplanting. During the maturity stage the population was comparatively low, being 6.00, 5.27, 4.00, 4.47 and 3.77 at twelve, thirteen, fourteen, fifteen and sixteen weeks after transplanting, just before harvest of the crop.

The population of other pests during virippu season ranged between 0.60 - 14.60 in the different growth phases of the crop. Very low population of the pests was recorded during the early vegetative stage 0.60 each on first and second weeks. The population flared up during the later vegetative stage and recorded 2.77, 2.47, 2.00 and 2.80, at three, four, five and six weeks after transplanting, respectively. In the reproductive stage the population of the minor pests was low and fluctuated between 1.07 - 3.40 in the seventh, eighth, ninth and tenth weeks, respectively. Towards the end of the reproductive stage, the population increased significantly to 11.80, eleven weeks after transplanting. The maturity stage recorded almost uniform population of the minor pests, 11.50, 13.07, 12.83 at twelve, thirteen and fourteen weeks after transplanting respectively. Significantly highest population was observed in the fifteenth week, 14.60 and the sixteenth week recorded 11.10 insects.

The population of insect natural enemies in rice ecosystem ranged from 3.37 - 23.07. During the early vegetative stage the population of natural enemies recorded was 3.37, 6.90 and 11.93, one, two and three weeks after transplanting respectively, where as the late vegetative stage recorded very high numbers of the insect natural enemies. The population recorded during fourth and fifth weeks were 17.10 and 20.97, respectively and significantly high population was recorded in the sixth week, 23.07. During the reproductive stage the population decreased and ranged from 10.63 – 19.43. In the maturity stage, the natural enemy population again increased to 20.87 at twelve weeks after transplanting, followed by 16.27, 13.37, 10.93 and 6.27 in the thirteenth, fourteenth, fifteenth and sixteenth weeks, respectively.

Neutrals were seen more during the first half of the crop period, when compared to the later half in the virippu season and ranged from 0.57 - 20.33. The population of neutrals built up gradually in the vegetative stage, 3.03 and 4.77, one and two weeks after transplanting. The population increased rapidly to 12.53 and 17.80 in the third and fourth weeks, and the significantly highest population being 20.33 was observed in the fifth week, followed by 16.63 in the sixth week. During the reproductive stage the population of neutrals slowly declined to 11.37, 7.90 and 5.63 in the seventh, eighth and ninth weeks. The late reproductive stage harboured very low population of neutrals, 3.10 and 2.27, ten and eleven weeks after transplanting, respectively. The maturity stage of the crop recorded relatively lower population ranging between 0.57 - 1.57 and were on par.

4.2.2 Mundakan Season

Spiders

Data on the occurrence of spiders in different crop stages during Mundakan season is presented in Table 5. As observed in the virippu season spiders belonging to the eleven families were recorded from the rice fields, and among them six families were found to be dominant over the others and the rest of the five were least represented. The mean population of spiders recorded in the different families ranged from 0.28 - 2.84 spiders. Tetragnathidae (2.84) recorded significantly higher mean population among the six major families, followed by Araneidae (1.30) and Salticidae (1.09) which were on par. The mean population recorded by Lycosidae (0.89) and Oxyopidae (0.78) were relatively low and were on par. Significantly lower number of spiders was recorded for Thomisidae (0.28) and 0.49 spiders by the other minor families which were on par.

The distribution of spiders over different weeks of the crop season ranged between 0.14 - 1.79. In the early vegetative stage the mean population was lower, 0.14, 0.41 and 0.82, during one, two and three weeks after transplanting, respectively. In the second half of the vegetative stage the mean population gradually increased,

Table 5 Occurrence of spiders in different stages of crop in the rice fields of Kalliyoor panchayat during Mundakan season

Spider families	Weeks After Transplanting (number per ten sweeps)																Mean
	Vegetative stage						Reproductive stage					Maturity stage					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Tetragnathidae	0.47	1.03	2.70	3.50	4.20	5.00	4.73	4.50	3.57	2.87	4.07	2.03	1.90	1.83	1.57	1.43	2.84
Araneidae	0.23	0.53	0.97	1.17	1.57	2.13	2.33	2.80	2.53	2.03	1.53	1.37	0.90	0.50	0.17	0.10	1.30
Salticidae	0	0.10	0.30	0.77	0.57	0.43	1.17	1.53	1.87	2.03	2.27	2.77	1.90	1.00	0.43	0.33	1.09
Lycosidae	0.07	0.50	0.67	0.33	0.50	0.93	1.20	1.27	1.33	1.47	1.03	1.43	1.50	1.23	0.60	0.17	0.89
Oxyopidae	0.10	0.43	0.60	0.73	1.30	1.63	2.27	1.47	1.30	0.83	0.97	0.40	0.27	0.10	0	0	0.78
Thomisidae	0	0.07	0.07	0.30	0.17	0.40	0.23	0.17	0.77	0.90	0.53	0.23	0.30	0.17	0.10	0.03	0.28
Others	0.10	0.17	0.47	0.33	0.57	0.17	0.43	0.80	0.70	1.23	0.83	0.37	0.53	0.67	0.30	0.23	0.49
Mean	0.14	0.41	0.82	1.02	1.27	1.53	1.77	1.79	1.72	1.62	1.61	1.23	1.04	0.79	0.45	0.33	

C.D (0.05) Spider families : (0.192)
C.D (0.05) Weeks :(0.290)
C.D (0.05) Treatments : (0.768)

1.02, 1.27 and 1.53 on four, five and six weeks after transplanting, respectively. The reproductive stage recorded the highest mean population of spiders. The mean population of spiders recorded at seven, eight, nine, ten and eleven weeks after transplanting were 1.77, 1.79, 1.72, 1.62 and 1.61 spiders, respectively and were on par. During the maturity stage of the crop, the mean population of spiders declined slowly along with the senescence of the crop. The mean population of the spiders recorded was observed 1.23, 1.04, 0.79, 0.45 and 0.33 on the twelfth, thirteenth, fourteenth, fifteenth and sixteenth weeks after transplanting of the crop, respectively.

The weekly population of tetragnathids during the Mundakan season ranged between 0.47 to 5.00. During the early vegetative stage the population of the spider was significantly low, being 0.47 and 1.03, one and two weeks after transplanting and were on par. The number of tetragnathids increased to 2.70 during the third week and 3.50 during the fourth week which were statistically on par. When the crop was at the maximum tillering stage, significantly high population of tetragnathids was recorded. The population recorded being 4.20 and 5.00, in the fifth and sixth weeks, respectively. During the reproductive stage, the tetragnathids were observed in higher numbers, being 4.73 and 4.50 during seventh and eighth weeks. There was a reduction in the spider number to 3.57 and 2.87, in the ninth and tenth weeks, respectively. The population again increased to 4.07 in the eleventh week. In the maturity stage of the crop the population of the spider slowly declined to 2.03, 1.90, 1.83, 1.57 and 1.43 during the twelfth, thirteenth, fourteenth, fifteenth and sixteenth weeks respectively and were on par.

The araneid population in the rice field during the crop season ranged from 0.10 - 2.80 spiders. During the vegetative stage of the crop, araneids were recorded in lower numbers, the population being 0.23, 0.53 and 0.97, one, two and three weeks after transplanting and were on par. In the later half of the vegetative stage, when the crop was at maximum tillering stage, the population of araneids increased to 1.17, 1.57 and 2.13, in the fourth, fifth and sixth weeks, respectively. The reproductive stage recorded relatively higher number of araneids. In the reproductive stage, 2.33, 2.80, 2.53, 2.03 and 1.53 araneids were recorded in the seventh, eighth, ninth, tenth and eleventh weeks after transplanting, respectively. During the maturity stage the population started declining and significant difference was observed in the population of the spiders during the different weeks, the population ranging from 0.10 – 1.37.

Salticids represented a population in the range of 0.10 - 2.77 spiders. One week after transplanting, no salticids were found in the field. The population of the spiders built up gradually from the second week onwards during the vegetative stage of the crop and recorded 0.10, 0.30, 0.77, 0.57 and 0.43 spiders, two, three, four, five and six weeks after transplanting, respectively and were on par. In the early reproductive stage the population increased and almost a uniform population was observed in the field, 1.17 and 1.53 1.87 in the seventh and eighth weeks and the late reproductive stage recorded still higher number of salticids, 1.87, 2.03 and 2.27, nine, ten and eleven weeks after transplanting. Significantly high population of 2.77 salticids was observed in the maturity stage, twelve weeks after transplanting, followed by 1.90, 1.00, 0.43 and 0.33 spiders in the thirteenth, fourteenth, fifteenth and sixteenth weeks.

The population of lycosid spiders in rice field ranged from 0.07 - 1.50 spiders. During the vegetative stage the population of lycosids was significantly low, ranging from 0.07 - 0.67, from one to five weeks after transplanting and were on par. The population increased to 0.93 spiders at six weeks after transplanting. Almost a uniform population was observed through out the reproductive stage, ranging from 1.03 - 1.47 spiders at seven to eleven weeks after transplanting. The higher population observed in the reproductive stage was continued till the maturity stage too, the population recorded being 1.23 – 1.50, twelve, thirteen and fourteen weeks after transplanting, respectively. During the later stage of the crop the population recorded was 0.60 and 0.17 spiders at fifteen and sixteen weeks after transplanting, respectively and were on par.

Family Oxyopidae represented a population in the range of 0.10 - 2.27 spiders. In the vegetative stage the population of oxyopids built up gradually and the population being 0.10, 0.43, 0.60 and 0.73, one, two, three and four weeks after transplanting and were on par. The population increased to 1.30, 1.63 and 2.27 in the fifth, sixth and seventh weeks, respectively. Thereafter the population decreased to 1.47 during the eighth week and subsequently to 0.83 – 1.30 during the late reproductive stage. In the maturity stage very low population of oxyopids was observed, ranging between 0.10 - 0.40, during twelfth, thirteenth and fourteenth weeks, and were on par. In the last two weeks just before harvest, when the crop was at senescence, at fifteen and sixteen weeks no oxyopids were encountered in the field.

Thomisidae recorded the least number of spiders among the six major families, and the population ranged from 0.00 - 0.90. One week after transplanting no thomisids were found in the field. In the vegetative stage the population of thomisid spiders ranged between 0.07 - 0.40 and were on par. During the reproductive stage the population was fluctuating and ranged from 0.17 - 0.90 spiders and were on par. In the maturity stage significantly low population of thomisids was recorded ranging between 0.30 – 0.03 spiders and were on par.

Clubionidae, Linyphiidae, Agelenidae, Theridiidae and Miturgidae constituted the minor families and were less populated than the other families, and the population ranged between 0.10 - 1.23 spiders distributed over the different weeks. During the vegetative stage the population of spiders ranged from 0.10 - 0.57 and were on par. During the reproductive stage population of the minor families ranged between 0.43 – 1.23 spiders and were on par. In the maturity stage of the crop the other families were represented in very low numbers and the population ranged between 0.23 - 0.67, and were on par.

Pests, insect natural enemies and neutrals

The population of pests, insect natural enemies and neutrals in the rice fields of Kalliyoor panchayat during the Mundakan season is presented in Table 6. The mean population of hoppers (15.73) in rice fields was significantly higher as observed in the virippu season than that of the insect natural enemies (14.78), bugs (12.67) and the neutrals (6.17). The mean population of the other groups of pests (4.93) represented by coleopterans, dipterans, orthopterans, thrips etc. was on par with the lepidopteran pests (4.67).

The weekly distribution of pests, insect natural enemies and neutrals over the different crop growth stages ranged between 2.53 - 13.23. In the vegetative stage the mean population of insects recorded were 2.53, 4.50, 6.56 and 8.72 at one, two, three and four weeks after transplanting respectively, and the number built up significantly in the fifth and sixth weeks, the mean population being, 12.12 and 12.52. In the reproductive stage of the crop significantly high mean population of insects was recorded, 13.23 in the seventh week, followed by 12.74, 13.08, 12.23 and 11.80, eight, nine, ten and eleven weeks respectively, after transplanting. During the maturity stage the mean population of insects recorded was relatively high, 11.76, 10.77 and 10.07 in the twelfth, thirteenth and fourteenth weeks. At the end stage of the crop the mean population of insects declined to 8.28 and 6.22 insects, at fifteen and sixteen weeks after transplanting, just before the harvest of the crop.

Among the pests, hoppers were the dominant group among the different pests, with a population ranging from 1.43 - 26.23 over the different growth stages of the crop. In the early vegetative stage the population of hoppers was low, being 1.43, 6.60 and 11.40 on first, second and third weeks after transplanting. The hoppers recorded at four, five and six weeks after transplanting were 15.67, 21.17 and 22.20, respectively. In the early reproductive stage the hopper population was very high being 23.83 and 22.67, seven and eight weeks after transplanting and were on par. The highest population of 26.23 hoppers was recorded during the ninth week,

Table 6 Population of pests, insect natural enemies and neutrals in the rice fields of Kalliyoor panchayat during the Mundakan season

Insects	Weeks After Transplanting (number per ten sweeps)																Mean
	Vegetative stage						Reproductive stage					Maturity stage					
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Pests																	
Hoppers	1.43	6.60	11.40	15.67	21.17	22.20	23.83	22.67	26.23	19.80	18.60	17.67	14.27	12.10	10.50	7.47	15.73
Bugs	0.07	0.13	0.60	2.57	5.20	11.77	16.40	21.57	22.10	24.17	25.30	22.43	17.23	13.43	11.37	8.33	12.67
Lepidopterans	0.17	0.43	1.47	3.87	4.67	4.97	5.67	6.00	8.00	8.50	7.50	6.83	5.83	4.23	4.00	2.50	4.67
Others	7.67	9.13	7.83	2.17	1.93	1.93	1.90	2.33	3.30	6.83	1.90	1.90	4.90	10.77	6.23	8.13	4.93
Natural enemies	3.33	5.20	8.63	12.30	21.00	23.40	23.40	18.67	14.53	10.17	14.37	18.77	19.73	17.83	15.87	9.23	14.78
Neutrals	2.53	5.50	9.43	15.77	18.77	10.83	8.20	5.20	4.30	3.90	3.13	2.97	2.67	2.07	1.73	1.67	6.17
Mean	2.53	4.50	6.56	8.72	12.12	12.52	13.23	12.74	13.08	12.23	11.80	11.76	10.77	10.07	8.28	6.22	

C.D (0.05) Pests : (0.358)
C.D (0.05) Weeks : (0.585)
C.D (0.05) Treatments : (1.432)

followed by 19.80 and 18.60 on tenth and eleventh weeks respectively. In the early maturity stage the numbers of hoppers observed were 17.67 and 14.27, twelve and thirteen weeks after transplanting. The populations of hoppers were low during the late maturity stage and ranged in between 7.47 - 12.10 hoppers.

The population of bugs during Mundakan season ranged from 0.07 - 25.30. The population of bugs were significantly low during the vegetative stage, the population ranging from 0.07 -11.77 from the first to sixth weeks after transplanting. The population of the pest was high during the reproductive stage and recorded 16.40 and 21.57 in the seventh and eighth weeks. In the late reproductive stage the population built up rapidly, 22.10, 24.17 and 25.30 nine, ten and eleven weeks after transplanting. During the maturity stage, the population recorded was 22.43, 17.23, 13.43, 11.37 and 8.33 bugs, twelve, thirteen, fourteen, fifteen and sixteen weeks after transplanting.

Lepidopteran pests in the rice field during the crop growth period ranged from 0.17 - 8.50 per week. The population of lepidopterans was comparatively low in the early vegetative stage and ranged between 0.17-1.47, one, two and three weeks after transplanting. In the later half of the vegetative stage the population increased, 3.87, 4.67 and 4.97 in the fourth, fifth and sixth weeks and were on par. The reproductive stage of the crop recorded more number of lepidopteran pests, the population being 5.67, 6.00, 8.00, 8.50 and 7.50 seven, eight, nine, ten and eleven weeks after transplanting. During the maturity stage the population was comparatively low, 6.83, 5.83, 4.23, 4.00 and 2.50 lepidopterans at twelve, thirteen, fourteen, fifteen and sixteen weeks after transplanting, just before harvest of the crop.

The other pests collected in very few numbers constituted by dipterans, coleopterans, orthopterans and thrips and the population ranged between 1.90 - 10.77 during the different growth phases of the crop. The other group of pests was observed in more numbers during the vegetative stage and the maturity stage and the population ranged between 1.93 – 9.13 and 1.90 – 10.77, respectively. During the reproductive stage the population was lower and ranged from 1.90 – 6.83.

During the mundakan season the population of insect natural enemies ranged from 3.33 - 23.40. In the early vegetative stage the population of natural enemies recorded was 3.33, 5.20 and 8.63, one, two and three weeks after transplanting respectively, where as the late vegetative stage recorded very high number of the insect natural enemies. The population recorded during fourth and fifth weeks was 12.30 and 21.00, and significantly high population was recorded in the sixth and seventh week, 23.40 each. In the reproductive stage the population of insect natural enemies observed was low at eight, nine, ten and eleven weeks after transplanting, being 18.67, 14.53, 10.17 and 14.37. In the maturity stage, the natural enemy population was observed in higher numbers, 18.77, 19.73, 17.83 and 15.87, twelve, thirteen, fourteen and fifteen weeks after transplanting respectively. The population was significantly reduced to 9.23 in the sixteenth week, just before harvest.

The population of neutrals ranged between 1.67 - 18.77 in the mundakan season. As observed in the virippu season, the population of neutrals was more during the first half of the crop period, when compared to the later half. In the vegetative stage of the crop the population of neutrals ranged between 2.53 – 18.77. In the early vegetative stage, the population of neutrals built up gradually, and increased rapidly during the later half of the vegetative stage. During the reproductive stage the population of neutrals slowly declined and ranged from 3.13 – 8.20. In the maturity stage of the crop relatively lower population of neutrals were recorded when compared to the vegetative and reproductive stages, and the population ranged between 1.67 – 2.97 and were on par.

4.2.3 Correlation of Weather Parameters with the Population of Spiders

The population of spiders recorded from the rice fields during the Virippu and Mundakan seasons showed non – significant correlation with all the six weather parameters studied. The occurrence and abundance of the spiders in rice fields during the Virippu season was negatively correlated with morning RH (-0.351), after noon RH (-0.091) maximum temperature (-0.058), minimum temperature (-0.134), rainfall (-0.404) and number of rainy days (-0.204). During the Mundakan season, population of the spiders was positively correlated with evening RH (+0.094) and maximum temperature (+0.002) and was negatively correlated with morning RH (- 0.402) minimum temperature (- 0.348), rainfall (- 0.485) and the number of rainy days (- 0.495).

4. 3 PREDATORY EFFICIENCY

The prey preference and predatory potential of the ten dominant spiders *viz, T. mandibulata, T. maxillosa, O. javanus, P. viridana, P. pseudoannulata, A. anasuja, N. rumpfi, T. dimidiata, B. carli* and *T. projectus* in the rice ecosystem were worked out and the results are presented in Tables 7 to 14.

4.3.1 Prey Preference of Spiders in a Mixed Diet

The prey preference of the dominant spiders when provided with a mixed diet of prey expressed as the number of prey insect consumed per spider per day is presented in Tables 7 – 10.

4.3.1.1 Hoppers

In the rice fields nine hoppers were encountered during the study period and from them five major hoppers were selected for testing the predatory efficiency. Among the hopper prey tested, the spiders fed voraceously on the nymphs and adults of the hoppers *viz, N. lugens, Nephotettix spp., C. spectra, S. furcifera* and *R. dorsalis.*

The highest preference for the hoppers was recorded by *T. projectus* (1.36), which was followed by *T. mandibulata* (1.24), *P. viridana* (1.22), *A. anasuja* (1.15) and *P. pseudoannulata* (1.14), and were statistically on par in a mixed diet of hoppers (Table 7). Relatively lower preference was observed in the case of *T. maxillosa* (1.13), *T. dimidiata* (1.10), *O. javanus* (1.06), *N. rumpfi* (1.05) and *B. carli* (0.95) and were on par.

When the individual hopper prey were considered, the most preferred prey was adults of *Nephotettix spp.* (2.87), preference of which was significantly superior to that of other prey insects. The preference for the adult *N. lugens* (2.10) was on par with the adults of *C. spectra* (2.05). The adults of *S. furcifera* (0.89) and nymphs of *Nephotettix spp.* (0.86) and *N. lugens* (0.79) were equally preferred by the spiders. Adults of *R. dorsalis* (0.57), nymphs of *R. dorsalis* (0.45), nymphs of *C. spectra* (0.44) and *S. furcifera* nymphs (0.39) were relatively less preferred by the spiders.

The nymphs of *N. lugens* was mostly preferred by *P. pseudoannulata* (1.58), followed by *P. viridana* (1.38), *N. rumpfi* (1.38) and *O. javanus* (0.95) and were on par. *T. mandibulata, A. anasuja* , *T. dimidiata* and *T. projectus* equally preferred the prey consuming 0.56 each, which was on par with that of *T. maxillosa* and *B. carli* , with a preference of 0.17 each. Significantly higher preference for the adults of *N. lugens* was shown by *P. pseudoannulata* (2.97) with a superior consumption rate. Relatively higher preference was recorded for *P. viridana* (2.56), *T. projectus* (2.56) and *A. anasuja* (2.52) and were on par. The relative preference shown by *O. javanus* (1.97), *B. carli* (1.97), *T. dimidiata* (1.93), *T. mandibulata* (1.58), *N. rumpfi* (1.58) and *T. maxillosa* (1.38), were statistically on par.

Among the ten spiders, the highest preference for the nymphs of *Nephotettix spp.* was recorded for *T. maxillosa* (1.58) and *T. mandibulata* (1.32) and were on par in their preference. Relatively lower preference was shown by *P. viridana* , *N. rumpfi* and *T. projectus* (0.95 each), and the preference for the prey was on par with that of *O. javanus, P. pseudoannulata, A. anasuja, T. dimidiata* and *B. carli* (0.56). Significantly higher preference for the adults of *Nephotettix spp.* was shown by the tetragnathids , *T. maxillosa* (5.58) and *T. mandibulata* (5.18), as evidenced by the high rate of consumption. The relative preference recorded for *A. anasuja* and *T. dimidiata* was 3.17 each respectively, which was on par with *T. projectus* (2.97). The spiders *B. carli* , *P. viridana* and *P. pseudoannulata* consumed 2.35, 2.15 and

Table 7 Relative preference of major spiders in rice ecosystem for hoppers infesting rice in a mixed diet

Spiders	Prey consumed in one day										Mean
	N. lugens		*Nephotettix* spp.		*S. furcifera*		*C. spectra*		*R.. dorsalis*		
	Nymph	Adult	Nymph	Adult	Nymph	Adult	Nymph	Adult	Nymph	Adult	
T. mandibulata	0.56 (1.25)	1.58 (1.60)	1.32 (1.52)	5.18 (2.49)	0.36 (1.17)	1.18 (1.48)	0.56 (1.25)	0.72 (1.31)	0.36 (1.17)	0.56 (1.25)	1.24 (1.45)
T. maxillosa	0.17 (1.08)	1.38 (1.54)	1.58 (1.60)	5.58 (2.56)	0.56 (1.25)	0.56 (1.25)	0.36 (1.17)	0.36 (1.17)	0.17 (1.08)	0.56 (1.25)	1.13 (1.40)
A. anasuja	0.56 (1.25)	2.52 (1.88)	0.56 (1.25)	3.17 (2.04)	0 (1.00)	0.36 (1.17)	0.36 (1.17)	3.77 (2.18)	0 (1.00)	0.17 (1.08)	1.15 (1.40)
N. rumpfi	1.38 (1.54)	1.58 (1.60)	0.95 (1.39)	0.77 (1.33)	0.56 (1.25)	1.58 (1.60)	0.72 (1.31)	0.17 (1.08)	1.58 (1.60)	1.18 (1.48)	1.05 (1.42)
T. dimidiata	0.56 (1.25)	1.93 (1.71)	0.56 (1.25)	3.17 (2.04)	0.36 (1.17)	0.77 (1.33)	0.17 (1.08)	2.97 (1.99)	0.17 (1.08)	0.36 (1.17)	1.10 (1.41)
B. carli	0.17 (1.08)	1.97 (1.72)	0.56 (1.25)	2.35 (1.83)	0 (1.00)	0.56 (1.25)	0.17 (1.08)	2.97 (1.99)	0.36 (1.17)	0.36 (1.17)	0.95 (1.35)
P. pseudoannulata	1.58 (1.60)	2.97 (1.99)	0.56 (1.25)	1.97 (1.72)	0.36 (1.17)	0.77 (1.33)	0.77 (1.33)	1.38 (1.54)	0.36 (1.17)	0.72 (1.31)	1.14 (1.44)
O. javanus	0.95 (1.39)	1.97 (1.72)	0.56 (1.25)	1.38 (1.54)	0.77 (1.33)	1.13 (1.46)	0.77 (1.33)	1.58 (1.60)	0.77 (1.33)	0.72 (1.31)	1.06 (1.43)
P. viridana.	1.38 (1.54)	2.56 (1.89)	0.95 (1.39)	2.15 (1.78)	0.36 (1.17)	0.36 (1.17)	0.36 (1.17)	3.17 (2.04)	0.36 (1.17)	0.51 (1.23)	1.22 (1.46)
T. projectus	0.56 (1.25)	2.56 (1.89)	0.95 (1.39)	2.97 (1.99)	0.56 (1.25)	1.58 (1.60)	0.17 (1.08)	3.39 (2.09)	0.36 (1.17)	0.51 (1.23)	1.36 (1.49)
Mean	0.79 (1.32)	2.10 (1.76)	0.86 (1.36)	2.87 (1.93)	0.39 (1.17)	0.89 (1.36)	0.44 (1.20)	2.05 (1.70)	0.45 (1.19)	0.57 (1.25)	

Figures in parentheses are $\sqrt{x+1}$ transformed values
C.D (0.05) Spiders : (0.053)
C.D (0.05) Prey : (0.081)
C.D (0.05) Treatments: (0.255)

1.97 *Nephotettix spp.* adults respectively and were on par. *O. javanus* (1.38) and *N. rumpfi* (0.77) recorded the least preference for the adult *Nephotettix spp.* when compared to the other spiders.

With the exception of *A. anasuja* and *B. carli*, which did not prey on *S. furcifera,* all the other spiders consumed the nymphs of the hopper in between a range of 0.36 – 0.77 and were on par. *N. rumpfi* and *T. projectus* equally recorded the highest rate of preference for the adults of *S. furcifera*, 1.58 each respectively, which were on par with *T. mandibulata* (1.18) and *O. javanus* (1.13). The rate of predation recorded for *P. pseudoannulata* and *T. dimidiata* was 0.77 each, was on par with that of *T. maxillosa* and *B. carli*, 0.56 each and *P. viridana* and *A. anasuja*, 0.36 each.

The relative preference recorded for the nymphs of *C. spectra* was more for *P. pseudoannulata* and *O. javanus* , each consuming 0.77 respectively, followed by *N. rumpfi* (0.72) and *T. mandibulata* (0.56) and *T. maxillosa, A. anasuja* and *P. viridana* which recorded 0.36 prey each and *T. dimidiata* , *B. carli* and *T. projectus* , 0.17 hoppers each and were statistically on par. *A. anasuja* (3.77) was found to be superior to other spiders in its preference for the adults of *C. spectra,* which was on par with *T. projectus* (3.39), *P. viridana* (3.17), *T. dimidiata* (2.97) and *B. carli* (2.97). The relative preference recorded for *O. javanus* (1.58) was on par with *P. pseudoannulata* (1.38). *T. mandibulata, T. maxillosa* and *N. rumpfi* recorded the least preference for the adult *C. spectra, i.e.,* 0.72, 0.36 and 0.17 hoppers, respectively and were on par.

N. rumpfi (1.58) recorded significantly higher preference for the nymphs of *R. dorsalis,* as evidenced by the rate of feeding. The green lynx spider, *O. javanus* (0.77) recorded relatively higher preference when compared to *T. mandibulata, P. viridana* , *P. pseudoannulata* , *B. carli* and *T. projectus* which consumed 0.36 each, and *T. maxillosa* and *T. dimidiata* recorded 0.17 each and were on par. The orb weaver, *A. anasuja* did not prefer nymphs of *R. dorsalis.* When the adults of *R. dorsalis* was considered, *N. rumpfi* (1.18) was found to be superior as proved by the rate of preference. The relative preference of *O. javanus* and *P. pseudoannulata* being

0.72 each was on par with *T. mandibulata* and *T. maxillosa* (0.56 each), and *P. viridana* and *T. projectus* (0.51 each), and *T. dimidiata* and *B. carli* (0.36 each) and *A. anasuja* (0.17).

Among the nymphs and adults of the five hoppers tested, the most preferred hopper for *T. mandibulata* , *T. maxillosa* and *T. dimidiata* were adults of *Nephotettix spp.*. The araneid, *A. anasuja*, *B. carli* and *T. projectus* showed maximum preference for adult *C. spectra*. *N. rumpfi* equally preferred the adults of *N. lugens* and *S. furcifera* and the nymphs of *R. dorsalis*. The green lynx spider, *O. javanus* and the lycosid, *P. pseudoannulata* mostly preferred the adult *N. lugens*. *P. viridana* recorded its highest preference for the *C. spectra* adults.

4.3.1.2 Bugs

Out of the seven bugs recorded from the paddy fields, three commonly occurring and predominant bugs infesting rice were selected. Among the three bugs tested the spiders fed on the nymphs of all the bugs *viz*, *L. acuta*, *Scotinophara* sp. , and *M. histrio* and some spiders fed on the adults of the three bugs tested.

The relative prey preference of spiders on bugs infesting rice is presented in Table 8. Among the different spiders tested *T. mandibulata* (0.70) showed the highest preference, followed, by *P. viridana* (0.66) and *A. anasuja* (0.65) and were on par in their preference for the bugs. *T. projectus* (0.54), *O.javanus* (0.53) and *T. maxillosa* (0.42) were superior to other spiders in their preference for these pests. The relative preference exhibited by *T. dimidiata* and *P. pseudoannulata* were, 0.34 and 0.25 , and were on par. The lowest preference was shown by *B. carli* (0.15) and *N. rumpfi* (0.09).

Among the individual bug pests, the most preferred prey was nymphs of *L. acuta*, with a mean preference of 1.03, which was on par with the preference for the nymphs of *M. histrio* (0.85). The nymphs of *Scotinophara sp.* (0.61) were more preferred when compared to adults of *M. histrio* (0.07), which was on par with adults of *L. acuta* (0.03). The adults of *Scotinophara* sp. was not at all consumed.

Table 8 Relative preference of major spiders in rice ecosystem for the bugs infesting rice in a mixed diet

Spiders	Prey consumed in one day						Mean
	L. acuta		*Scotinophara* spp.		*M. histrio*		
	Nymph	Adult	Nymph	Adult	Nymph	Adult	
T. mandibulata	2.38 (1.84)	0 (1.00)	0.72 (1.31)	0 (1.00)	0.95 (1.39)	0.17 (1.08)	0.70 (1.27)
T. maxillosa	1.58 (1.60)	0 (1.00)	0.36 (1.17)	0 (1.00)	0.56 (1.25)	0 (1.00)	0.42 (1.17)
A. anasuja	0.89 (1.38)	0.17 (1.08)	0.95 (1.39)	0 (1.00)	1.54 (1.59)	0.36 (1.17)	0.65 (1.27)
N. rumpfi	0 (1.00)	0 (1.00)	0.17 (1.08)	0 (1.00)	0.36 (1.17)	0 (1.00)	0.09 (1. 04)
T. dimidiata	0.36 (1.17)	0 (1.00)	0.72 (1.31)	0 (1.00)	0.96 (1.39)	0 (1.00)	0.34 (1.15)
B. carli	0.36 (1.17)	0 (1.00)	0.36 (1.17)	0 (1.00)	0.17 (1.08)	0 (1.00)	0.15 (1. 07)
P. pseudoannulata	0.56 (1.25)	0 (1.00)	0.56 (1.25)	0 (1.00)	0.36 (1.17)	0 (1.00)	0.25 (1.11)
O. javanus	1.54 (1.59)	0 (1.00)	0.72 (1.31)	0 (1.00)	0.89 (1.38)	0 (1.00)	0.53 (1.21)
P. viridana	1.93 (1.71)	0.17 (1.08)	0.56 (1.25)	0 (1.00)	1.13 (1.46)	0.17 (1.08)	0.66 (1.26)
T. projectus	0.72 (1.31)	0 (1.00)	0.96 (1.39)	0 (1.00)	1.58 (1.60)	0 (1.00)	0.54 (1.22)
Mean	1.03 (1.40)	0.03 (1.02)	0.61 (1.26)	0 (1.00)	0.85 (1.35)	0.07 (1.03)	

Figures in parentheses are $\sqrt{x+1}$ transformed values
C.D (0.05) Spiders : (0.053)
C.D (0.05) Prey : (0.081)
C.D (0.05) Treatments: (0.255)

The highest preference for the nymphs of *L. acuta* was shown by *T mandibulata* (2.38), followed by *P. viridana* (1.93), *T. maxillosa* (1.58) and *O. javanus* (1.54) and were on par in their preference. The rate of consumption by the orb weaver, *A. anasuja* was 0.89, which was on par with *T. projectus* (0.72), *P. pseudoannulata* (0.56), *T. dimidiata* (0.36) and *B. carli* (0.36). *N. rumpfi* did not prefer the nymphs of *L. acuta.* The adult *L. acuta* was preferred by only the araenid, *A. anasuja* and the green lynx spider, *P. viridana* preying on 0.17 prey each. *T. dimidiata* and *T. projectus* killed the adult bugs but did not consumed it. The other spiders neither killed nor consumed the prey.

The nymphs of *Scotinophara* sp. were preferred by all the spiders. Significantly higher preference was exhibited by *T. projectus* (0.96), followed by *A. anasuja* (0.95). The spiders *T. mandibulata* , *O. javanus* and *T. dimidiata* , equally preferred the prey, 0.72 each, which was on par with *P. pseudoannulata* and *P. viridana*, 0.56 each, and *T. maxillosa* and *B. carli* , 0.36 each and *N. rumpfi* (0.17). The adults of *Scotinophara sp.* was not preferred by the spiders.

T. projectus (1.58) was found to be a superior predator of *M. histrio* nymphs, followed by *A. anasuja* (1.54), *P. viridana* (1.13), *T. dimidiata* (0.96), *T. mandibulata* (0.95) and *O. javanus* (0.89) and were statistically on par in their preference. The relative preference recorded for *T. maxillosa* (0.56) was on par with *N. rumpfi* and *P. pseudoannulata*, 0.36 each and *B. carli* (0.17). The adults of *M. histrio* was preferred by only three spiders, *viz, A. anasuja* (0.36), *P. viridana* (0.17) and *T. mandibulata* (0.17) and the rate of preference was found to be statistically on par. The other spiders did not prefer the adults of *M. histrio.*

The most preferred bug pest of *T. mandibulata* , *T. maxillosa, O. javanus* and *P. viridana* were the nymphs of *L. acuta*, where as, *P. pseudoannulata* and *B. carli* preferred the nymphs of *L. acuta* and *Scotinophara* sp. equally. *A. anasuja, N. rumpfi, T. dimidiata* and *T. projectus* preferred the nymphs of *M. histrio.*

4.3.1.3 Lepidopterans

In the rice fields nine lepidopterans were encountered during the study period. Among them four most common lepidopteran prey insects were tested to find out the relative preference for the spiders. The spiders fed more on the adults of *S. incertulas* and adults and larvae of *C. medinalis*, *P. stagnalis* and *M. leda-ismene*. The hairy caterpillars and large sized, last instar caterpillars were totally left unfed, whereas the small and soft bodied first instar caterpillars were fed. The medium sized moths were most preferred for feeding.

The results on the prey preference on lepidopteran pests is given in the Table 9. When the lepidopteran pests were given as a mixed diet to the spiders, *A. anasuja* showed significantly higher preference (2.54) for the lepidopterans, followed by *T. projectus* (2.14) and *T. dimidiata* (1.88) which were on par in their preference. *P. pseudoannulata* and *P. viridana* preferred 1.70 and 1.52 lepidopteran prey respectively and were on par in their feeding and were superior to *B. carli* (1.37), *T. mandibulata* (1.13), *O. javanus* (0.98) and *T. maxillosa* (0.93). The least preference for lepidopteran pests was shown by *N. rumpfi* (0.86).

Considering the lepidopteran prey insects, the most preferred prey was moths of *C. medinalis* (3.12), followed by moths of *P. stagnalis* (2.55) and moths of *S. incertulas* (2.39), which were on par. The larvae of *C. medinalis* (1.01) was less preferred. The *P. stagnalis* larvae (0.71) and the adults of *M. leda-ismene* (0.53) were also less preferred and were on par. The least preferred prey was the larvae of *M. leda-ismene* (0.23).

A. anasuja was found to be a superior predator of *S. incertulas* adults, (4.55) followed by *T. projectus* (3.77) which were on par. The relative preference for *S. incertulas* adults by *T. dimidiata* (3.15) and *B. carli* (2.58) were on par. Relatively low preference was shown by *P. viridana* (1.97), P. *pseudoannulata* (1.75), *T. mandibulata* (1.58), *T. maxillosa* (1.58), *N. rumpfi* (1.54) and *O. javanus* (1.38) and were on par.

Table 9 Relative preference of major spiders in rice ecosystem for lepidopteran pests of rice in a mixed diet

Spiders	Prey consumed in one day							Mean
	S. incertulas	*C. medinalis*		*P. stagnalis*		*M. leda-ismene*		
	Adult	Larvae	Adult	Larvae	Adult	Larvae	Adult	
T. mandibulata	1.58 (1.60)	0 (1.00)	3.39 (2.09)	0 (1.00)	2.58 (1.89)	0 (1.00)	0.36 (1.17)	1.13 (1.39)
T. maxillosa	1.58 (1.60)	0 (1.00)	3.19 (2.05)	0 (1.00)	1.58 (1.60)	0 (1.00)	0.17 (1.08)	0.93 (1.33)
A. anasuja	4.55 (2.36)	0.95 (1.39)	5.58 (2.56)	0.36 (1.17)	3.59 (2.14)	0 (1.00)	2.76 (1.94)	2.54 (1.79)
N. rumpfi	1.54 (1.59)	1.54 (1.59)	1.58 (1.60)	0 (1.00)	1.18 (1.48)	0.17 (1.08)	0 (1.00)	0.86 (1.33)
T. dimidiata	3.15 (2.04)	1.75 (1. 66)	2.76 (1.94)	1.38 (1.54)	3.17 (2.04)	0.36 (1.1 7)	0.56 (1.25)	1.88 (1. 66)
B. carli	2.58 (1.89)	1.18 (1.48)	2.76 (1. 94)	0.56 (1.25)	2.32 (1.82)	0.17 (1.08)	0 (1.00)	1.37 (1.49)
P. pseudoannulata	1.75 (1.66)	1.58 (1.60)	2.93 (1.98)	1.38 (1.54)	3.34 (2.08)	0.72 (1.31)	0.17 (1.08)	1.70 (1.61)
O. javanus	1.38 (1.54)	0.72 (1.31)	2.15 (1. 78)	0.89 (1.38)	1.38 (1.54)	0.36 (1.17)	0 (1.00)	0.98 (1.39)
P. viridana	1.97 (1.72)	0.95 (1.39)	2.76 (1.94)	1.13 (1.46)	2.76 (1.94)	0.51 (1.23)	0.56 (1.25)	1.52 (1.56)
T. projectus	3.77 (2.18)	1.38 (1.54)	4.14 (2.27)	1.38 (1.54)	3.59 (2.14)	0 (1.00)	0.72 (1.31)	2.14 (1.71)
Mean	2.39 (1.82)	1.01 (1.40)	3.12 (2.02)	0.71 (1.29)	2.55 (1.87)	0.23 (1.10)	0.53 (1.21)	

Figures in parentheses are $\sqrt{x+1}$ transformed values
C.D (0.05) Spiders : (0.053)
C.D (0.05) Prey : (0.081)
C.D (0.05) Treatments: (0.255)

The larvae of *C. medinalis* was preferred more by *T. dimidiata* (1.75), followed by *P. pseudoannulata* (1.58) and *N. rumpfi* (1.54) and were statistically on par in their preference. Relatively lower preference was shown by the spiders, *T. projectus*, *B. carli*, *A. anasuja*, *P. viridana* and *O. javanus* which recorded 1.38, 1.18, 0.95, 0.95 and 0.72, respectively. *T. mandibulata* and *T. maxillosa* did not prefer the larvae of *C. medinalis* in a mixed diet. The orb web weaver, *A. anasuja* showed significantly higher preference for adults of *C. medinalis* (5.58) as evidenced by its feeding, followed by *T. projectus* (4.14), which differed significantly with the preference of other spiders. The rate of consumption for *T. mandibulata* was 3.39, which was on par with *T. maxillosa* (3.19), *P. pseudoannulata* (2.93) and *P. viridana*, *T. dimidiata* and *B. carli* which recorded 2.76 each. Very low feeding was observed for *O. javanus* (2.15) and *N. rumpfi* (1.58) and were on par.

The larvae of *P. stagnalis* was equally preferred by *P. pseudoannulata*, *T. dimidiata* and *T. projectus*, the mean number consumed being 1.38, and were on par with *P. viridana* (1.13) in their preference. The rate of consumption by *O. javanus* was 0.89, which was on par with that of *B. carli* (0.56) and *A. anasuja* (0.36). *T. mandibulata*, *T. maxillosa* and *N. rumpfi* did not prefer the larvae of *P. stagnalis*. *A. anasuja* was found to be a superior predator of adults of *P. stagnalis* (3.59), which was followed by *T. projectus* (3.59) and *P. pseudoannulata* (3.34) and were on par in their preference for adults of *P. stagnalis*. Relatively lower preference was recorded by *T. dimidiata* , *P. viridana*, *T. mandibulata* and *B. carli* which were 3.17, 2.76, 2.58 and 2.32 respectively and were on par. *T. maxillosa* (1.58), *O. javanus* (1.38) and *N. rumpfi* (1.18) were found to be poor consumers of *P. stagnalis* adults and were on par.

P. pseudoannulata preferred the *M. leda-ismene* larvae more (0.72), when compared to *P. viridana* (0.51), *O. javanus* (0.36), *T. dimidiata* (0.36), *N. rumpfi* (0.17), and *B. carli* (0.17), and were on par. But *T. mandibulata*, *T. maxillosa*, *A. anasuja* and *T. projectus* did not prefer the larvae. Significantly higher preference was exhibited by *A. anasuja* (2.76) for the adults of *M. leda-ismene* as proved by its higher rate of consumption, when compared to other spiders. Relatively lower preference was shown by *T. projectus, P. viridana* , *T. dimidiata* , *T. mandibulata* , *T. maxillosa* and *P. pseudoannulata,* and the mean consumption being 0.72, 0.56, 0.56, 0.36, 0.17 and 0.17 respectively and were on par. *O. javanus, N. rumpfi* and *B. carli* showed pure negligence for the prey.

The most preferred prey of *T. mandibulata, T. maxillosa, A. anasuja* , *N. rumpfi* , *B. carli* , *T. projectus* and *O. javanus* were adults of *C. medinalis,* where as *P. viridana* equally preferred *C. medinalis* and *P. stagnalis* adults. *P. pseudoannulata* and *T. dimidiata* preferred mainly *P. stagnalis* adults as evidenced by its preference from among the mixed diet.

4.3.1.4 Grass hoppers and Beetles

Out of the ten spiders tested to evaluate the prey range among grass hoppers and beetle pests of rice, four spiders *viz., A. anasuja, P. viridana, T. dimidiata* and *T. projectus* readily consumed both group of pests. Among the five orthopteran pests collected from the survey, two common grass hoppers were tested to evaluate the predatory efficiency. The spiders fed on the adults and nymphs of *O. chinensis* and nymphs of *C. pallidus.* From the rice fields eight coleopteran pests were collected and four most commonly seen beetles were selected for studying the relative preference. Among the coleopteran pests, the spiders consumed adults of *L. pygmaea, H. cyanea, O. affinis* and *D. armigera.*

Among the four spiders, *A. anasuja* (1.38) recorded significantly higher preference for the grass hoppers, which was followed by *T. projectus* (0.85), which was on par with *T dimidiata* and *P. viridana* which recorded 0.57 each.

Among the different grass hoppers, the most preferred was nymphs of *O. chinensis* (1.32), which was followed by the nymphs of *C. pallidus* (0.87) and the least preferred among the three was the adults of *O. chinensis* (0.34).

A. anasuja (1.78) recorded significantly higher preference for the nymphs of *O. chinensis*. The relative preference recorded for *T. projectus* (1.38) and *P. viridana* (1.18) was on par with *T. dimidiata* (0.95). The adults of *O. chinensis* were preferred by *A. anasuja* (1.18) and *P .viridana* (0.17) and were statistically on par in their rate of preference. *T. dimidiata* and *T. projectus* did not show any preference.

The nymphs of *C. pallidus* was equally preferred by *A. anasuja* and *T. projectus* as evidenced by their higher rate of consumption, *i.e.,* 1.18 each, where as relatively lower preference was recorded for *T. dimidiata* (0.77) which was on par with that of *P. viridana* (0.36).

The most preferred orthopteran prey for all the four spiders tested *viz.*, *A. anasuja*, *P. viridana* , *T. dimidiata* and *T. projectus* was nymphs of *O. chinensis* .

Out of the four spiders, *A. anasuja* (1.41) recorded the highest preference for the beetles, which was significantly higher followed by *T. dimidiata* (1.07), *T. projectus* (1.00) and *P. viridana* (0.87) and were on par.

The most preferred beetle was adults of *L. pygmaea* (1.47) which was significantly higher. The adult *D. armigera* (1.11) was preferred more than adults of *O. affinis* (1.02) and adults of *H. cyanea* (0.76) and were on par.

T. dimidiata (1.97) recorded maximum preference for adults of *L. pygmaea*, which was on par with *T. projectus* (1.75) and *P. viridana* (1.58). The least preference for the pest was shown by *A. anasuja* (0.56).

The *H. cyanea* adults were preferred by all the four spiders. Relatively higher preference was exhibited by *T. dimidiata* (1.18), which was on par with *A. anasuja* (0.95). The relative preference recorded for *T. projectus* (0.72) and *P. viridana* were 0.72 and 0.17, respectively.

Table 10 Relative preference of major spiders in rice ecosystem for orthopteran and coleopteran pests of rice in a mixed diet

Spiders	Prey consumed in one day								Mean
	O. chinensis		*C. pallidus*	Mean	*L. pygmaea*	*H. cyanea*	*O. affinis*	*D. armigera*	
	Nymph	Adult	Nymph		Adult	Adult	Adult	Adult	
A. anasuja	1.78 (1.67)	1.18 (1.48)	1.18 (1.48)	1.38 (1.54)	0.56 (1.25)	0.95 (1.40)	1.97 (1.72)	2.15 (1.78)	1.41 (1.54)
P. viridana	1.18 (1.48)	0.17 (1.08)	0.36 (1.17)	0.57 (1.24)	1.58 (1.60)	0.17 (1.08)	1.18 (1.48)	0.56 (1.25)	0.87 (1.35)
T. dimidiata	0.95 (1.39)	0 (1.00)	0.77 (1.33)	0.57 (1.24)	1.97 (1.72)	1.18 (1.48)	0.36 (1.17)	0.77 (1.33)	1.07 (1.42)
T. projectus	1.38 (1.54)	0 (1.00)	1.18 (1.48)	0.85 (1.34)	1.75 (1.66)	0.72 (1.31)	0.56 (1.25)	0.95 (1.40)	1.00 (1.40)
Mean	1.32 (1.52)	0.34 (1. 14)	0.87 (1.36)		1.47 (1.56)	0.76 (1.32)	1.02 (1.40)	1.11 (1.44)	
C.D (0.05)	Spiders : (0.120) Prey : (0.104) Treatments : (0.207)				Spiders : (0.140) Prey : (0.140) Treatments : (0.280)				

Figures in parentheses are $\sqrt{x+1}$ transformed values

A. anasuja (1.97) recorded significantly higher preference for *O. affinis* followed by *P. viridana* (1.18) and were on par. *T. projectus* (0.56) recorded a lower preference, which was on par with *T. dimidiata* (0.36).

A. anasuja (2.15), was found to be superior for its preference to *D. armigera*. Relatively lower preference was recorded for *T. projectus* (0.95) which was on par with that of *T. dimidiata* (0.77) and *P. viridana* (0.56).

The most preferred coleopteran prey for *A. anasuja* was *D. armigera*. *P. viridana*, *T. dimidiata* and *T. projectus* recorded its maximum preference for *L. pygmaea*.

4.3.2 Predatory Potential

The feeding potential of the spiders expressed as the mean number of each prey insect consumed by each spider per day is presented in Tables 11 – 14.

4.3.2.1 Hoppers

The predatory potential of *T. mandibulata* (5.68) on the nymphs of *N. lugens* was significantly higher when compared with the rate of predation of other spiders. The predatory potential of *T. projectus* (5.31) was on par with *P. pseudoannulata* (5.19) and *T. maxillosa* (4.85). The rate of consumption of *O. javanus* was 4.08, which was on par with *T. dimidiata* (3.74). The feeding efficiency of *B. carli* and *P. viridana* were 3.22 and 1.74 respectively. *N. rumpfi* (1.48) and *A. anasuja* (1.42) consumed the least number of prey and were on par in their feeding potential.

A. anasuja was found to be a superior predator of the adult *N. lugens*, as evidenced by the significantly high rate of predation of 14.88 hoppers, followed by *P. viridana* (14.00) and *T. mandibulata* (10.94) which showed significant difference in their rate of consumption. The spiders *T. dimidiata, P. pseudoannulata, T. projectus* and *T. maxillosa* recorded a moderately higher rate of consumption being 9.68, 9.63, 9.57 and 9.40 respectively and were on par. The feeding potential of *O. javanus* was 8.91 and was on par with that of *B. carli* (8.68). The lowest rate of feeding was recorded for *N. rumpfi* (2.76).

The tetragnathid spiders, *T. mandibulata* (7.96) and *T maxillosa* (6.36) were found to be superior to other spiders, in the rate of feeding on nymphs of *Nephotettix* spp. and showed significant difference when compared to the other spiders. Relatively higher value was recorded for, *P. pseudoannulata, T. projectus* and *O. javanus,* the predation being 6.22, 5.77 and 5.76. The rate of consumption for *T. dimidiata* was 4.88 followed by *P. viridana* (4.12). *N. rumpfi* recorded a lower value of predation, 3.70 which was on par with *A. anasuja* (3.64). *B. carli,* with a feeding potential of 2.04, least preferred the hoppers.

As evidenced by the heavy predation on the adult *Nephotettix spp.*, *P. viridana* was superior to other spiders with significantly higher feeding potential of 16.11 hoppers. Moderately higher rate of predation was recorded for *A. anasuja* (15.14) which was statistically on par with that of *T. maxillosa* (14.34). *T. mandibulata* consumed 13.34 hoppers. The feeding potential of *O. javanus* (10.31), was on par with that of *P. pseudoannulata* (10.17) and *T. projectus* (9.71), and were on par. Relatively lower consumption was observed for *T. dimidiata* (8.94), *B. carli* (6.53) and *N. rumpfi* (1.74).

T. dimidiata (4.17) recorded the highest rate of predation on *S. furcifera* nymphs, which was on par with the feeding potential of *N. rumpfi* (3.93). The feeding of *P. viridana* (3.00) was on par with that of *T. mandibulata* (2.79). The rate of consumption of *O. javanus* and *T. projectus* were 2.48 and 2.31 respectively and were on par. *P. pseudoannulata* recorded a feeding rate of 1.60, followed by *T. maxillosa* (1.46) which was on par with that of *A. anasuja* (1.25). *B. carli* (0.85) recorded the least rate of consumption when compared to other spiders.

The predatory potential of *A. anasuja, P. viridana* and *T. projectus* on the adult *S. furcifera* were 10.97, 9.65 and 8.88 hoppers per spider respectively and was superior to other spiders and differed significantly, as proved by their consumption. The spiders *T. dimidiata* and *O. javanus* recorded relatively higher feeding potential of 7.17 and 6.97 respectively and were on par. The feeding potential of *P. pseudoannulata*

Table-11 Predatory potential of major spiders in rice ecosystem on the hoppers infesting rice

Spiders	Prey consumed in one day									
	N. lugens		*Nephotettix* spp.		*S. furcifera*		*C. spectra*		*R. dorsalis*	
	Nymph	Adult	Nymph	Adult	Nymph	Adult	Nymph	Adult	Nymph	Adult
T. mandibulata	5.68 (2.58)	10.94 (3.46)	7.96 (3.00)	13.34 (3.79)	2.79 (1.95)	5.11 (2.47)	0.84 (1.35)	2.34 (1.83)	1.16 (1.47)	5.77 (2.60)
T. maxillosa	4.85 (2.42)	9.40 (3.22)	6.36 (2.71)	14.34 (3.92)	1.46 (1.57)	4.00 (2.24)	0.62 (1.27)	2.57 (1.89)	1.51 (1.58)	3.97 (2.23)
A. anasuja	1.42 (1.55)	14.88 (3.99)	3.64 (2.15)	15.14 (4.02)	1.25 (1.50)	10.97 (3.46)	2.80 (1.95)	9.91 (3.30)	0.64 (1.28)	4.20 (2.28)
V. rumpfi	1.48 (1.58)	2.76 (1.94)	3.70 (2. 17)	1.74 (1.65)	3.93 (2.22)	2.16 (1.78)	1.05 (1.43)	0 (1.00)	3.33 (2.08)	1.93 (1.71)
T. dimidiata	3.74 (2.18)	9.68 (3.27)	4.88 (2.43)	8.94 (3.15)	4.17 (2.27)	7.17 (2.86)	0.40 (1.18)	7.14 (2.85)	1.25 (1.50)	4.94 (2.44)
B. carli	3.22 (2.05)	8.68 (3.11)	2.04 (1.74)	6.53 (2.74)	0.85 (1.36)	4.17 (2.27)	3.19 (2.05)	1.51 (1.59)	2.07 (1.75)	1.54 (1.59)
P. pseudoannulata	5.19 (2.49)	9.63 (3.26)	6.22 (2.69)	10.17 (3.34)	1.60 (1.61)	5.93 (2.63)	1.31 (1.52)	4.08 (2.25)	1.68 (1.64)	7.17 (2.86)
O. javanus	4.08 (2.25)	8.91 (3.15)	5.76 (2.60)	10.31 (3.36)	2.48 (1.87)	6.97 (2.82)	1.48 (1.58)	4.20 (2.28)	2.09 (1.76)	6.08 (2.66)
P. viridana	1.74 (1.66)	14.00 (3.87)	4.12 (2.26)	16.11 (4.14)	3.00 (2.00)	9.65 (3.26)	1.48 (1.58)	8.20 (3.03)	0.57 (1.25)	3.00 (2.00)
T. projectus	5.31 (2.51)	9.57 (3.25)	5.77 (2.60)	9.71 (3.27)	2.31 (1.82)	8.88 (3.14)	1.01 (1.42)	8.05 (3.01)	2.22 (1.79)	6.14 (2.67)

Figures in parentheses are $\sqrt{x+1}$ transformed values
C.D (0.05) Treatments: (0.096)

and *T. mandibulata* were 5.93 and 5.11 respectively. The rate of consumption by *B. carli* (4.17) was on par with *T. maxillosa* (4.00). The least preference was shown by *N.rumpfi*, with a predatory potential of 2.16 adult *S. furcifera*.

The nymphs of *C. spectra* was consumed more by *B. carli* and *A. anasuja*, with a predatory potential of 3.19 and 2.80 hoppers per spider and were on par in there rate of consumption. *O. javanus*, *P. viridana* and *P. pseudoannulata* consumed 1.48, 1.48 and 1.31 hoppers, respectively. Relatively lower rate of feeding was observed for *N. rumpfi* (1.05), *T. projectus* (1.01) and *T. mandibulata* (0.84). The lowest feeding potential on the nymphs of *C. spectra* was exhibited by *T. maxillosa* (0.62), which was on par with that of *T. dimidiata* (0.40).

A. anasuja (9.91) was found to be the superior predator of adults of *C. spectra* as proved by the heavy rate of consumption when compared to the other spiders. *P. viridana* and *T. projectus* recorded relatively higher rate of consumption, being 8.20 and 8.05, respectively and were on par. *T. dimidiata* consumed 7.14 hoppers. The predatory potential of *O. javanus* (4.20) was on par with that of *P. pseudoannulata* (4.08). The rate of consumption on the adults of *C. spectra* by the tetragnathids were 2.57 and 2.34 by *T. maxillosa* and *T. mandibulata,* respectively and were on par. Relatively low feeding potential was observed for *B. carli* (1.51). *N. rumpfi* did not prefer the prey.

When the nymphs of *R. dorsalis* was supplied, *N. rumpfi* (3.33) showed superior rate of feeding, which significantly differed from among the other spiders. The rate of consumption by the spiders *T. projectus*, *O. javanus* and *B. carli* were 2.22, 2.09 and 2.07, respectively and were on par. The feeding rate of *P. pseudoannulata* (1.68) was on par with *T. maxillosa* (1.16). Relatively lower feeding was observed for *T. dimidiata* (1.25) which was on par with that of *T. mandibulata* (1.16). The lowest predatory potential was recorded by *A. anasuja* (0.64) which was on par with *P. viridana* (0.57) in the rate of predation.

The adult *R. dorsalis* was more consumed by *P. pseudoannulata* (7.17) as evidenced by its superior rate of feeding and showed significant difference, with the other spiders' rate of consumption. The spiders *T. projectus* , *O. javanus* and *T. mandibulata* recorded 6.14, 6.08 and 5.77, respectively and were on par. The salticid *T. dimidiata* consumed 4.94 hoppers. *A. anasuja* recorded a feeding rate of 4.20 which was on par with *T. maxillosa* (3.97). Relatively lower consumption was observed in the case of *P. viridana* (3.00), *N. rumpfi* (1.93) and *B. carli* (1.54), which differed significantly in their feeding potential.

4.3.2.2 Bugs

Among the ten spiders, the superior predator of the nymphs of *L. acuta* was the araneid, *A. anasuja* as evidenced by the heavy rate of predation for the pest, *i.e.,* 4.20 nymphs per spider, which was significantly higher, followed by *P. viridana* (3.25) and *T. mandibulata* (2.45) which differed significantly in their predatory potential for the nymphs of *L. acuta* when compared to the other spiders. The rate of feeding by *T. maxillosa* (1.57) was on par with that of *T. dimidiata* (1.40). Relatively lower rate of consumption was recorded for *O. javanus* and *P. pseudoannulata*, the feeding potential being 0.71 and 0.59 respectively. The lowest rate of predation was observed for *B. carli* (0.33), which was on par with *T. projectus* (0.39). *N. rumpfi* did not consume the prey.

A. anasuja (2.34) was a superior predator of the *Scotinophara* sp. nymphs, with a significantly high rate of predation. The predatory potential on the prey recorded by *T. dimidiata* and *T. projectus* was 2.14 and 1.93 respectively and were on par. *O. javanus, T. mandibulata* and *T. maxillosa* recorded a feeding potential of 1.80, 1.71 and 1.46 respectively and were on par. Relatively lower predation was recorded for *P. viridana* (0.71), *P. pseudoannulata* (0.71), *B. carli* (0.51) and *N. rumpfi* (0.50) and were on par.

Table 12 Predatory potential of major spiders in rice ecosystem on the bugs infesting rice

Spiders	Prey consumed in one day		
	L. acuta	*Scotinophara spp.*	*M. histrio*
	Nymph	Nymph	Nymph
T. mandibulata	2.45 (1.86)	1.71 (1.64)	2.17 (1.78)
T. maxillosa	1.57 (1.60)	1.46 (1.57)	1.65 (1.63)
A. anasuja	4.20 (2.28)	2.34 (1.83)	3.06 (2.01)
N. rumpfi	0 (1.00)	0.50 (1.23)	1.25 (1.50)
T. dimidiata	1.40 (1.55)	2.14 (1.77)	0.87 (1.37)
B. carli	0.33 (1.15)	0.51 (1.23)	1.46 (1.57)
P. pseudoannulata	0.59 (1.26)	0.71 (1.31)	1.57 (1.60)
O. javanus	0.71 (1.31)	1.80 (1.67)	1.43 (1.56)
P. viridana	3.25 (2.06)	0.71 (1.31)	2.83 (1.96)
T. projectus	0.39 (1.18)	1.93 (1.71)	1.60 (1.61)

Figures in parentheses are $\sqrt{x+1}$ transformed values
C.D (0.05) Treatments: (0.096)

The feeding potential of *A. anasuja* on the nymphs of *M. histrio* was 3.06, which was superior to that of other spiders, and was on par with *P. viridana* (2.83). *T. mandibulata* recorded a feeding rate of 2.17. The spiders *T. maxillosa* and *T. projectus* consumed 1.65 and 1.60 nymphs of *M. histrio* and were on par. *P. pseudoannulata* consumed 1.57 nymphs of *M. histrio* which was on par with *B. carli* (1.46), *O. javanus* (1.43) and *N. rumpfi* (1.25). The lowest rate of predation was recorded for *T. dimidiata* (0.87).

4.3.2.3 Lepidopterans

Considering the moths of *S. incertulas*, the highest rate of feeding was recorded for *A. anasuja* (7.54) as evidenced by the heavy rate of consumption and found to be superior to others. The spiders *T. dimidiata, P. viridana* and *T. projectus* consumed relatively higher numbers, 5.57, 5.08 and 4.14 respectively. The rate of predation by *P. pseudoannulata* was 3.51 and was on par with *B. carli* (3.08). *O. javanus* recorded a feeding potential of 2.02 moths of *S. incertulas*. The tetragnathids, *T. mandibulata* and *T. maxillosa* consumed 1.54 and 1.51 prey respectively and were on par. The lowest feeding potential on *S. incertulas* moths was observed for *N. rumpfi*, which consumed very low number of prey, *i.e.,* 1.01 moths per spider.

The green lynx spider, *O. javanus* (4.31) consumed, the maximum number of *C. medinalis* larvae, which was on par with the consumption of *T. projectus* (4.14), which were significantly superior to the predation by other spiders. The rate of consumption recorded for *T. dimidiata, P. viridana* and *T. maxillosa* were 3.08, 1.82 and 1.28 larvae per spider. The feeding potential of *T. mandibulata* on the larvae of *C. medinalis* was 0.96 and was on par with that of *P. pseudoannulata* (0.85). Relatively lower rate of feeding was recorded for *A. anasuja* and *B. carli*, the number predated being 0.59 and 0.49 respectively and were on par. The least rate of consumption was exhibited by *N. rumpfi* (0.22).

Table 13 Predatory potential of major spiders in rice ecosystem on lepidopteran pests of rice.

Spiders	Prey consumed in one day					
	S. incertulas	*C. medinalis*		*P. stagnalis*		*M. leda-ismene*
	Adult	Larvae	Adult	Larvae	Adult	Larvae
T. mandibulata	1.54 (1.59)	0.96 (1.40)	3.49 (2.12)	0 (1.00)	2.43 (1.85)	0 (1.00)
T. maxillosa	1.51 (1.58)	1.28 (1.51)	3.96 (2.23)	0 (1.00)	1.51 (1.58)	0 (1.00)
A. anasuja	7.54 (2.92)	0.59 (1.26)	8.91 (3.15)	0.29 (1.13)	4.12 (2.26)	1.34 (1.53)
N. rumpfi	1.01 (1.42)	0.22 (1.11)	1.77 (1.66)	0.45 (1.21)	1.37 (1. 54)	0 (1.00)
T. dimidiata	5.57 (2.56)	3.08 (2.02)	6.14 (2.67)	3.71 (2.17)	5.82 (2.61)	2.43 (1.85)
B. carli	3.08 (2.02)	0.49 (1.22)	2.22 (1.79)	0.45 (1.21)	3.42 (2.10)	0 (1.00)
P. pseudoannulata	3.51 (2.12)	0.85 (1.36)	4.97 (2.44)	2.28 (1.81)	5.96 (2.64)	0.32 (1.15)
O. javanus	2.02 (1.74)	4.31 (2.30)	5.62 (2.57)	1.91 (1.70)	5.11 (2.47)	0.67 (1.29)
P. viridana	5.08 (2.47)	1.82 (1.68)	6.97 (2.82)	0.90 (1.38)	7.97 (2.99)	0.82 (1.35)
T. projectus	4.14 (2.27)	3.88 (2.21)	4.91 (2.43)	1.29 (1.51)	6.48 (2.74)	1.63 (1.62)

Figures in parentheses are $\sqrt{x+1}$ transformed values
C.D (0.05) Treatments: (0.096)

A. anasuja (8.91) recorded the highest rate of predation on the adults of *C. medinalis*, which was found to be a superior predator when compared with the other spiders, followed by *P. viridana* (6.97). *T. dimidiata* recorded relatively higher rate of feeding on the adults of *C. medinalis,* the number consumed being 6.14 which was on par with *O. javanus* (5.62). The rate of feeding recorded for *P. pseudoannulata* and *T. projectus* were 4.97 and 4.91 respectively and were on par. Relatively lower feeding was recorded for *T. maxillosa* (3.96), *T. mandibulata* (3.49), *B. carli* (2.22) and the lowest feeding potential was for *N. rumpfi* (1.77) and differed significantly in their rate of consumption on the adults of *C. medinalis*.

Considering the predatory potential on the larvae of *P. stagnalis*, *T. dimidiata* showed significantly high rate of predation, with a feeding potential of 3.71 larvae per spider, which was followed by *P. pseudoannulata* (2.28), *O. javanus* (1.91), *T. projectus* (1.29) and *P. viridana* (0.90) which differed significantly in their predation and were superior to other spiders. Relatively lower rate of feeding was recorded for *N. rumpfi, B. carli* and *A. anasuja* , 0.45, 0.45 and 0.29 respectively and were on par. *T. mandibulata* and *T. maxillosa* did not consume the prey.

P. viridana was the efficient predator of *P. stagnalis* adults, as evidenced by the rate of consumption, with a predatory potential of 7.97 moths, which was superior to other spiders, followed by *T. projectus* (6.48) with a moderately high rate of feeding and differed significantly. The spiders *P. pseudoannulata* and *T. dimidiata* consumed 5.96 and 5.82 adults of *P. stagnalis* and were on par. Relatively lower predation was found for *O. javanus, A. anasuja, B. carli* and *T. mandibulata* and the number consumed being 5.11, 4.12, 3.42 and 2.43 adults respectively. The lowest feeding rate was recorded for *T. maxillosa* (1.51) which was on par with *N. rumpfi,* with a consumption rate of 1.37 adults of *P. stagnalis.*

The larvae of *M. leda-ismene* was consumed more by *T. dimidiata* (2.43), with a superior rate of predation, which differed significantly with the other spiders. The spiders *T. projectus* consumed 1.63 larvae of *M. leda-ismene* which was on par with that of *A. anasuja*. The rate of predation recorded for *P. viridana* was 0.82 was on par with that of *O. javanus*. The lowest feeding potential was exhibited by *P. pseudoannulata* (0.32), where as *T. mandibulata, T. maxillosa, N. rumpfi* and *B. carli* did not consume the prey.

4.3.2.4 Grass hoppers and Beetles

A. anasuja was found to be a superior predator of the nymphs of *O. chinensis*, as proved by its high rate of consumption *i.e.,* 3.57, which was followed by the predation by *T. projectus* (2.19). The lowest predatory potential was recorded for *P. viridana* (1.68) which was on par with that of *T dimidiata* (1.60).

The adults of *O. chinensis* were consumed by *A. anasuja* and *P. viridana,* and the rate of consumption were 1.45 and 0.68, respectively the other two spiders did not prefer the prey.

Among the four spiders, *A. anasuja* recorded significantly high rate of feeding on the nymphs of *C. pallidus*, as evidenced by the superior consumption of 1.94 nymphs. The rate of predation of the spiders *T. projectus* and *T. dimidiata* on the nymphs of *C. pallidus* were 1.65 and 1.51 respectively and were on par. The lowest predation was by *P. viridana* with a feeding potential of 0.74 nymphs.

T. dimidiata (3.46) recorded the maximum predation on *L. pygmaea*, and the rate of consumption differed significantly when compared to the other spiders. The spiders *P. viridana* and *T. projectus* consumed relatively lower numbers, being 2.68 and 2.51 respectively and the least consumption was recorded for *A. anasuja* (0.93).

When the predatory potential on *H. cyanea* was considered, the maximum predatory efficiency was observed for *A. anasuja* (3.03), with the significantly superior rate of feeding. The rate of feeding for *T. projectus* was 1.63 followed by *P. viridana* (1.51) and *T. dimidiata* (0.80).

Table-14 Predatory potential of major spiders in rice ecosystem on orthopteran and coleopteran pests of rice.

Spiders	Prey consumed in one day						
	O. chinensis		*C. pallidus*	*L. pygmaea*	*H. cyanea*	*O. affinis*	*D. armigera*
	Nymph	Adult	Nymph	Adult	Adult	Adult	Adult
A. anasuja	3.57 (2.14)	1.45 (1.57)	1.94 (1.72)	1.05 (1.43)	3.51 (2.12)	4.05 (2.25)	1.60 (1.61)
P. viridana	1.68 (1.64)	0.68 (1.30)	0.74 (1.32)	2.68 (1.92)	1.51 (1.58)	1.31 (1.52)	0.68 (1.30)
T. dimidiata	1.60 (1.61)	0 (1.00)	1.51 (1.59)	3.46 (2.11)	0.80 (1.34)	1.51 (1.58)	1.59 (1.61)
T. projectus	2.19 (1.79)	0 (1.00)	1.65 (1.63)	2.51 (1.87)	1.63 (1.62)	1.50 (1.58)	1.37 (1.54)
C.D (0.05)	Treatments : (0.069)			Treatments : (0.031)			

Figures in parentheses are $\sqrt{x+1}$ transformed values

A. anasuja (4.05) was superior to other spiders in the consumption of *O. affinis*, which recorded a significantly higher value of predation and differed from the other spiders. Relatively lower rate of consumption was recorded for *T. projectus* (1.50), *T. dimidiata* (1.51) and *P. viridana* (1.31).

The highest rate of predation on *D. armigera* was recorded for *A. anasuja* (1.60), which was on par with that of *T. dimidiata* (1.59), *T. projectus* (1.37) and *P. viridana* (0.68).

4.3.3 Hyper Predation

Insect predators

Apart from the pests in the rice fields, the spiders preyed on the insect natural enemies too. Hence the major insect natural enemies observed during the survey *viz., Agriocnemis* sp., *C. lividipennis*, *M. vitatticollis*, grubs and adults of *Micraspis* sp. were screened for their hyper predation by spiders. The data on the hyper predation of the major spiders on the insect predators expressed as the mean number of insect predators consumed by the spider predators in one day is presented in Table 15.

Among the spiders, *P. viridana* (3.98) recorded the highest cross predation on insect natural enemies, which was on par with *A. anasuja* (3.72). The extent of hyper predation of *T. mandibulata* (2.95) was statistically on par with the rate of consumption of *T. projectus* (2.78). *T. maxillosa* exhibited a consumption of 2.36 which was followed by *T. dimidiata* (2.19), *O. javanus* (2.00), *P. pseudoannulata* (1.73), *B. carli* (1.36) and the lowest rate of cross predation was recorded for *N. rumpfi* (0.49).

Considering the insect natural enemies, the most preferred and the more predated one was the mirid bug predator *C. lividipennis* (6.01). *Agriocnemis* sp. (2.80) was preferred next to the mirid bugs, followed by the gryllid predator, *M. vitatticollis* (1.13) and the grubs of *Micraspis* sp. (1.08). The least consumed insect predator was adults of *Micraspis* sp. (0.76).

Table 15 Hyperpredation of the major spiders in rice ecosystem on insect natural enemies in the rice fields.

Spiders	Prey consumed in one day					Mean
	Agriocnemis sp.	*C. lividipennis*	*M. vitatticollis*	*Micraspis* sp.		
				Grub	Adult	
T. mandibulata	3.09 (2.02)	9.24 (3.20)	1.29 (1.51)	0 (1.00)	1.14 (1.46)	2.95 (1.84)
T. maxillosa	7.28 (1.81)	8.29 (3.05)	0.57 (1.25)	0 (1.00)	0.66 (1.29)	2.36 (1.68)
A. anasuja	5.62 (2.57)	4.52 (2.35)	4.95 (2.44)	0 (1.00)	3.52 (2.13)	3.72 (2.10)
N. rumpfi	0 (1.00)	1.71 (1.65)	0 (1.00)	0.76 (1.33)	0 (1.00)	0.49 (1.19)
T. dimidiata	2.29 (1.81)	6.19 (2.68)	1.08 (1.44)	0.76 (1.33)	0.62 (1.27)	2.19 (1.71)
B. carli	1.24 (1.50)	4.00 (2.24)	0 (1.00)	1.57 (1.60)	0 (1.00)	1.36 (1.47)
P. pseudoannulata	1.66 (1.63)	5.33 (2.52)	0 (1.00)	1.66 (1.63)	0 (1.00)	1.73 (1.56)
O. javanus	2.38 (1.84)	4.43 (2.33)	0 (1.00)	3.19 (2.05)	0 (1.00)	2.00 (1.64)
P. viridana	5.00 (2.45)	10.14 (3.34)	2.05 (1.75)	2.09 (1.76)	0.61 (1.27)	3.98 (2.11)
T. projectus	4.48 (2.34)	6.23 (2.69)	1.37 (1.54)	0.80 (1.34)	1.04 (1.43)	2.78 (1.87)
Mean	2.80 (1.90)	6.01 (2.60)	1.13 (1.39)	1.08 (1.40)	0.76 (1.29)	

Figures in parentheses are $\sqrt{x+1}$ transformed values
C.D (0.05) Spiders : (0.043)
C.D (0.05) Prey : (0.030)
C.D (0.05) Treatments: (0.095)

T. mandibulata exhibited the highest rate of predation on the mirid bug predator, *C. lividipennis* (9.24), followed by *Agriocnemis* sp. (3.09). The extent of cross predation on *M. vitatticollis* (1.29) was on par with that of adults of *Micraspis* sp. (1.46). The grubs of the *Micraspis* sp. were not at all consumed.

T. maxillosa recorded significantly higher rate of cross predation on *C. lividipennis* (8.29), followed by *Agriocnemis* sp. (2.28). The rate of consumption on the adult *Micraspis* sp. (0.66) was on par with that of the *M. vitatticollis* (0.57) and the grubs of *Micraspis* sp. were not preferred.

A. anasuja recorded the highest rate of cross predation on *Agriocnemis* sp. (5.62), as proved by its heavy consumption, which was followed by *M. vitatticollis* (4.95) which was on par with that of *C. lividipennis* (4.52). The lowest rate of hyper predation was for adults of *Micraspis* sp. (3.52) and the grubs of *Micraspis* sp. were not preferred.

Being a poor predator, *N. rumpfi* recorded the highest rate of consumption on *C. lividipennis* (1.71) which was the lowest when compared to the other spiders, followed by grubs of *Micraspis* sp. (0.76). The other insect natural enemies like *Agriocnemis* sp., *M. vitatticollis* and adult *Micraspis* sp. were not consumed.

T. dimidiata recorded significantly higher rate of hyper predation on the mirid bug predator, *C. lividipennis* (6.19), followed by *Agriocnemis* sp. (2.29) and *M. vitatticollis* (1.08). The lowest rate of cross predation was on the adults of *Micraspis* sp. (0.62), which was on par with that of grubs of *Micraspis* sp. (0.76).

C. lividipennis (4.00) was the mostly prefered predator of *B . carli*, followed by the grubs of *Micraspis* sp. (1.57) which was on par with the cross predation on *Agriocnemis* sp. (1.24). The *M. vitatticollis* and adult *Micraspis* sp. were not at all consumed.

P. pseudoannultata consumed more *C. lividipennis* (5.38), which was significantly higher when compared to the cross predation on *Agriocnemis* sp. (1.66) and grubs of *Micraspis* sp. (1.66). The *M. vitatticollis* and the adult *Micraspis* sp. were not prefered.

Among the different insect natural enemies screened, *O. javanus* consumed more *C. lividipennis* (4.43), than grubs of *Micraspis* sp. (3.19) and *Agriocnemis* sp. (2.38). The spider did not prefer *M. vitatticollis* and adult *Micraspis* sp.

Hyper predation on *C. lividipennis* (10.14) was extremely high for *P. viridana* as evidenced by its heavy rate of predation, followed by *Agriocnemis* sp. (5.00). The rate of consumption of the grubs of *Micraspis* sp. (2.09) was on par with that of the *M. vitatticollis* (2.05). The lowest cross predation was exhibited for the adult *Micraspis* sp. (0.61)

T. projectus recorded significantly higher rate of cross predation for *C. lividipennis* (6.23), followed by *Agriocnemis* sp. (4.48) and *M. vitatticollis* (1.37). The lowest rate of hyper predation was recorded for the grubs of *Micraspis* sp. (0.80) which was on par with that of adult *Micraspis* sp. (1.04).

Parasitoids

The spiders did not consume any of the hymenopteran parasitoids evaluated for hyper predation.

4.4 EVALUATION OF TOXICITY / SAFETY OF SYNTHETIC INSECTICIDES AND BOTANICALS

4.4.1 Laboratory Evaluation

The commonly used synthetic insecticides and neem based formulations for pest management in rice ecosystem were tested against the dominant spiders in rice ecosystem inorder to evaluate their toxicity /safety to the spiders, and the results expressed in mortality percentage are given in Tables 16 to 20.

4.4.1.1 Effect on Tetragnatha mandibulata

The mortality of *T. mandibulata* when treated with the synthetic insecticides like triazophos 0.05 per cent and quinalphos 0.05 per cent in the dosage recommended for pest management was extremely high, 56.73 and 35.56, respectively. The mortality caused by acephate 0.05 per cent (30.58) was on par with that of azadirachtin 0.004 per cent (24.50). The mortality caused by imidacloprid 0.005 per cent (17.46) was relatively lower than that caused by neem oil 2 per cent (17.73) and were on par. NSKE 5 per cent (5.72) recorded the least mortality to the spider and differed significantly from the other chemicals.

When the two methods were considered, the topical application of the pesticides caused maximum mortality of 36.67 to *T. mandibulata* and when it was released on pesticide sprayed plants, the mortality was too low (14.97).

Among the different insecticides, triazophos 0.05 per cent caused maximum mortality of *T. mandibulata*, when treated through topical application (71.80). Except imidacloprid, the synthetic insecticides resulted in high mortality of spiders. Quinalphos 0.05 per cent caused 49.80 per cent mortality of *T. mandibulata*, which was on par with acephate 0.05 per cent (41.66). Topical application of azadirachtin 0.004 per cent (33.83) was on par with imidacloprid 0.005 per cent (27.52) and neem oil 2 per cent (21.84). NSKE 5 per cent caused the least mortality of spiders (10.29) and differed significantly from the other treatments.

When the spiders were released on the treated plants, triazophos 0.05 per cent caused the maximum mortality, followed by quinalphos 0.05 per cent (21.31) which was on par with acephate 0.05 per cent (19.49). The mortality caused by azadirachtin 0.004 per cent (15.16) was on par with neem oil 2 per cent (13.62) and imidacloprid 0.005 per cent (7.39). The mortality was significantly low when the spiders were released on NSKE 5 per cent (1.14).

4.4.1.2 Effect on Tetragnatha maxillosa

The mortality of *T. maxillosa* was 64.78 and 46.79 per cent, upon treatment with triazophos 0.05 per cent and quinalphos 0.05 per cent, respectively. Acephate 0.05 per cent caused 36.75 per cent mortality which was on par with azadirachtin

Table 16 Effect of synthetic insecticides and neem formulations on *Tetragnatha mandibulata* and *Tetragnatha maxillosa* (Tetragnathidae:Araneae).

Treatments	*T. mandibulata*			*T. maxillosa*		
	Mortality percentage		Mean	Mortality percentage		Mean
	Topical application	Release on sprayed plants		Topical application	Release on sprayed plants	
Acephate 0.05%	41.66 (6.53)	19.49 (4.53)	30.58 (5.53)	47.72 (6.98)	25.77 (5.17)	36.75 (6.08)
Imidacloprid 0.005%	27.52 (5.34)	7.39 (2.90)	17.46 (4.12)	37.65 (6.22)	13.52 (3.81)	25.59 (5.01)
Triazophos 0.05%	71.80 (8.53)	41.66 (6.53)	56.73 (7.53)	77.82 (8.88)	51.73 (7.26)	64.78 (8.07)
Quinalphos 0.05%	49.80 (7.13)	21.31 (4.72)	35.56 (5.93)	67.80 (8.29)	25.77 (5.17)	46.79 (6.73)
Azadirachtin 0.004%	33.83 (5.90)	15.16 (4.02)	24.50 (4.96)	47.72 (6.98)	21.31 (4.72)	34.52 (5.85)
Neem oil 2 %	21.84 (4.78)	13.62 (3.82)	17.73 (4.30)	35.83 (6.07)	5.99 (2.64)	20.91 (4.36)
NSKE 5%	10.29 (3.36)	1.14 (1.46)	5.72 (2.41)	17.26 (4.27)	7.14 (2.85)	12.20 (3.56)
Mean	36.67 (5.94)	17.11 (4.00)		47.41 (6.81)	21.60 (4.52)	
C.D (0.05)	Insecticides : (0.825) Methods : (0.441) Treatments : (1.167)			Insecticides : (0.803) Methods : (0.429) Treatments : (1.136)		

Figures in parentheses are $\sqrt{x+1}$ transformed values

0.004 per cent (34.52). Imidacloprid 0.005 per cent caused 25.59 per cent mortality of the spider, which was on par with that of neem oil 2 per cent (20.91). NSKE 5 per cent caused the least mortality (12.20).

Between the two methods, topical application of chemicals was found to be detrimental to the spiders (41.48), compared to release of spiders on sprayed plants (21.60).

Triazophos 0.05 per cent caused the highest mortality (77.82) of *T. maxillosa* when applied topically, which was on par with quinalphos 0.05 per cent (67.80). The mortality caused by the topical application of acephate 0.05 per cent, azadirachtin 0.004 per cent, imidacloprid 0.005 per cent and neem oil 2 per cent were 47.72, 47.72, 37.65 and 35.83, respectively. NSKE 5 per cent (17.26) caused the lowest mortality of the spiders when applied topically.

When the spiders were released on the treated paddy plants, triazophos 0.05 per cent again recorded significantly very high mortality of the spider, *i.e.*, 51.73. Quinalphos 0.05 per cent and acephate 0.05 per cent recorded the same percent mortality of *T. maxillosa,* which was 25.77 per cent each. Azadirachtin 0.004 per cent (21.31) and imidacloprid 0.005 per cent (13.52) caused relatively lower mortality of the spiders, and were on par. The mortality caused due to NSKE 5 per cent (12.20) treatment was on par with that of neem oil 2 per cent (5.99).

4.4.1.3 Effect on Argiope anasuja

Among the different insecticides used, the maximum mortality of *A. anasuja* was caused by triazophos 0.05 per cent, which recorded a significantly high mortality of 38.55. The toxicity of quinalphos 0.05 per cent caused a mortality of 23.59, which was on par with acephate 0.05 per cent (20.70) and azadirachtin 0.004 per cent (16.79). Imidacloprid 0.005 per cent was found to be relatively safe when compared to other three synthetic insecticides, and caused a mortality of 12.10 which was on par with neem oil 2 per cent (7.90). NSKE 5 per cent (2.93) caused the lowest mean mortality of *A. anasuja.*

Between the two methods, topical application of chemicals was found to be harmful to the spiders, which recorded a high per cent mortality of *A. anasuja*, *i.e.*, 23.70. However when *A. anasuja* was released on pesticide treated plants, the extent of mortality was too low and recorded a much low value of 11.31.

Considering the topical application of the chemicals, triazophos 0.05 per cent (53.89) recorded maximum mortality of *A. anasuja*, which was significantly higher, followed by quinalphos 0.05 per cent (31.55). Acephate 0.05 per cent caused a mortality of 25.77 which was on par with azadirachtin 0.004 per cent (21.84) and imidacloprid 0.005 per cent (19.49). Relatively lower mortality was observed upon the topical application of neem oil 2 per cent and NSKE 5 per cent which recorded a mortality of 8.65 and 4.71, respectively.

When *A. anasuja* was released on triazophos 0.05 per cent sprayed plants, a mean mortality of 23.21 per cent was observed which was on par with acephate 0.05 per cent (15.62) and quinalphos 0.05 per cent (15.62), which were relatively higher. Azadirachtin 0.004 per cent caused a mortality of 11.74 which was on par with neem oil 2 per cent (7.14). The lowest mortality was observed for imidacloprid 0.005 per cent and NSKE 5 per cent, which were on par and recorded 4.71 and 1.14, respectively.

4.4.1.4 Effect on Neoscona rumpfi

The mortality of *N. rumpfi* caused by triazophos 0.05 per cent was significantly very high, *i.e.*, 85.90 which was very toxic to the spider, followed by quinalphos 0.05 per cent, which recorded a mortality of 70.79 and differed significantly with the other treatments. Acephate 0.05 per cent caused a mortality of 63.90 which was on par with azadirachtin 0.004 per cent (59.81). The toxicity of imidacloprid 0.005 per cent caused a mortality of 51.71, which was on par with the

Table 17 Effect of synthetic insecticides and neem formulations on *Argiope anasuja* and *Neoscona rumpfi* (Araneidae:Araneae).

Treatments	*A. anasuja*			*N. rumpfi*		
	Mortality percentage		Mean	Mortality percentage		Mean
	Topical application	Release on sprayed plants		Topical application	Release on sprayed plants	
Acephate 0.05%	25.77 (5.17)	15.62 (4.08)	20.70 (4.63)	79.88 (8.99)	47.91 (6.99)	63.90 (7.99)
Imidacloprid 0.005%	19.49 (4.53)	4.71 (2.39)	12.10 (3.46)	65.77 (8.17)	37.65 (6.22)	51.71 (7.19)
Triazophos 0.05%	53.89 (7.41)	23.21 (4.92)	38.55 (6.17)	99.99 (10.05)	71.80 (8.53)	85.90 (9.29)
Quinalphos 0.05%	31.55 (5.70)	15.62 (4.08)	23.59 (4.89)	83.80 (9.21)	57.77 (7.67)	70.79 (8.44)
Azadirachtin 0.004%	21.84 (4.78)	11.74 (3.57)	16.79 (4.18)	77.95 (8.89)	41.66 (6.53)	59.81 (7.71)
Neem oil 2%	8.65 (3.11)	7.14 (2.85)	7.90 (2.98)	61.77 (7.92)	35.83 (6.07)	48.80 (7.00)
NSKE 5%	4.71 (2.39)	1.14 (1.46)	2.93 (1.93)	35.60 (6.05)	19.49 (4.53)	27.55 (5.29)
Mean	23.70 (4.73)	11.31 (3.34)		72.11 (8.47)	44.58 (6.65)	
C.D (0.05)	Insecticides: (0.800) Methods : (0.428) Treatments : (1.132)			Insecticides: (0.474) Methods : (0.253) Treatments : (0.670)		

Figures in parentheses are $\sqrt{x+1}$ transformed values

effect of neem oil 2 per cent (48.80). NSKE 5 per cent (27.55) recorded a lowest mortality of the spider.

The topical application of the chemicals was observed to be highly fatal to the spiders, as evidenced by the significantly high mortality recorded, *i.e.*, 72.11, where as the spiders when brought in contact with the treated plants the spiders exhibited a low mortality (44.58).

Nearly cent per cent mortality was recorded when triazophos 0.05 per cent was applied topically on the spider, *i.e.*, 99.99 per cent, which was significantly very high when compared to other insecticides. The mean mortality caused by the topical application of quinalphos 0.05 per cent was on par with acephate 0.05 per cent and azadirachtin 0.004 per cent and the mortality being 83.80, 79.88 and 77.95, respectively. The toxicity of imidacloprid 0.005 per cent (65.77) was on par with neem oil 2 per cent, which recorded a mean mortality of 61.77. NSKE 5 per cent (35.60) when sprayed topically on *N. rumpfi* caused the lowest mortality of the spiders.

Considering the impact of the chemicals when *N. rumpfi* was released on a treated surface, triazophos 0.05 per cent was found to be highly toxic, with a significantly high per cent mortality of 71.80 per cent followed by quinalphos 0.05 per cent (57.77), acephate 0.05 per cent (47.91). Azadirachtin 0.004 per cent caused a mortality of 41.66, which was on par with imidacloprid 0.005 per cent (37.65) and neem oil 2 per cent (35.83). The lowest mortality of 19.49 was observed when the spiders were brought in contact with NSKE 5 per cent.

4.4.1.5 Effect on Telamonia dimidiata

Considering the mortality of *T. dimidiata* caused by different insecticides, significantly high mortality was recorded by triazophos 0.05 per cent (65.73). The toxicity of quinalphos 0.05 per cent caused a mortality of 41.85 which was on par with acephate 0.05 per cent (38.88) and azadirachtin 0.004 per cent (38.71).

imidacloprid 0.005 per cent recorded a relatively lower mortality of the spider, *i.e.*, 31.02, followed by neem oil 2 per cent (17.21) and NSKE 5 per cent (11.63).

Between the two methods, topical application caused higher mortality of *T. dimidiata* (44.91) when compared to the toxicity caused when the spiders were released into sprayed plants (24.38).

The topical application of triazophos 0.05 per cent recorded the highest mortality of *T. dimidiata i.e.*, 87.84 per cent followed by quinalphos 0.05 per cent (57.93). Both acephate 0.05 per cent and azadirachtin 0.004 per cent caused 45.87 per cent mortality which was on par with that of imidacloprid 0.005 per cent (33.83). The topical treatment with neem oil 2 per cent (25.77) was less toxic and was on par with NSKE 5 per cent (17.26).

When *T. dimidiata* was released on treated paddy plants, maximum mortality was observed for triazophos 0.05 per cent which was significantly high when compared to the other treatments, *i.e.*, 43.61. The mortality caused by acephate 0.05 per cent (31.89) was on par with azadirachtin 0.004 per cent, quinalphos 0.05 per cent and imidacloprid 0.005 per cent and the mortality recorded being 31.55, 25.77 and 23.21, respectively. Neem oil 2 per cent (8.65) and NSKE 5 per cent (5.99) were the least toxic among the different treatments.

4.4.1.6 Effect on Bianor carli

B. carli was found to be more sensitive to triazophos 0.05 per cent which recorded a mortality of 66.89, which was significantly higher followed by quinalphos 0.05 per cent (58.67) and azadirachtin 0.004 per cent (47.80). Neem oil 2 per cent caused a mortality of 35.82 per cent, which was on par with acephate 0.05 per cent (33.51). Relatively lower mortality was recorded for NSKE 5 per cent (26.72) and the least by imidacloprid 0.005 per cent (25.73) and were on par.

Considering the two methods, topical application of chemicals was highly detrimental, as observed by the significantly high rate of mortality, *i.e.*, 52.02, where

Table 18 Effect of synthetic insecticides and neem formulations on *Telamonia dimidiata* and *Bianor carli* (Salticidae:Araneae).

Treatments	*T. dimidiata*			*B. carli*		
	Mortality percentage		Mean	Mortality percentage		Mean
	Topical application	Release on sprayed plants		Topical application	Release on sprayed plants	
Acephate 0.05%	45.87 (6.85)	31.89 (5.73)	38.88 (6.29)	39.50 (6.36)	27.52 (5.34)	33.51 (5.85)
Imidacloprid 0.005%	33.83 (5.90)	23.21 (4.92)	31.02 (5.41)	35.83 (6.07)	15.62 (4.08)	25.73 (5.07)
Triazophos 0.05%	87.84 (9.43)	43.61 (6.68)	65.73 (8.05)	79.88 (8.99)	53.89 (7.41)	66.89 (8.20)
Quinalphos 0.05%	57.93 (7.68)	25.77 (5.17)	41.85 (6.43)	71.66 (8.52)	45.68 (6.83)	58.67 (7.68)
Azadirachtin 0.004%	45.87 (6.85)	31.55 (5.70)	38.71 (6.28)	61.77 (7.92)	33.83 (5.90)	47.80 (6.91)
Neem oil 2%	25.77 (5.17)	8.65 (3.11)	17.21 (4.14)	45.87 (6.85)	25.77 (5.1 7)	35.82 (6.01)
NSKE 5%	1 7.26 (4.27)	5.99 (2.64)	11.63 (3.46)	29.67 (5.54)	23.77 (4.98)	26.72 (5.26)
Mean	44.91 (6.59)	24.38 (4.85)		52.02 (7.18)	32.30 (5.67)	
C.D (0.05)	Insecticides: (0.707) Methods : (0.378) Treatments :(1.000)			Insecticides : (0.518) Methods : (0.277) Treatments : (0.733)		

Figures in parentheses are $\sqrt{x+1}$ transformed values

as releasing the spiders on treated plants was found to be relatively safe as the mortality was low, *i.e.*, 32.30.

The topical application of triazophos 0.05 per cent caused maximum mortality (79.88) of *B. carli*. The mortality caused by quinalphos 0.05 per cent (71.66) upon topical application was on par with azadirachtin 0.004 per cent (61.77). The toxicity of neem oil 2 per cent (45.87) was on par with that of acephate 0.05 per cent (39.50). Imidacloprid 0.005 per cent and NSKE 5 per cent was on par in their toxicity and recorded a mortality of 35.83 and 29.67, respectively.

The toxicity of triazophos 0.05 per cent (53.89) was relatively high when spiders were released on treated surface, which was on par with quinalphos 0.05 per cent (45.68). The mortality caused by azadirachtin 0.004 per cent was 33.83. Acephate 0.05 per cent, neem oil 2 per cent and NSKE 5 per cent were on par with each other and the mortality being 27.52, 25.77 and 23.77, respectively. The synthetic insecticide imidacloprid 0.005 per cent recorded the least mortality of *B. carli* (15.62) which showed significant difference with the other treatments.

4.4.1.7 Effect on Pardosa pseudoannulata

Triazophos 0.05 per cent was highly toxic to *P. pseudoannulata*, as proved by the significantly high mortality of 53.70 per cent, followed by quinalphos 0.05 per cent (39.47). The mortality caused by acephate 0.05 per cent (31.49) was on par with that of azadirachtin 0.004 per cent (30.53), neem oil 2 per cent (27.66) and imidacloprid 0.005 per cent (26.55). The lowest mortality of *P. pseudoannulata* was observed for NSKE 5 per cent (12.01).

Among the two methods of application of the chemicals, topical application seem to be more toxic, as evidenced by the higher rate of mortality, *i.e.*, 41.66 per cent when compared to the release of spiders in treated plants (21.60).

Upon topical application of triazophos 0.05 per cent, significantly high mortality of *P. pseudoannulata* occurred, which was 71.80, followed by quinalphos

0.05 per cent (49.60). The mortality caused by acephate 0.05% (41.66) was on par with imidacloprid 0.005 per cent (35.83), neem oil 2 per cent (35.83) and azadirachtin 0.004 per cent (35.60). NSKE 5 per cent recorded the lowest mortality (21.31).

When *P. pseudoannulata* were released on paddy plants treated with triazophos 0.05 per cent, a maximum mortality of 35.60 per cent was observed which was on par with quinalphos 0.05 per cent (29.34). Azadirachtin 0.004 per cent caused a mortality of 25.46 per cent, which was on par with that of acephate 0.05 per cent (21.31), neem oil 2 per cent (19.49) and imidacloprid 0.005 per cent (17.26). The spiders released on NSKE 5 per cent treated plants exhibited a very low mortality of 2.71 per cent.

4.4.1.8 Effect on Thomisus projectus

The mortality of *T. projectus* when treated with triazophos 0.05 per cent (54.76) was significantly higher. The mortality caused by quinalphos 0.05 per cent (45.72) was on par with that of azadirachtin (36.70). Acephate 0.05 per cent caused a mortality of 25.71 per cent and was on par with neem oil 2 per cent (24.82). Imidacloprid 0.005 per cent and NSKE 5 per cent recorded the lowest mortality of 17.83 and 12.10, respectively and were on par.

Considering the two methods, the topical application of pesticides resulted in very high mortality (42.64), as compared to the release of spiders into treated surface, which recorded a mortality of 19.55.

Topical spraying of triazophos 0.05 per cent was highly detrimental to *T. projectus*, as proved by the significantly high rate of mortality, *i.e.*, 73.92, followed by quinalphos 0.05 per cent (61.77) and were on par. The mortality caused by azadirachtin 0.004 per cent was 45.87. Acephate 0.05 per cent recorded a mortality of 35.83 per cent, which was on par with that of neem oil 2 per cent (31.89) and imidacloprid 0.005 per cent (29.67). NSKE 5 per cent (19.49) recorded the lowest mortality of *T. projectus*.

Table 19 Effect of synthetic insecticides and neem formulations on *Pardosa pseudoannulata* (Lycosidae) and *Thomisus projectus* (Thomisidae).

Treatments	*P. pseudoannulata*			*T. projectus*		
	Mortality percentage			Mortality percentage		
	Topical application	Release on sprayed plants	Mean	Topical application	Release on sprayed plants	Mean
Acephate 0.05%	41.66 (6.53)	21.31 (4.72)	31.49 (5.63)	35.83 (6.07)	15.62 (4.08)	25.71 (5.07)
Imidacloprid 0.005%	35.83 (6.07)	17.26 (4.27)	26.55 (5.17)	29.67 (5.54)	5.99 (2.64)	17.83 (4.09)
Triazophos 0.05%	71.80 (8.53)	35.60 (6.05)	53.70 (7.29)	73.92 (8.66)	35.60 (6.05)	54.76 (7.35)
Quinalphos 0.05%	49.60 (7.11)	29.34 (5.51)	39.47 (6.31)	61.77 (7.92)	29.67 (5.54)	45.72 (6.73)
Azadirachtin 0.004%	35.60 (6.05)	25.46 (5.14)	30.53 (5.60)	45.87 (6.85)	27.52 (5.34)	36.70 (6.09)
Neem oil 2%	35.83 (6.07)	19.49 (4.53)	27.66 (5.30)	31.89 (5.73)	17.74 (4.33)	24.82 (5.03)
NSKE 5%	21.31 (4.72)	2.71 (1.93)	12.01 (3.33)	19.49 (4.53)	4.71 (2.39)	12.10 (3.46)
Mean	41.66 (6.44)	21.60 (4.59)		42.64 (6.47)	19.55 (4.34)	
C.D (0.05)	Insecticides: (0.719) Methods : (0.384) Treatments :(1.020)			Insecticides : (0.694) Methods : (0.371) Treatments : (0.982)		

Figures in parentheses are $\sqrt{x+1}$ transformed values

When the spiders were released into triazophos 0.05 per cent treated plants, maximum mortality was recorded, *i.e.*, 35.60, which was on par with quinalphos 0.05 per cent (29.67) and azadirachtin 0.004 per cent (27.52). The mean mortality recorded for neem oil 2 per cent (17.74) was on par with acephate 0.05 per cent (15.62). The mortality of *T. projectus*, when it was released into plants sprayed with imidacloprid 0.005 per cent (5.99) was very low and was on par with NSKE 5 per cent (4.71).

4.4.1.9 Effect on* Oxyopes *javanus

Triazophos 0.05 per cent caused maximum mortality of *O. javanus* (70.74), which was significantly higher, followed by acephate 0.05 per cent (51.73) and differed significantly with the other treatments. The mortality caused by quinalphos 0.05 per cent (35.72) was on par with that of azadirachtin 0.004 per cent (34.82). Toxicity of imidacloprid 0.005 per cent to *O. javanus* was 29.52, which was on par with neem oil 2 % (22.63). The least toxic among the tested insecticides to *O. javanus* was NSKE 5 per cent (16.30).

Comparing the two methods of application of the chemicals, again topical application recorded maximum mortality of the spiders (45.93), where as release on treated plants was relatively safe to the spiders, as evidenced by the mortality (28.77).

Triazophos 0.05 per cent was extremely toxic to the spider on topical application as proved by the high mortality (83.70) of *O. javanus*, which was significantly higher than the other chemicals. The mortality caused by acephate 0.05 per cent (55.73) was on par with quinalphos 0.05 per cent (49.60), imidacloprid 0.005 per cent (43.87) and azadirachtin 0.004 per cent (43.87). The mortality caused by neem oil 2 per cent (25.77) was on par with that of NSKE 5 per cent (18.98), which was the lowest.

When the spiders were brought in contact with the sprayed plants, maximum mortality was caused by triazophos 0.05 per cent (57.77) which was on par with that of acephate 0.05 per cent (47.72). Azadirachtin 0.004 per cent and quinalphos 0.05

Table 20 Effect of synthetic insecticides and neem formulations on *Oxyopes javanus* and *Peucetia viridana* (Oxyopidae:Araneae).

Treatments	*O. javanus*			*P. viridana*		
	Mortality percentage		Mean	Mortality percentage		Mean
	Topical application	Release on sprayed plants		Topical application	Release on sprayed plants	
Acephate 0.05%	55.73 (7.53)	47.72 (6.98)	51.73 (7.26)	33.48 (5.87)	27.84 (5.3 7)	30.66 (5.62)
Imidacloprid 0.005%	43.87 (6.70)	15.16 (4.02)	29.52 (5.36)	25.46 (5.14)	8.65 (3.11)	17.06 (4.13)
Triazophos 0.05%	83.70 (9.20)	57.77 (7.67)	70.74 (8.43)	59.67 (7.79)	43.61 (6.68)	51.64 (7.23)
Quinalphos 0.05%	49.60 (7.11)	21.84 (4.78)	35.72 (5.95)	47.91 (6.99)	13.62 (3.82)	30.77 (5.41)
Azadirachtin 0.004%	43.87 (6.70)	25.77 (5.17)	34.82 (5.94)	31.89 (5.73)	15.16 (4.02)	23.53 (4.88)
Neem oil 2%	25.77 (5.17)	19.49 (4.53)	22.63 (4.85)	1 7.26 (4.27)	11.74 (3.57)	14.50 (3.92)
NSKE 5%	18.98 (4.47)	13.62 (3.82)	16.30 (4.15)	10.29 (3.36)	4.71 (2.39)	7.50 (2.88)
Mean	45.93 (6.70)	28.77 (5.28)		32.29 (5.60)	17.91 (4.14)	
C.D (0.05)	Insecticides:(0.606) Methods : (0.324) Treatments : (0.857)			Insecticides: (0.791) Methods : (0.423) Treatments : (1.120)		

Figures in parentheses are $\sqrt{x+1}$ transformed values

per cent recorded a mortality of 25.77 and 21.84, respectively and were on par. Toxicity of neem oil 2 per cent (19.49) was on par with that of imidacloprid 0.005 per cent (15.16) and NSKE 5 per cent (13.62) to *O. javanus*.

4.4.1.10 Effect on Peucetia viridana

Among the different inecticides used, the maximum mortality of *P. viridana* was caused by triazophos 0.05 per cent (51.64), which was significantly higher than that of other insecticides. The mortality caused by acephate 0.05 per cent (30.66) was on par with quinalphos 0.05 per cent (30.77) and azadirachtin (23.53). Imidacloprid 0.005 per cent resulted in 17.06 per cent mortality of *P. viridana* which was statistically on par with neem oil 2 per cent (14.50). The lowest mortality was recorded by NSKE 5 per cent (7.50).

Between the two methods of application, topical application proved to be more fatal to the spiders with a significantly high mortality (32.29), where as when spiders were released on treated surface the mortality occurred was only 17.91 per cent.

The topical application of triazophos 0.05 per cent (59.67) resulted in maximum mortality of *P. viridana*, which was on par with that of quinalphos 0.05 per cent (47.91). The mortality caused by the topical spraying of acephate 0.05 per cent (33.48) was on par with azadirachtin 0.004 per cent (31.89) and imidacloprid 0.005 per cent (25.46). The neem products, neem oil 2 per cent (17.26) and NSKE 5 per cent (10.29) caused relatively low mortality of *P. viridana* and were on par.

The toxicity of triazophos 0.05 per cent (43.61) was significantly higher when *P. viridana* were released on the insecticide treated plants as proved by its high mortality. The mortality caused by acephate 0.05 per cent (27.84) was on par with that of quinalphos 0.05 per cent (13.62), azadirachtin 0.004 per cent (15.16) and imidacloprid 0.005 per cent (8.65). As in the case of topical application, neem oil 2 per cent (11.74) and NSKE 5 per cent (4.71) recorded the least toxicity to the spiders.

4.4.2 Field Evaluation of the Effect of Different Insecticides and Botanicals

The results of the field trial on the safety / toxicity of insecticides and botanicals on spiders, insect natural enemies and pests, assessed in terms of number per ten sweeps is presented in Tables 21, 22, 23.

4.4.2.1 Effect on spiders

One day after spraying, there was significant reduction in the population of spiders in the treated plots when compared to the control plots (9.52). Among the treatments, the spider population was recorded in the plots treated with the botanicals, NSKE 5 per cent treatment (1.17) which was on par with neem oil 2 per cent (0.29) and acephate 0.05 per cent (0.29). In the other plots with the treatments imidacloprid 0.005 per cent, triazophos 0.05 per cent, azadirachtin 0.004 per cent and quinalphos 0.05 per cent, there were no spiders at all.

Three days after the application of the pesticides and botanicals, the control plot (9.60) recorded significantly higher number of spiders, followed by the plot treated with NSKE 5 per cent, with a population of 2.82 spiders. The population of spiders recorded from the plots treated with neem oil 2 per cent (1.59), imidacloprid 0.005 per cent (0.91), azadirachtin 0.004 per cent (0.78) and acephate 0.05 per cent (0.30) were on par, where as the plots treated with triazophos 0.05 per cent and quinalphos 0.05 per cent did not record any spiders.

Five days after spraying, slight increase was registered in the population build up of spiders. The control plot recorded significantly higher number of spiders (11.84), when compared to the plots treated with NSKE 5 per cent (4.30) which was on par with the neem oil 2 per cent (3.52) treated plots. The plots sprayed with imidacloprid 0.005 per cent (2.59), azadirachtin 0.004 per cent (1.74) and acephate 0.05 per cent (0.55) were on par in the population of spiders recorded. No spiders were observed in triazophos 0.05 per cent and quinalphos 0.05 per cent sprayed plots.

Table 21 Effect of synthetic insecticides and neem formulations on spiders when sprayed in the field

Treatments	Number of spiders per ten sweeps					
	1DAS	3DAS	5DAS	7DAS	10DAS	15DAS
Acephate 0.05%	0.29 (1.14)	0.30 (1.14)	0.55 (1.24)	0.30 (1.14)	1.74 (1.66)	4.66 (2.38)
Imidacloprid 0.005%	0 (1.00)	0.91 (1.38)	2.59 (1.89)	2.82 (1.95)	3.78 (2.19)	7.49 (2.91)
Triazophos 0.05%	0 (1.00)	0 (1.00)	0 (1.00)	0.30 (1.14)	0.91 (1.38)	2.55 (1.88)
Quinalphos 0.05%	0 (1.00)	0 (1.00)	0 (1.00)	0.30 (1.14)	1.31 (1.52)	3.58 (2.14)
Azadirachtin 0.004%	0 (1.00)	0.78 (1.35)	1.74 (1.66)	1.40 (1.55)	6.92 (2.81)	9.94 (3.31)
Neem oil 2%	0.29 (1.14)	1.59 (1.61)	3.52 (2.13)	2.82 (1.95)	11.55 (3.54)	12.59 (3.69)
NSKE 5%	1.17 (1.47)	2.82 (1.95)	4.30 (2.29)	8.93 (3.15)	10.44 (3.38)	14.07 (3.88)
Control	9.52 (3.24)	9.60 (3.26)	11.84 (3.58)	12.85 (3.72)	12.97 (3.74)	13.64 (4.08)
C.D (0.05)	(0.478)	(0.618)	(0.676)	(0.779)	(0.917)	(0.389)

Figures in parentheses are $\sqrt{x+1}$ transformed values

One week after spraying, all the experimental plots recorded a representative population of spiders. The control plot still recorded the highest population of 12.85 spiders, which was on par with the NSKE 5 per cent treated plot (8.93). The treatments neem oil 2 per cent and imidacloprid 0.005 per cent recorded equal number of spiders *i.e.,* 2.82. Relatively lower population was recorded from the treatments azadirachtin 0.004 per cent, acephate 0.05 per cent, triazophos 0.04 per cent and quinalphos 0.05 per cent were found detrimental to the spiders and recorded 1.40, 0.30, 0.30 and 0.30 spiders respectively and were statistically on par.

The control plot recorded significantly higher population (12.97) of spiders ten days after spraying. The plots treated with the neem formulations recorded relatively higher population of spiders. Neem oil 2 per cent, NSKE 5 per cent and azadirachtin 0.004 per cent recorded 11.55, 10.44 and 6.92 spiders, respectively and were on par. The synthetic insecticides *viz.,* imdiacloprid 0.004 per cent (3.78), acephate 0.05 per cent (1.74), quinalphos per cent (1.31) and triazophos per cent (0.91) recorded relatively lower population of spiders and were on par.

Fifteen days after insecticidal treatment, the control plot recorded higher number of spiders (15.64), which was on par with the population obtained from the NSKE 5 per cent treated plot (14.07). The neem oil 2 per cent treated plot was on par with that of azadirachtin 0.004 per cent treatment, which recorded a population of 12.59 and 9.94 spiders, respectively. A mean number of 7.49 spiders was obtained from the imidacloprid 0.005 per cent treated plot, followed by the acephate 0.05 per cent treatment (4.66). Relatively lower popoulation of spiders was observed in the treatments, quinalphos 0.05 per cent (3.58) and triazophos 0.05 per cent (2.55) which were on par.

4.4.2.2 Effect on insect natural enemies

One day after the application of treatments, there was significant reduction in the population of the insect natural enemies in the treated plots when compared to the control plot, which recorded a very high population (20.97). The plots treated with

NSKE 5 per cent (6.28) and neem oil 2 per cent (4.59) were on par in the population of insect natural enemies recorded. The treatments *viz.,* azadirachtin 0.004 per cent and imidacloprid 0.004 per cent were on par, the population being 2.48 and 1.94, respectively. However, significant reduction in the population of insect natural enemies was observed in the plots which received quinalphos 0.05 per cent (0.63) and triazophos 0.05 per cent (0.30) spray. Plots treated with acephate 0.05 per cent recorded no insect natural enemies.

Three days after spraying, the control plot (20.17) recorded significantly high population of insect natural enemies, followed by NSKE 5 per cent treated plots with a population of 12.95. The treatments *viz.,* neem oil 2 per cent imidacloprid 0.005 per cent and azadirachtin 0.004 per cent resulted in a population of 7.29, 4.55 and 4.18 insect natural enemies respectively and were statistically on par and differed significantly from the control plot and the treatment NSKE 5 per cent. The population recorded by the other treatments, *viz.,* quinalphos 0.05 per cent, acephate 0.05 per cent and triazophos 0.05 per cent were 0.91, 0.30 and 0.30, respectively and were on par.

Five days after the application of the insecticides and botanicals, the control plot and the treatments NSKE 5 per cent differed significantly from the other treatments and recorded high population of 21.30 and 11.88, respectively. The neem formulations, neem oil 2 per cent and azadirachtin 0.004 per cent and the synthetic insecticides imidacloprid 0.004 per cent, recorded a population of 8.93, 6.92 and 5.56, respectively and were on par. However, the chemical pesticide treatments *viz.,* acephate 0.04 per cent, quinalphos 0.05 per cent and triazophos 0.05 per cent were found to be detrimental to the insect natural enemies, which recorded a population of 1.64, 1.49 and 0.63, respectively.

One week after the treatments, the control plot and the NSKE 5 per cent treated plots still recorded significantly higher population of 21.30 and 13.19 insect natural enemies, respectively. The treatment neem oil 2 per cent (10.24) was on par

Table 22 Effect of synthetic insecticides and neem formulations on insect natural enemies when sprayed in the field.

Treatments	Number of insect natural enemies per ten sweeps					
	1DAS	3DAS	5DAS	7DAS	10DAS	15DAS
Acephate 0.05%	0 (1.00)	0.30 (1.14)	1.64 (1.63)	3.25 (2.06)	2.32 (1.82)	7.49 (2.91)
Imidacloprid 0.005%	1.94 (1. 72)	4.55 (2.35)	5.56 (2.56)	10.19 (3.34)	8.92 (3.15)	16.24 (4.15)
Triazophos 0.05%	0.30 (1.14)	0.30 (1.14)	0.63 (1.28)	0.91 (1.38)	2.26 (1.80)	5.44 (2.54)
Quinalphos 0.05%	0.63 (1.28)	0.91 (1.38)	1.49 (1.58)	2.22 (1.79)	2.82 (1.95)	6.92 (2.81)
Azadirachtin 0.004%	2.48 (1.87)	4.18 (2.28)	6.92 (2.81)	7.14 (2.85)	14.96 (3.99)	14.11 (3.89)
Neem oil 2%	4.59 (2.37)	7.29 (2.88)	8.93 (3.15)	10.24 (3.35)	14.53 (3.94)	20.97 (4.69)
NSKE 5%	6.28 (2.70)	12.95 (3.74)	11.88 (3.59)	13.19 (3.77)	18.25 (4.39)	24.27 (5.03)
Control	20.97 (4.69)	20.17 (4.60)	21.30 (4.72)	21.30 (4.72)	21.24 (4.72)	26.63 (5.26)
C.D (0.05)	(0.514)	(0.672)	(0.705)	(0.634)	(0.811)	(0.766)

Figures in parentheses are $\sqrt{x+1}$ transformed values

with imidacloprid 0.005 per cent (10.19) and azadirachtin 0.004 per cent (7.14). The other treatments *viz.*, acephate 0.05 per cent, quinalphos 0.05 per cent and triazophos 0.05 per cent resulted in a population of natural enemies in the range of 0.91- 3.25 and were statistically on par.

Ten days after spraying, the population recorded from the treated plots *viz.*, NSKE 5 per cent (18.25) and azadirachtin 0.004 per cent (14.96) were on par with the control plot (21.24). The treatments neem oil 2 per cent and imidacloprid 0.005 per cent were on par and recorded a population of 14.53 and 8.92 insect natural enemies respectively. The population obtained from the plot treated with quinalphos 0.05 per cent (2.82) was on par with acephate 0.05 per cent (2.32) and triazophos 0.05 per cent (2.26).

At fifteen days after spraying, the treatments NSKE 5 per cent (24.27) and neem oil 2 per cent (20.97) were on par with the control plot (26.63) and recorded very high population of insect natural enemies. The population observed in the plot treated with imidacloprid 0.005 per cent (16.24) was on par with that of the plot with the treatment azadirachtin 0.004 per cent (14.11). The treatments *viz.*, acephate 0.05 per cent, quinalphos 0.05 per cent and triazophos 0.05 per cent were on par and the population collected being 7.49, 6.92 and 5.44 insect natural enemies, respectively.

4.4.2.3 Effect on pests

Twenty four hours after spraying significant reduction in the pest population was observed in the treatments *viz.*, imidacloprid 0.005 per cent, triazophos 0.05 per cent, quinalphos 0.05 per cent, acephate 0.05 per cent, neem oil 2 per cent, azadirachtin 0.004 per cent and NSKE 5 per cent when compared to the control plot. In the plot treated with imidacloprid 0.005 per cent, no pests were observed. The treatments *viz.*, triazophos 0.05 per cent, quinalphos 0.05 per cent, acephate 0.05 per cent and neem oil 2 per cent recorded a population of 0.55, 0.63, 0.91 and 1.59 pests, respectively and were on par. The population of pests collected from the azadirachtin 0.004 per cent (3.78) treated plot was on par with that of the NSKE 5 per cent (4.89).

Three days after the application of treatments, the plot treated with imidacloprid 0.004 per cent recorded no pests. The number of pests collected from the treatments quinalphos 0.05 per cent (0.91), triazophos 0.05 per cent (1.17), acephate 0.05 per cent (1.21), NSKE 5 per cent (3.13) and neem oil 2 per cent (3.78) were relatively very low when compared to the control plot and were on par. The population of pests collected from the azadirachtin 0.004 per cent treated plot was 6.61 and the control plot (56.19) recorded significantly very high population of pests when compared to the treatment plots.

At five days after spraying, the treatment imidacloprid 0.005 per cent recorded no pests. The synthetic insecticides quinalphos 0.05 per cent, triazophos 0.05 per cent and acephate 0.05 per cent recorded a population of 2.32, 2.22 and 1.59 pests, respectively and were statistically on par. The neem treatments *viz.*, NSKE 5 per cent, neem oil 2 per cent and azadirachtin 0.004 per cent were on par and the population obtained being 8.24, 6.19 and 5.17, respectively. The control plot (52.84) recorded significantly high population of pests.

One week after the application of chemicals and botanicals the control plot (54.25) recorded significantly high population of pests, followed by the treatment, NSKE 5 per cent which recorded a population of 11.55 pests and differed significantly with the other treatments. Relatively lower population was observed in the plots treated with neem oil 2 per cent, acephate 0.05 per cent, quinalphos 0.05 per cent, triazophos 0.05 per cent, azadirachtin 0.004 per cent and imidacloprid 0.005 per cent when compared with the control plot and the population being 7.49, 6.61, 6.28 and 4.29 pests, respectively and were on par.

Ten days after treatment of chemicals and botanicals, the same trend observed at one week after spraying was noticed. Significantly lower population of pests was obtained from the treatments *viz.*, neem oil 2 per cent (17.01), triazophos 0.05 per

Table 23 Effect of synthetic insecticides and neem formulations on the pests when sprayed in the field.

Treatments	Number of pests per ten sweeps					
	1DAS	3DAS	5DAS	7DAS	10DAS	15DAS
Acephate 0.05%	0.91 (1.38)	1.21 (1.48)	1.59 (1.61)	6.61 (2.76)	10.31 (3.36)	11.25 (3.50)
Imidacloprid 0.005%	0 (1.00)	0 (1.00)	0 (1.00)	4.29 (2.30)	9.86 (3.30)	10.83 (3.44)
Triazophos 0.05%	0.55 (1.24)	1.17 (1.47)	2.22 (1. 79)	6.28 (2.70)	14.04 (3.88)	17.58 (4.31)
Quinalphos 0.05%	0.63 (1.28)	0.91 (1.38)	2.32 (1.82)	6.61 (2.76)	10.61 (3.41)	12.62 (3.69)
Azadirachtin 0.004%	3.78 (2.19)	6.61 (2.76)	5.17 (2.48)	6.11 (2.67)	12.41 (3.66)	18.87 (4.46)
Neem oil 2%	1.59 (1.61)	3.78 (2.19)	6.19 (2.68)	7.49 (2.91)	17.01 (4.24)	23.54 (4.95)
NSKE 5%	4.89 (2.43)	3.13 (2.03)	8.24 (3.04)	11.55 (3.54)	17.63 (4.32)	21.96 (4.79)
Control	52.27 (7.30)	56.19 (7.56)	52.84 (7.34)	54.25 (7.43)	52.60 (7.32)	54.95 (7.48)
C.D (0.05)	(0.674)	(0.805)	(0.596)	(0.901)	(1.002)	(0.871)

Figures in parentheses are $\sqrt{x+1}$ transformed values

cent (14.04), azadirachtin 0.004 per cent (12.41), quinalphos 0.04 per cent (10.61), acephate 0.04 per cent (10.31) and imidacloprid 0.005 per cent (9.86) when compared to the control and were on par. The control plot (52.60) and the treatment NSKE 5 per cent (17.63) recorded higher population of pests and differed significantly with the other treatments.

At fifteen days after spraying, the chemical treatments *viz.*, triazophos 0.05 per cent, quinalphos 0.05 per cent, acephate 0.05 per cent and imidacloprid 0.004 per cent recorded relatively lower number of pests, *i.e.*, 17.58, 12.62, 11.25 and 10.83, respectively and were on par when compared to the control. The neem formulations *viz.*, neem oil 2 per cent (23.54) was on par with the other two treatments, NSKE 5 per cent (21.96) and azadirachtin 0.004 per cent (18.87) recorded lower number of pests when compared to the control plot which recorded significantly higher population of 54.95 pests.

Discussion

5. DISCUSSION

Rice, the most important crop of Kerala, is infested by a range of pests. The practice of over pouring of chemical pesticides for pest management in the crop is on the verge of extinction due to 'poisonous cultivation and production' and the related hazards caused to mankind and his environment. Notwithstanding, the changing status of insect pests, pest resurgence and inundation of biotypes instigated by the misuse of the chemicals add up to deterioration of safe cultivation of rice.

A growing need to switch over to newer modes of pest management and the urge for organic farming has ushered in the need for pesticide free, environmentally safe strategies of crop protection, preferably, natural biological control for better rice production. Rice fields are enriched with diverse groups of natural enemies, *viz.,* predators, parasitoids and pathogens. Among the predators, spiders are the least explored natural enemy. As generalists, spiders are ingenious predators and their inherent ability to regulate pest numbers is ineffable and thus heaves the role of these carnivorous arthropods in rice pest management. These multi-predator complexes, can be exploited effectively for reducing the multi-prey complex in the rice fields (Nentwig, 1982). The strange nature of the hunting spiders and the magnificent webs of the web builders vanquish the diverse pest species in rice ecosystem. Additionally, spiders in a particular guild could be enhanced to go after a particular kind of pest and the density of the spiders required is very less compared to the vast numbers of pest species. In order to optimize natural biological control utilizing spiders, full investigation on the distribution of the arachnofauna in the rice ecosystem, their foraging strategies and the effect of chemical and botanical pesticides on the araneae is of paramount importance. Based on the information gathered, a novel strategy of pest management in rice by incorporating spiders in IPM and conservation biological control could be developed and made useful to farmers.

5.1 SPIDERS IN RICE ECOSYSTEM

The study conducted to document the abundance and diversity of spiders in rice ecosystem indicated that rice fields harbour a vast assemblage of spiders. Sixty five species distributed in the two major foraging groups *viz.,* hunters and web builders and seven guilds were recorded from the rice fields. Though high population of the web builders prevailed in the fields, the species – wise distribution indicated that the hunters constituted 53.85 per cent of the total spider species, while the web builders contributed 46.15 per cent (Fig. 1) of the species. The hunters which follow a 'pursue and kill' foraging strategy, comprised of the guilds stalkers (SK), ground runners (GR), ambushers (AB) and foliage runners (FR), while the web builders which adopt a passive 'sit and wait' strategy for prey capture included the guilds orb web weavers (OWW), scattered line weavers (SLW) and sheet web builders (SWB). Among the seven guilds, the orb web weavers comprising of 41.54 per cent of the species predominated in the rice ecosystem followed by stalkers (27.69 per cent), ground runners (9.23 per cent), ambushers (9.23 per cent) and foliage runners (7.70 per cent) (Fig 2). Sheet web builders (3.08) and scattered line weavers (1.54) were the less represented guilds in the rice fields.

The spiders documented belonged to eleven families *viz.,* Tetragnathidae, Araneidae, Theridiidae, Agelenidae, Linyphiidae, Salticidae, Oxyopidae, Lycosidae, Thomisidae, Miturgidae and Clubionidae (Fig. 3). The family with more species composition was Araneidae (24.62 per cent) which represented 16 species out of the total spiders collected, followed by Salticidae (21.54 per cent) with 14 species and Tetragnathidae (16.92 per cent) with 11 species. Lycosidae and Thomisidae each accounted for 9.23 per cent of the species recorded and Oxyopidae constituted 6.15 per cent of the total spiders collected. The other families were recorded in very low numbers and ranged in between 1.54 – 4.62 per cent.

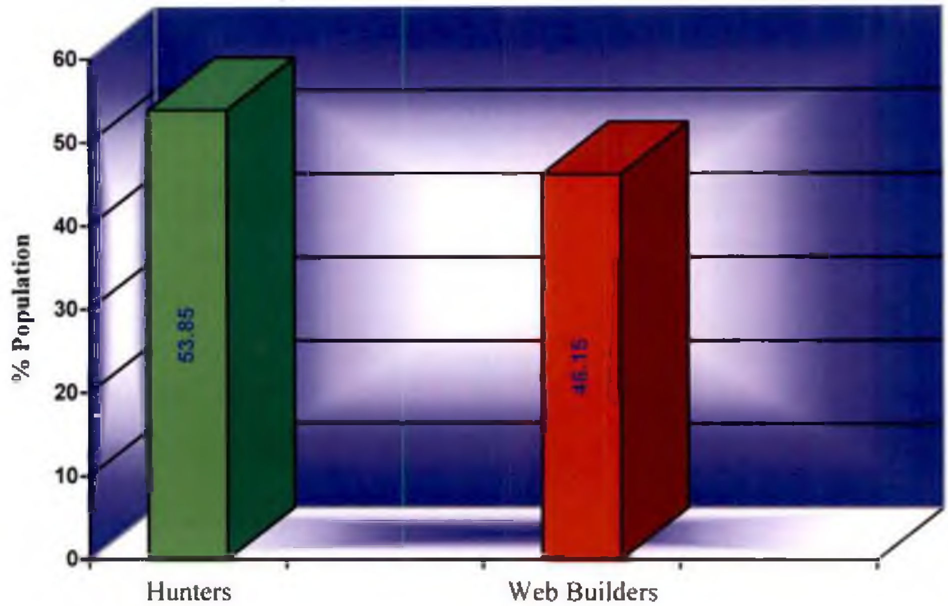


Fig.1. Species composition of hunters and web builders in the rice fields

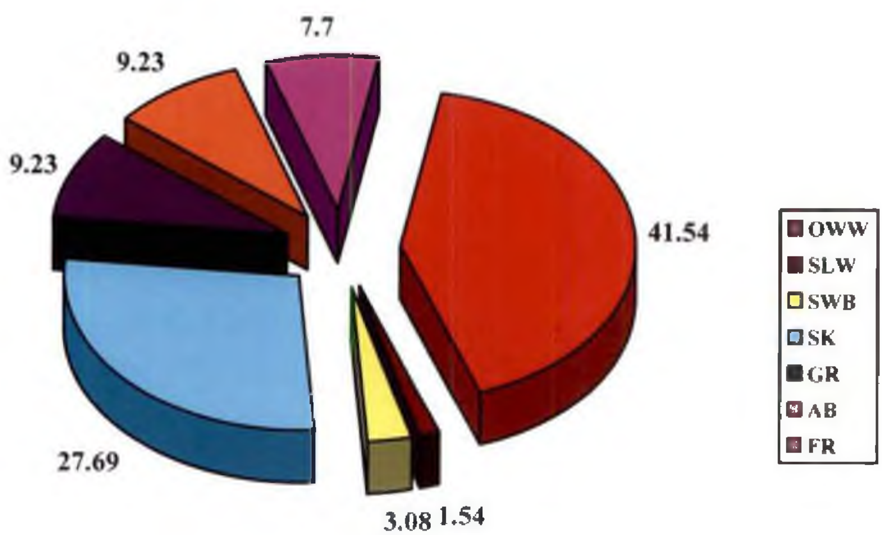


Fig.2. Guild structure of the spiders in rice fields

The spiders identified represented 33 genera. *Tetragnatha* was the predominant genus (27.27 per cent) and represented wide diversity (Fig. 4). It was followed by *Argiope*, *Neoscona* and *Pardosa* each of which accounted for 12.12 per cent of the total genera documented. The other important genera observed included *Telamonia* (3.03), *Bianor* (6.06), *Oxyopes* (9.09), *Peucetia* (3.03) and *Thomisus* (9.09). The dominance of the genus *Tetragnatha* in rice ecosystem has been reported earlier (Murata, 1995; Thakur *et al.*, 1995; Vungsilabutr, 1998; Kraker *et al.*, 1999; Sigsgaard, 2000).

Among the 65 species of spiders observed, seventeen species *viz.*, *T. viridorufa*, *N. rumpfi*, *Agelena* sp., *B. carli*, *E. indicus*, *B. kairali*, *T. bhamoensis*, *C. vidus*, *M. plataleoides*, *Matidia* sp., *C. danieli*, *Runcinia* sp., *Xysticus* sp., *Misumena* sp., *T. projectus*, *T. pugilis* and *P. amkhaensis* were recorded for the first time from the paddy fields of Kerala. Among these *N. rumpfi*, *B. carli* and *T. projectus* were dominant in the field. Most of these species were hunters, the group which is usually found in lesser numbers in paddy fields. Probably, the food resources and the crop environment during the period had a positive impact on the hunting spiders, which are more attracted to moving and active prey.

The investigation revealed that fifteen species of spiders occurred regularly in the rice fields. This included five species of *Tetragnatha viz.*, *T. mandibulata*, *T. maxillosa*, *T. javana*, *T. viridorufa* and *T. vermiformis*. Among them *T. mandibulata* was the most dominant species found followed by *T. maxillosa*. Bhardwaj and Pawar (1987 b) and Thakur *et al.* (1995) also observed that *T. mandibulata* was the predominant species in the rice fields. *A. anasuja* and *N. rumpfi* were the predominant araneid spiders recorded. The prominent salticids were *T. dimidiata* and *B. carli*. Out of the oxyopid spiders documented *O. javanus* and *P. viridana* were the most represented. *O. shweta* too occurred regularly in the field. *P. pseudoannulata* was the most populated dominant lycosid, Sigsgaard and Villareal (1999) observed this in the irrigated rice fields of Philippines and among the ambushers, *T. projectus* was

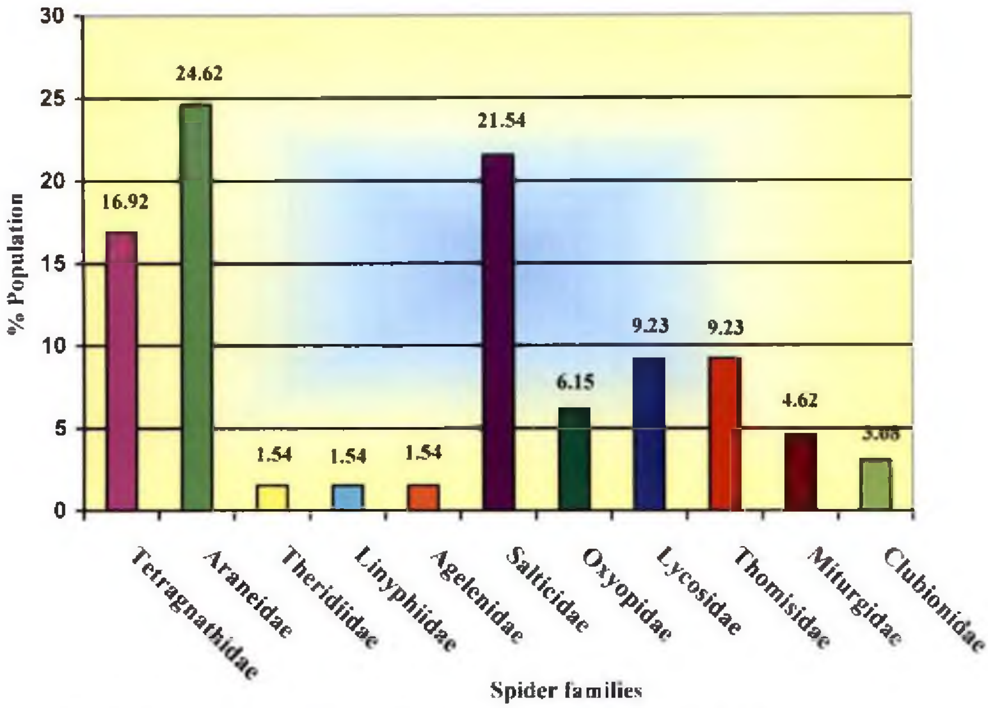


Fig. 3. Species composition of different spider families in the rice fields

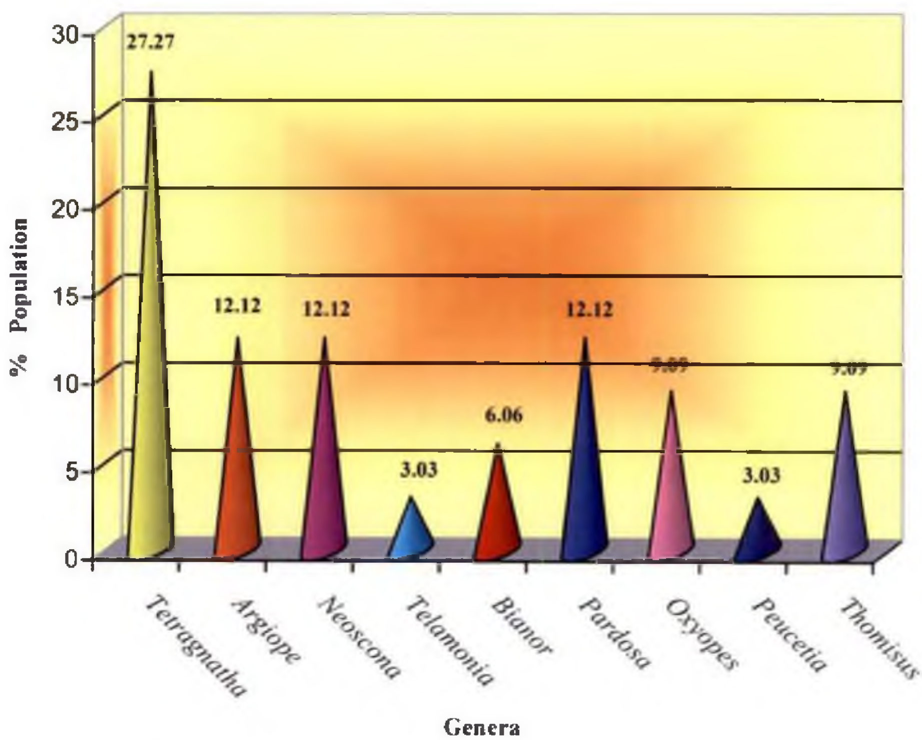


Fig. 4. Species composition of dominant spider genus in the rice ecosystem

the most encountered spider species. The other species found in the paddy field through out the crop season was *Theridion* spp. The spiders which were encountered rarely in the paddy ecosystem were *Dyschiriognatha* sp., *Eriovixia* sp., *C. citricola, G. geminata, Linyphia* sp., *Agelena* sp., *Myrmarachne* sp. and *Thomisus* sp. The rest of the spiders were seen either frequently or occasionally in the crop ecosystem. Even in the rice nursery spiders were found inhabiting the micro niche. The species *T. mandibulata, T. maxillosa, T. javana, T. viridorufa, T. cochinensis, N. rumpfi, Theridion* spp., *H. semicupreus* and *O. javanus* were the major species collected from the paddy nursery. Certain spiders, particularly the ambushers were found to be stage specific, with the spiders appearing in more numbers when the crop was in the flowering stage. The increased pest activity in the field and availability of hiding places for camouflage of the spiders in the paddy inflorescence during the period, probably favoured the abundance of the guild during the period.

Spiders were collected from diverse habitats within the paddy field. Most of the spiders were collected from the crop canopy. They were also recorded from the field bunds, border weeds, and in the flood water. This is in agreement with similar observations made by Kamal *et al.* (1990), Tandon and Abraham (2000), Mathirajan (2001) and Fang *et al.* (2003).

Obviously the seven guilds of spiders possessing diverse prey capturing techniques play a key role in the regulation of pest population in rice fields. The orb web weavers which create geometrical snares called orb webs trap many insects. The scattered line weavers found lining silk over the crop canopy, capture small flying and walking insects, in the irregular mazes. The sheet web builders spin an irregular web and cling upside down beneath the web. When flying and jumping insects are dropped rather than trapped, the spiders run over the surface rapidly and pull the prey. The strongly built hunting spiders with keen sight, pursue and overpower their prey by strength, speed and alertness. The stalkers specialized for a life especially on plants with their precise prey capturing nature aided by keen eye sight are efficient specialist predators. They spy the prey at a distance, creep slowly forward until very near and leap suddenly upon the prey and pounce upon it with great strength. The ground runners are dominant predators and capture prey with vigour and power. Ambushers, well known for their camouflage in flowers and buds, catch prey in disguise or in ambush. The foliage runners are mostly seen on the foliage, inside or outside the nests built on individual leaves and trap the insects sitting on the leaves or on the stem. In short, these various guilds of spiders inhabiting complementary niches, leave only few refuges for the pests in the rice fields.

Moreover most of the wet land paddy field inhabiting spiders possesses amazing adaptations which enable better survival of the spiders. Many spiders were found swimming through the surface of the water. *P. pseudoannulata* possessed the ability to swim and dive in water and hide under water. Similar observations were made earlier by Morrill and Rubia (1990). All the tetragnathids had the habit of hoping through the water surface like water striders. The ambushing spiders especially, *T. projectus* had the ability to move along the waves in the water and thus moved from one plant to another. In short, the diversity within the different species, within the family, between the families, between the genera and between the guilds, in predation, prey capturing, adaptation and habitat selection are factors which render spiders, as potential dominant predators in agro ecosystems.

5.2 SEASONAL OCCURRENCE OF ARTHROPODS

The occurrence of the spiders did not show any remarkable difference during the virippu and mundakan seasons (Fig. 5). Spiders belonging to the eleven families observed during the random survey prevailed in the field during both the seasons. Among the different families, Tetragnathidae, Araneidae, Salticidae, Lycosidae, Oxyopidae and Thomisidae were more populated. Only a few spiders were recorded in the families Theridiidae, Linyphiidae, Agelenidae, Miturgidae and Clubionidae. Family Tetragnathidae maintained fairly high population through out the crop period

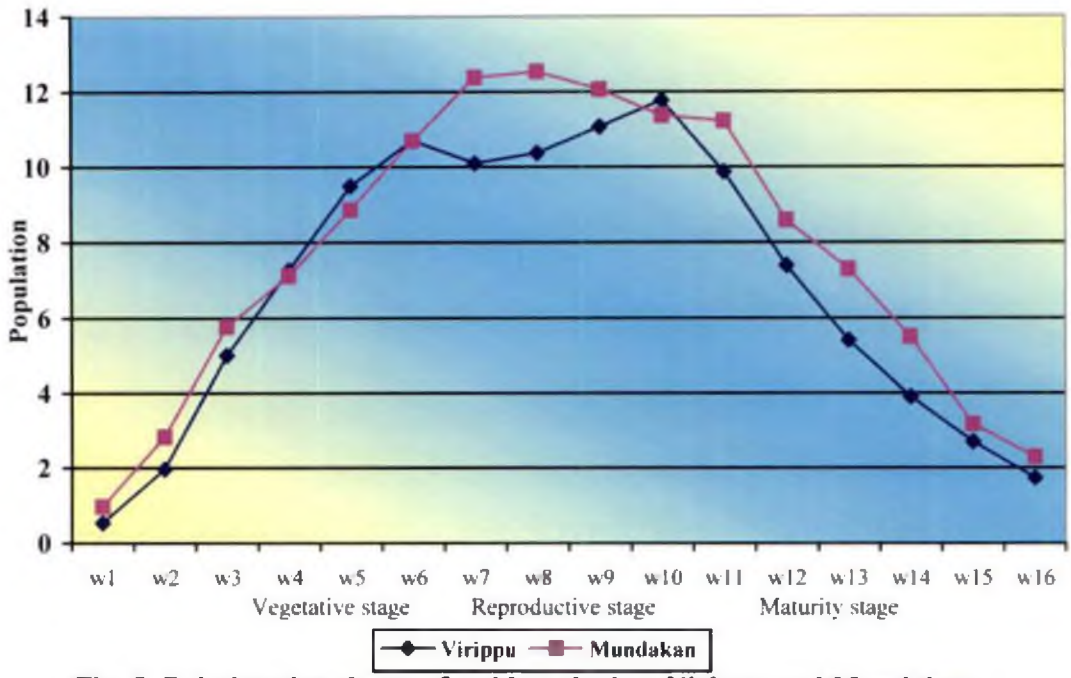


Fig. 5. Relative abundance of spiders during Virippu and Mundakan seasons

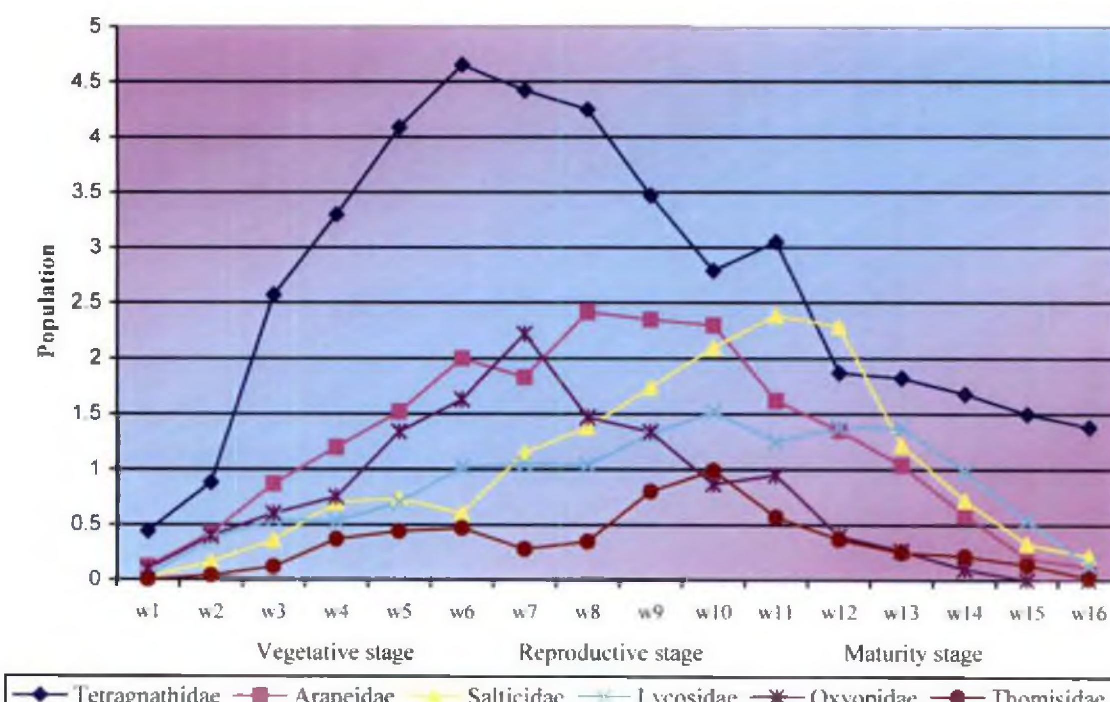


Fig. 6. Seasonal distribution of the six major families during the two crop periods

followed by Araneidae and Salticidae. This is in concordance with the earlier studies conducted by Murata (1995) and Thakur *et al.* (1995).

The growth stages of the crop had a remarkable influence on the abundance and diversity of the spiders. The spider population gradually increased during the early crop growth stage, built up to a maximum and reached a peak during the reproductive stage of the crop and later the population declined with the senescence of the crop. The observations made were in concordance with the findings of Heong *et al.* (1992), Chander (2001) and Chander and Sing (2003). The vegetative and reproductive stages attracted more spiders than the maturity stages. This was due to the abundance of prey insects such as hoppers, bugs, lepidopterans etc. during the period. Earlier studies have also proved this [Cheng (1989); Heong *et al.* (1991 b); Chander (2001)]. Between the vegetative and reproductive stages, the reproductive stage harboured more spiders. Lekha (2003) made similar observation. The occurrence of the six major families at different crop stages differed greatly (Fig. 6). Tetragnathid spiders were observed right from one week after transplanting till the harvest of the crop. The small to medium sized web builder mostly preferred the space in between the plants rather than the lush growth of the paddy plants for web construction and its subsistence was supported by the neutrals in the early days of crop establishment. The maximum population was observed during the reproductive stage (Fig. 7). A total population of 15.92, 17.97 and 8.24 spiders was recorded during the vegetative, reproductive and maturity stages, respectively. The population of araneids was low in the early crop growth stage, when compared to the tetragnathids probably due to the non – availability of webbing sites since most araneids build large webs between three or four plants. The peak population of the spiders was observed during the reproductive stage. The total population of araneids recorded was 6.12, 10.51 and 3.29 during the vegetative, reproductive and maturity stages, respectively. Very low population of the salticid spiders was observed in the early stage of the crop. Higher population was observed in the reproductive stage

(8.75), the peak population being recorded at the late reproductive stage. The vegetative and maturity stages recorded 2.55 and 4.76 spiders, respectively. The lycosid spiders followed a similar trend as that of salticids. Maximum population was observed during the reproductive stage (6.17) and the vegetative and maturity stages recorded 3.20 and 4.40, respectively. Both salticids and lycosids recorded more population in the maturity stage than the vegetative stage. The population of oxyopids built up slowly in the early vegetative stage and increased during the late vegetative stage and the peak population was observed during the early reproductive stage. Towards the later stages, the population decreased and during the senescence stage of the crop practically no oxyopids were encountered in the field both during the two seasons. The population recorded was 4.82, 6.84 and 0.77 spiders in the vegetative, reproductive and maturity stages, respectively. Thomisid spiders were recorded in less numbers during the vegetative stage (1.42) and the population increased in the reproductive stage (2.98) and the peak was observed after flowering. The maturity stage recorded very low population (0.99).

Presumably, the spiders migrated into the rice field from the adjacent fields or adjoining weed flora, once the crop is established. Depending on the foraging habit, their influx into the crop field varied in time and space. Consequent to their appearance in the crop field, egg laying and mass multiplication would have taken place in the natural habitat and the population flared up. Earlier studies by Anbalagan and Narayanasamy (1999), Cruz and Litsinger (1986), Shepard *et al.*(1989), Venkateshalu *et al.* (1998) proved this. Thus, the increase in the population of the spiders was directly related to the crop growth stages and the pests associated with the different stages and this was in agreement with Thakur *et al.* (1995) and Kraker *et al.* (1999).

When the population of pests during both virippu and mundakan seasons was studied, the population was observed to build up by the late vegetative stage and reach maximum during the reproductive stage. Yasumatsu and Torii (1968) and

Heong *et al.* (1992) made similar observations. Among the pests, hoppers were the major group and maintained fairly good population through out the crop season. The major hopper was the green leaf hoppers, *Nephotettix* spp. The populations of bugs were more in the reproductive stage and then declined. During the maturity stage, the red spotted ear head bug, *M. histrio* appeared in large numbers. The population of insect natural enemies increased by the late vegetative stage and decreased during reproductive stage and again increased during the early maturity stage. This was due to the high population of the generalist predators during the early half of the crop period and the occurrence of parasitoids during the later stage of the crop. This was in conformity with the observations made by Settle (1994), Settle *et al.* (1996) and Nalinakumari and Hebsybai (2002) regarding the existence of higher numbers of detritus feeding generalists during early crop growth stages and the influx of parasitoids in the later phase of the crop. The population of neutrals was high during the early crop growth stages and declined afterwards.

The population of spiders was not influenced by the major weather parameters studied. Temperature, relative humidity and rainfall had no significant correlation with the spiders. Bhaskar (1999) had made similar observations. Hence the major factor which influenced the spider population was the crop growth stages and the pests associated with the crop which supported the predators and not the weather factors. Thakur *et al.* (1995) and Anbalagan and Narayanasamy (1999) had made similar conclusions.

Considering the relative distribution of the spiders, insect natural enemies and pests in the rice field during the period of study, while, the population of spiders was 35.62, 56.38 and 24.00 during the vegetative, reproductive and maturity stages, respectively, it was 78.60, 77.32, 74.57 for the insect natural enemies and 118.90, 252.27 and 189.09 for the pests, respectively (Fig. 8). The ratio of spiders to insect natural enemies and pests was 1:2.21:3.33 in the vegetative stage, in the reproductive and maturity stages were 1:3.11:7.88 and 1:1.37:4.47, respectively. Apparently, the

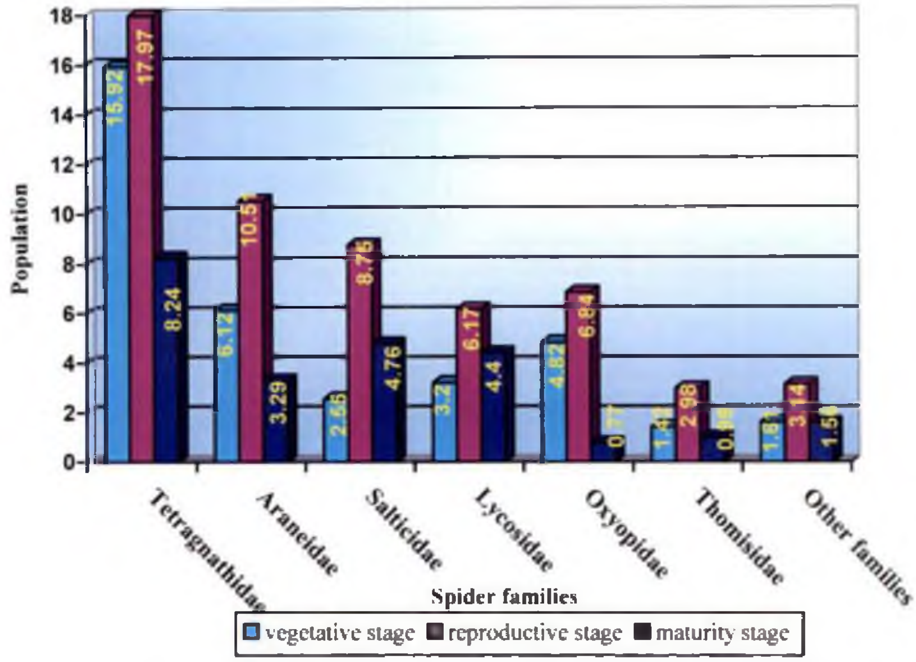


Fig. 7. Population of spiders during the vegetative, reproductive and maturity stages of the crop

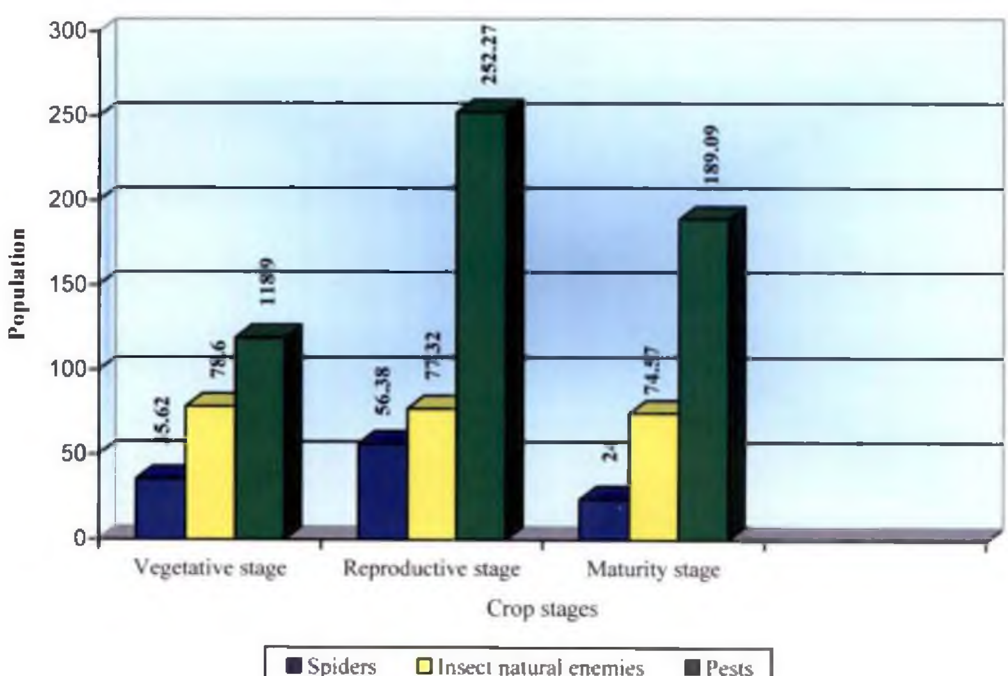


Fig. 8. Relative abundance of spiders, insect natural enemies and pests in the field during the vegetative, reproductive and maturity stages of the crop

spiders which contribute to the decimation of more number of prey insects by their varied mode of foraging activities than any other natural enemies could be positively correlated with effective pest control in the field. Spiders serve as buffers that limit the initial exponential growth of pest populations (Rajeswaran *et al.*, 2005). Through conservation of the spiders, natural biocontrol will be effectively executed in the rice fields. The neutrals helped these predators to thrive during the early crop stages, when the pest numbers were low. Later, the pest population increased, the population of neutrals declined, ample supply of food for spiders. Thus a natural balance was maintained through out the cropping period. In such a robust naturally maintained field, pest problem will be less.

5.3 PREDATORY EFFICIENCY

The ten spiders showed a definite preference for the different hoppers, bugs and lepidopterans when evaluated for their prey preference. The spiders *A. anasuja, P. viridana, T. dimidiata* and *T. projectus* broadened their preference to the Orthopteran and Coleopteran pests (Fig. 9).

Out of the different groups of pests tested, all the ten spiders exhibited almost equal preference for the hopper prey, the relative preference for the pest ranging from 9.47 to 13.61. In a mixed diet of both adults and nymphs of the hoppers, *viz., N. lugens*, *Nephotettix* spp., *C. spectra*, *S. furcifera* and *R. dorsalis*, the spiders consumed more adults than the nymphs, probably to meet their dietary requirements. Among the ten spiders the highest preference for the hoppers was shown by the ambushing spider, *T. projectus*. The most preferred hopper was adults of green leaf hoppers. The two tetragnathids significantly preferred higher number of adults of *Nephotettix* spp. The observation agreed with the earlier reports on the preference of tetragnathid spiders for *Nephotettix* spp. (Samiayyan and Chandrasekharan, 1998 a). Other spiders preferring *Nephotettix* spp. was *T. dimidiata*. The nymphs and adults of *N. lugens* were more preferred by *P. pseudoannulata*. The spider is considered to be the most important predator of BPH (IRRI, 1973; Dyck and Orlido, 1977; Bhardwaj and Pawar,

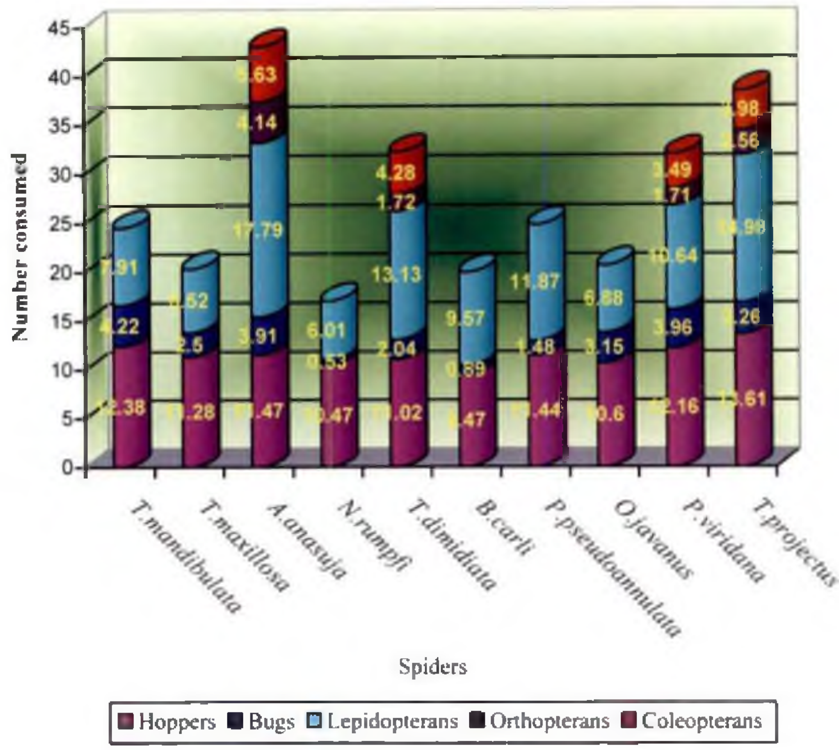


Fig. 9. Relative preference of spiders in rice ecosystem for various pests

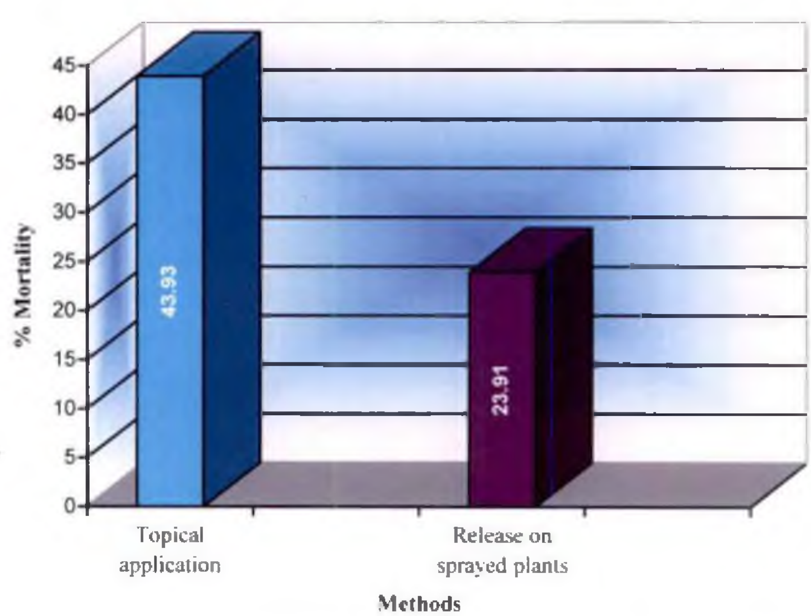


Fig. 10. Mortality of spiders when the synthetic insecticides and botanicals were topically applied and released on treated plants

1986). Others preferring *N. lugens* were *O. javanus* and *P. viridana*. With the exception of *N. rumpfi* which consumed in general from the mixed diet of hoppers almost equally and more preference was shown for adults of *N. lugens* and *S. furcifera* and the nymphs of *R. dorsalis*. *C. spectra* were more preferred by *A. anasuja, B. carli* and *T. projectus*. Spiders in rice fields are the major natural enemies of hoppers, because of their higher preference for the prey (IRRI, 1980; Gupta and Pawar, 1989). The relative preference for the bugs ranged between 0.53 – 4.22. Among the bugs, the soft bodied nymphs were more preferred than the adults. The nymphs of *L. acuta* were the most preferred prey and *T. mandibulata* recorded the highest preference for the bugs. Significant difference was observed among the spiders in their preference for the lepidopteran pests, the rate of consumption ranging from 6.01 – 17.79 per day. Generally the moths were more preferred than the caterpillars. The moths of rice leaf roller were the most preferred and accepted lepidopteran diet. The araneid, *A. anasuja* had the highest preference for the lepidopteran pests. The hunting spiders had comparatively more preference for the lepidopteran pests than the web builders. The spiders *A. anasuja, P. viridana, T. dimidiata* and *T. projectus* fed on the orthopteran and coleopteran pests. The relative preference for the orthopteran and coleopteran pests for the four spiders ranged from 1.71 – 4.14 and 3.49 – 5.63, respectively. *A. anasuja* preferred more orthopteran and coleopteran pests. This was on par with the observation made by Garg *et al.* (2002) about the preference of *Argiope* sp. to grass hoppers and crickets.

When the predatory potential of the spiders was analyzed, it was found that the spiders which consumed more number of prey insects per day in a mixed diet took comparatively lower numbers of hoppers when the prey insects were provided individually. As observed in the prey preference studies, the adult hoppers, nymphs of bugs and adult lepidopterans were more preferred than their nymphs, adults and caterpillars, respectively, when provided individually. While the per day consumption ranged from 9.47 – 13.61 when provided with a mixed diet, the rate of predation ranged from 0.00 – 16.11 when supplied individually. However, with the exception of *N. rumpfi*, all the other spiders satisfied their per day dietary requirements by consuming the adults of *N. lugens* and *Nephotettix* spp. *A. anasuja*, *P. viridana* and *T. projectus* predated on the adults of *S. furcifera* and *C. spectra* additionally. *N. rumpfi* which consumed nearly 10.47 hoppers per day from a mixed diet refrained from consuming at the same rate when the prey was provided individually. The spider was found to favour a mixed diet more to meet its daily requirement. The per day consumption of bugs ranged from 0.53 – 4.22 when provided with a mixed diet. But when provided individually, except *T. projectus* and *O. javanus*, the other spiders consumed almost at the same rate. The lepidopteran pests were consumed @ 6.01 – 17.79 per day by the spiders, but when supplied individually, the rate of consumption was very low and ranged between 0.29 – 8.91. The per day consumption of orthopteran and coleopteran pests by the four spiders ranged between 1.71 – 4.14 and 3.49 – 5.63, respectively but when forced to feed the prey individually, the consumption was relatively low as in the case of other pests.

From this, it can be concluded that the spiders preferred feeding from a mixed diet, which is similar to the natural condition in the field. As generalists, they feed on any prey insect, in the near vicinity, preferably one with more body fluid. By utilizing the diverse prey capturing techniques the spiders consume all types of prey insects, including pests, insect predators and neutrals. The study also indicated that even when provided with a mixed diet and the spider had to choose from among them, the choice was mostly biased towards the most preferred prey. The wide range of prey substrates of the diversified spider groups is significant, since the trait renders them as potential defenders in rice ecosystem capable of maintaining pest population at a manageable level.

Considering hyper predation, the highest rate of cross predation was recorded for *P. viridana* and the lowest for *N. rumpfi*. The most predated insect predator was *C. lividipennis*. Earlier reports by Salim and Heinrichs (1986 a) , Heong *et al.* (1989 and

1991 a), Rubia *et al.* (1990), Ganeshkumar and Velusamy (1996 b), supported the hyper predation of spiders on *C. lividipennis*. Reportedly, the insect predator was consumed @ 22 per day (Heong *et al.*, 1989). Hyper predation is considered to be a means of survival of spiders when the prey is scarce. Hence, hyper predation is thought to be a competitive interaction in a robust ecosystem (Sunderland, 1999). Interestingly the spiders did not consume any of the hymenopterans tested. The result was contradictory to the observations of Heong *et al.* (1989) who reported that the spiders usually consume the hymenopteran parasitoids in the crop ecosystem and need further clarification.

5.4 EVALUATION OF SAFETY / TOXICITY OF SYNTHETIC INSECTICIDES AND BOTANICALS

Topical application of synthetic and botanical insecticides on spiders caused significantly higher mortality of spiders (43.98 per cent) than when the araneae were released on treated plants (23.91 per cent) (Fig. 10). The low mortality recorded when released on the treated surface, was probably due to lack of direct contact with the chemicals. The spiders came in contact with the toxicants only indirectly or either through intake of poisoned prey or by drinking water from field or plant caused the mortality of the spiders.

Out of the different synthetic insecticides evaluated, the most toxic was triazophos 0.05 per cent which caused significantly high mortality of the spiders, *i.e.*, 60.94 per cent (Fig. 11). The observation was in agreement with the study by Babu *et al.* (2002), but contradictory to the observation made by Pasalu *et al.* (2001), which suggested that the spray formulation of triazophos was safe to spiders. The mortality of spiders caused by quinalphos 0.05 per cent was 42.89 per cent, which was followed by acephate 0.05 per cent, the mortality being 36.39 per cent. The result was in conformity with Mandal and Somchoudhury (1994), who suggested that quinalphos caused highest spider mortality. Ku and Wang (1981) and Thang *et al.* (1987) reported that acephate was toxic to spiders and reduced the growth and predation of spiders, where as Fabellar and Heinrichs (1984), Ganeshkumar and Velusamy (1996c and 1997) and Gopan (2004), observed that acephate was safe to spiders. Imidacloprid 0.005 per cent caused 25.46 per cent mortality of the spiders and thus found to be a safer chemical when compared to others tested. The observation agreed with the findings of Mao and Liang (1995), Panda and Mishra (1998), Katole and Patil (2000), Kannan *et al.* (2004). Contrarily, Manjunatha and Shivanna (2001), Widiarta *et al.* (2001), Krishnaiah *et al.* (2003) and Lekha (2003) reported that the chemical was highly toxic to the spiders.

Among the neem products, the most toxic was azadirachtin 0.004 per cent, which caused relatively high mortality (34.77 per cent) and was almost similar to the synthetic chemical pesticides in its effect. Neem oil 2 per cent and NSKE 5 per cent were safe to the spiders, the mortality of spiders being 23.80 and 13.47 per cent, respectively. This was in agreement with the observations made by Babu *et al.* (1995), Samiayyan and Chandrasekharan (1998 b).

Imidacloprid was safer than azadirachtin, as proved by the relatively low mortality caused by the chemical and was on par with the effect of the neem formulations neem oil 2 per cent and NSKE 5 per cent in the laboratory.

Among the ten major spiders tested to evaluate the safety / toxicity of different chemicals, *A. anasuja* was the hardy spider with relatively very low mortality both for the synthetic insecticides and neem products (17.51 per cent), when compared to the other spiders (Fig. 12). *T. mandibulata* and *P. viridana* showed moderate resistance to the effect of the chemicals and neem formulations, and the mortality being 26.89 and 25.10 per cent, respectively. *N. rumpfi* was the most sensitive spider among the ten (58.35 per cent). Nearly cent per cent mortality on topical application with triazophos 0.05 per cent was observed. The mortality of the other spiders ranged between 31.63 – 42.16 per cent.

When the synthetic insecticides and botanicals were applied in the field, the spider population was greatly reduced when observed one day after spraying. This is

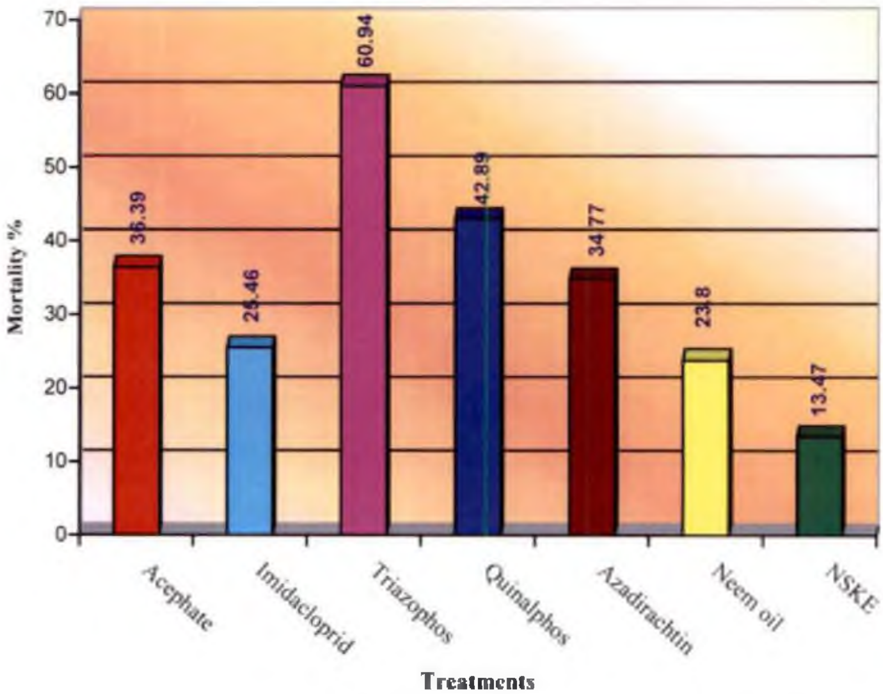


Fig. 11. Mortality of spiders when treated with different chemicals

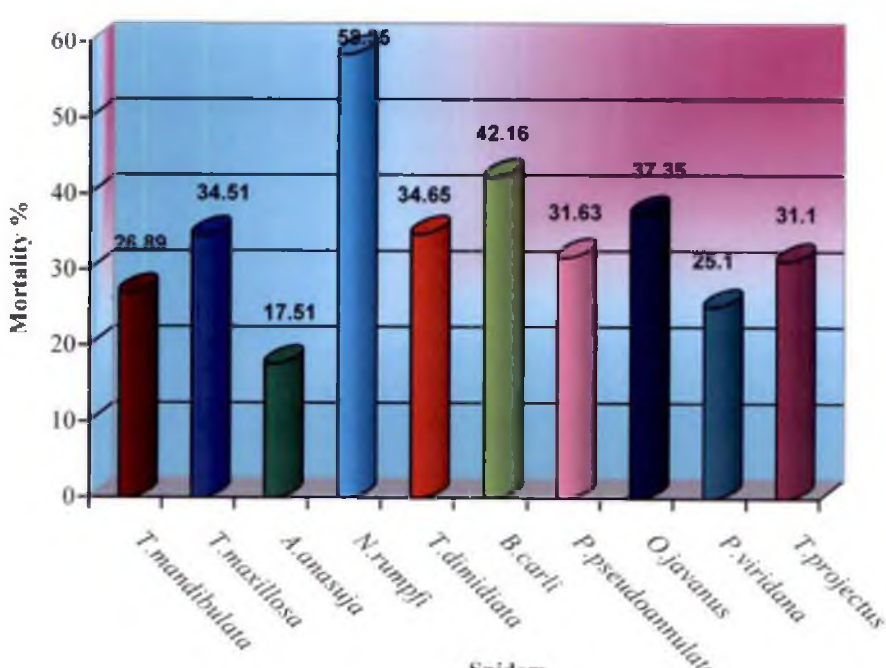


Fig. 12. Effect of synthetic insecticides and neem formulations on the major spiders

in agreement with the observations made by Yasumatsu and Torii (1968) regarding the reduction in the population of spiders after the application of chemicals. The population of spiders built up gradually and the recolonization became active, after ten days of treatment of the chemicals in the plots sprayed with imidacloprid 0.005 per cent, azadirachtin 0.004 per cent, neem oil 2 per cent and NSKE 5 per cent and the recolonization of spiders was better. The observation agreed with the earlier reports by Mohan *et al.* (1991), Dash *et al.* (2001), Lee and Kim (2001). The neem formulations were found to be safe to the spiders when compared to the synthetic pesticides, except imidacloprid, because an average population of spiders was maintained in these plots. Similar observations were made earlier by Samiayyan and Chandrasekharan (1998 b) and Rajeswaran *et al.* (2005). The earlier reports proved that the application of insecticides reduced the population density of spiders in rice fields (Kim, 1992; Yoon, 1997) and they had a negative effect not only on the number but also on species diversity (Lee *et al.*, 1993). The insecticides which protected the other natural enemies often had a deleterious impact on spiders (Clausen, 1990). Reports suggested that the hunting spiders suffered more damage than web builders (Bostanian *et al.*, 1984), while the active hunters suffered more than less active ones. The reduction in the population of spiders was not only because the spiders were killed by the insecticides, but because their prey was killed and due to lack of enough diet, which was the major influencing factor for the spiders to occupy a particular niche, the spiders migrated into other fields in search of food (Lee *et al.*, 1993).

When the insect natural enemies in the rice fields treated with chemicals was considered, as in the case of spiders, triazophos 0.05 per cent was found to be the most toxic, followed by quinalphos 0.05 per cent and acephate 0.05 per cent. The population was greatly reduced. But the neem formulations and imidacloprid 0.005 per cent was safer to them.

Regarding the pests in the treated fields, better suppression was brought about by imidacloprid 0.005 per cent. This is in concordance with the observation made by Panda and Mishra (1998) about the safety of the chemical to spiders and other natural enemies. The other chemicals, acephate 0.05 per cent and quinalphos 0.05 per cent moderately suppressed the pest population, followed by triazophos 0.05 per cent. The neem formulations partially reduced the pest population when compared to the chemical treatments.

In short, among the synthetic chemicals evaluated, imidacloprid 0.005 per cent was safer to spiders and insect natural enemies in the rice ecosystem and detrimental to the pests.

The present investigation brought to light that the rice fields are enriched with diverse arachnofauna, which could play a decisive role in pest regulation in the field. The web builders dominating in the field numerically. The ten dominant species collected was *T. mandibulata, T. maxillosa, A. anasuja, N. rumpfi, T. dimidiata, B. carli, P. pseudoannulata, O. javanus, P. viridana* and *T. projectus* represented six major families and nine dominant genera. *Tetragnatha* was the predominant genus and *T. mandibulata* was the most prominent species. The population of spiders was directly related to the crop growth stages and the pest population associated with the different stages rather than the weather parameters. The spiders consumed different groups of insects in the rice fields, the size ranging from small to large. The spiders recorded almost equal preference for the hoppers. The adults of the hoppers and lepidopterans were more preferred than the nymphs and larvae, respectively. Spiders chose to feed from among a multi prey complex, which resembled that of the natural ecosystem. *A. anasuja* was the potential predatory spider of the pests in rice fields as proved by its higher rate of consumption. And it recorded higher preference for all types of prey insects including the beetles and the grass hoppers apart from consuming. The most cross predated insect predator was *C. lividipennis* and the insect parasitoids were not consumed. Synthetic pesticides were found to be more toxic to spiders, as they caused higher mortality of spiders, except imidacloprid. Neem products were safer to spiders. *A. anasuja* had higher resistance to the chemicals, but *N. rumpfi* was the most sensitive spider. In the field situation, the recolonization of spiders was becoming active only after ten days of spraying. Imidacloprid was the spider friendly synthetic molecule and was safe to other beneficials in rice fields, but quite promising against pests.

It can be concluded that the individual spider species are unlikely to regulate the numerous pest populations in the rice fields, but when assembled into groups, representing various guilds with diverse prey capturing abilities, and adaptations, which is of prime importance in agricultural situation, they could contribute to significant reductions in pest numbers, which have a positive effect on crop production and is beneficial to farmers. Conservation of the spiders in rice fields is of utmost importance, through which natural biocontrol will be effectively executed in the rice fields by these generalists. Imidacloprid 0.005 per cent which proved to be a spider friendly pesticide which could be utilized for pest control when infestation is severe without harming the spider fauna.

Summary

6. SUMMARY

The rice fields are good sources of self depending ecosystems with a built - in mechanism of pest control with diverse groups of natural enemies. An investigation was carried out to explore the abundance and diversity of spiders in a rice ecosystem and to bring out the role the araneae could play in pest regulation in the field. The survey for documenting the spiders was conducted in the extensive rice growing region of Upaniyur padasekharam in the Kalliyoor panchayat of Thiruvananthapuram district. The seasonal occurrence and abundance of the spiders was studied during Virippu and Mundakan seasons. The prey preference and predatory efficiency of ten major spiders identified in the survey were studied in the laboratory. The relative toxicity / safety of acephate 0.05 per cent, imidacloprid 0.005 per cent, triazophos 0.05 per cent, quinalphos 0.05 per cent azadirachtin 0.004 per cent, neem oil 2 per cent and NSKE 5 per cent to the ten major spiders was studied in the laboratory and field.

The major findings of the study are summarized as follows;.

- The study revealed the presence of 65 species of spiders belonging to two major groups, *viz.,* Hunters and Web builders, distributed in seven guilds. The species composition of hunters was more than web builders.
- The seven guilds of spiders documented were orb web weavers, scattered line weavers, sheet web builders, stalkers, ground runners, ambushers and foliage runners. Orb web weavers constituted the major guild in the rice field.
- The eleven families encountered during the study were Tetragnathidae, Araneidae, Theridiidae, Linyphiidae, Agelenidae, Salticidae, Oxyopidae, Lycosidae, Thomisidae, Miturgidae and Clubionidae. Araneidae was the predominant family with higher species composition, followed by Salticidae and Tetragnathidae.
- *Tetragnatha* was the dominant genus.

- The spiders documented were *T. mandibulata, T. maxillosa, T. javana, T. viridorufa, T. vermiformis, T andamanensis, T. fletcheri, T. cochinensis, Tetragnatha* spp., *D. dentata, Dyschiriognatha* sp., *A. anasuja, A. aemula, A. catenulata, A. pulchella, N. rumpfi, N. bengalensis, N. mukerjei, Neoscona* spp., *A. ellipticus, Araneus* spp., *E. laglaizei, Eriovixia* sp., *Larinia* sp., *C. keralaensis, C. citricola G. geminata, Theridion* spp., *Linyphia* spp., *Agelena* sp., *T. dimidiata, B. carli, Bianor* sp., *P. paykulli, Plexippus* sp., *B. kairali, T. bhamoensis, E. indicus, C. vidus, Carhottus* sp., *H. semicupreus, Hyllus* sp., *M. plataleoides, Myrmarachne* sp., *O. javanus, P. viridana, O. shweta, O. sunandae, P. pseudoannulata, P. sumatrana, P. amkhaensis, Pardosa* sp., *L. tista, Lycosa* sp., *T. projectus, Misumena* sp., *T. pugilis, Thomisus* sp., *Runcinia* sp., *Xysticus* sp., *C. danieli, C. melanostomum, Cheiracanthium* sp., *Matidia* sp. and *Clubiona* sp.
- Among the spiders documented, seventeen species *viz., T. viridorufa, N. rumpfi, Agelena* sp. , *B. carli, E. indicus , B. kairali, T. bhamoensis, C. vidus, M. plataleoides, Matidia* sp., *C. danieli, Runcinia* sp., *Xysticus* sp. , *Misumena* sp., *T. projectus, T. pugilis and P. amkhaensis* were recorded for the first time from the paddy fields of Kerala.
- The dominant species noted in rice ecosystem were *T mandibulata, T. maxillosa, A. anasuja, N. rumpfi, T. dimidiata, B. carli, P. pseudoannulata, O. javanus, P. viridana* and *T. projectus,* of which *N. rumpfi, B. carli* and *T. projectus* were reported for the first time.
- Fifteen species were found occurring regularly in the field. Others were seen frequently and occasionally. Some rare species were also there.
- Apart from the crop canopy, spiders were observed to inhabit the border weeds, field bunds, in webs made in between plants and in snares made on

single leaves. Paddy fields harboured more number of spiders than the temporary niches.

- The seasonal occurrence of the spiders during the Virippu and Mundakan seasons showed that there was no remarkable difference in the populations of spiders recorded during both the seasons. Spiders in the families Tetragnathidae, Araneidae, Salticidae, Lycosidae, Oxyopidae and Thomisidae were abundant in the field during both the seasons. Tetragnathidae was the most dominant family and maintained fairly high population through out the crop period.
- Among the different crop growth stages, vegetative and reproductive stages recorded more number of spiders and the maturity stage recorded the lowest population. Between the vegetative and reproductive stage, the reproductive stage of the crop harboured more population of spiders. The increase in the population of the spiders was directly related to the crop growth stages and the pests associated with the different stages.
- Among the different groups of pests recorded, the hoppers were dominant and the *Nephotettix* spp. was the predominant hopper observed. The pest population was high during the reproductive stage of the crop, mostly during the flowering and milky stages of the crop. The peak population of neutrals was observed during the vegetative stage. The insect natural enemies were found in more numbers during the reproductive stage.
- Weather parameters studied *viz.*, maximum and minimum temperature, morning and afternoon relative humidity, rainfall and the number of rainy days had no significant influence on the population of the spiders.
- All the ten dominant spiders preferred diverse groups of prey insects *viz.*, hoppers, bugs and lepidopterans, except beetles and grass hoppers which was also preferred by the four spiders, *A. anasuja, P. viridana, T. dimidiata* and *T. projectus*. All the ten spiders exhibited equal preference for the hoppers

and the adults of the hoppers were more consumed than the nymphs. The highest preference for the hoppers was shown by *T. projectus* and the most preferred hopper was adults of green leaf hoppers. The nymphs of the bugs were more preferred than the adults. The nymphs of *L. acuta* were the most preferred bug and *T. mandibulata* recorded the highest preference for the bugs. Among the lepidopteran pests, the moths of rice leaf roller were the most preferred lepidopteran diet and *A. anasuja* had the highest preference for the lepidopterans.

- The predatory potential of the spiders proved that the spiders consumed lower numbers of prey insects per day when the prey insects were provided individually.
- Among the tested spiders, *A. anasuja* was found to be the most potential predator of the pests in rice fields as proved by the higher rate of consumption by the spider. And it recorded higher preference for all types of prey insects including the beetles and the grass hoppers.
- The most cross predated insect predator was the mirid bug predator, *C. lividipennis,* and the prolific cross predating spider predator was *P. viridana.*
- The hymenopteran parasitoids were not at all consumed by the spiders.
- Topical application of synthetic chemicals and neem formulations was found to be more fatal to the rice dwelling spiders than when released on the treated plants.
- Among the insecticides tested triazophos 0.05 per cent, acephate 0.05 per cent and quinalphos 0.05 per cent proved toxic to the spiders and insect natural enemies. Imidacloprid 0.005 per cent was comparatively safe to the spiders. Azadirachtin 0.004 per cent too caused high mortality of the spiders.
- The botanicals were relatively safe except azadirachtin.

- When the effect of the chemicals on individual spiders was studied, the hardiest spider was *A. anasuja*, which recorded the lowest mortality against all the treatments evaluated. *N. rumpfi* was the most sensitive spider.
- The spider population was reduced greatly in the chemical sprayed plots than the neem formulations sprayed plots. The recolonization of spiders in the field was better in the neem formulations sprayed plots. Among the chemical treatments imidacloprid was safe to the spiders.
- The population of spiders built up gradually and the recolonization became active, after ten days of treatment of the chemicals in the plots sprayed with imidacloprid 0.005 per cent, azadirachtin 0.004 per cent, neem oil 2 per cent and NSKE 5 per cent and the recolonization of spiders was better.

It can be concluded that the individual spider species are unlikely to regulate the numerous pest populations in the rice fields, but when assembled into groups, representing various guilds with diverse prey capturing abilities, and adaptations, they could contribute to significant reductions in pest numbers, which have a positive effect on crop production and is beneficial to farmers. Hence, conservation of the spiders in rice fields is of utmost importance, through which natural biocontrol will be effectively executed.

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* Originals not seen

Appendix

APPENDIX I

Weather parameters at Instructional farm, College of Agriculture, Vellayani, during Virippu season of the rice crop (July 2005 – November 2005)

Weeks	Temperature (°C)		Relative humidity (%)		Rain fall (mm)	Number of rainy days
	Maximum	Minimum	Morning	After noon		
July-1	29.67	22.93	92.57	74.43	21.99	5
July-2	29.61	23.5	94.57	77	1.73	3
August-1	29.99	23.4	93	74	1.11	2
August-2	30.07	22.49	90.71	74.23	9.79	3
August-3	29.4	22.69	91	73.71	2.26	5
August-4	30.91	23.46	88.43	68.43	0	0
September-1	30.74	23.58	88	65.86	0	0
September-2	29.76	22.8	92.57	75.71	7.57	3
September-3	29.43	23	92.86	76.29	13.66	5
September-4	30.36	23.24	92	74.71	3.1	3
October-1	30.1	22.96	93.86	78	4.44	4
October-2	29.47	22.8	93.29	78.57	14.21	4
October-3	31.04	23.04	87.43	69.86	2.21	1
October-4	31.29	23.26	90.86	71.86	1.46	1
November-1	30.76	23.04	94.57	71.14	3.57	3
November-2	30.1	22.97	93.71	76	9.44	6

APPENDIX II

Weather parameters at Instructional farm, College of Agriculture, Vellayani, during Mundakan season of the rice crop (December 2005 – April 2006)

Weeks	Temperature (°C)		Relative humidity (%)		Rain fall (mm)	Number of rainy days
	Maximum	Minimum	Morning	After noon		
December-1	29.57	23.11	94.86	80.23	12.97	4
December-2	30.94	22.8	95.29	70	0.7	1
December-3	31.46	22.44	95	63	0	0
January-1	32.13	21.81	94.14	67.86	0	0
January -2	32.43	23.61	91.57	67.86	1.89	1
January -3	29.07	22.96	95	67.57	1.32	2
January -4	30.71	19.46	96.14	74.57	0	0
February-1	31.31	22.36	94	76.43	0	0
February -2	32.44	20.65	90	80.57	0	0
February -3	32.03	21.16	93.14	71	0	0
February -4	32.43	23.73	91.29	59.57	0	0
March-1	32.14	20.98	94.14	63.43	0	0
March -2	31.64	22.54	93.43	69.29	1	2
March -3	33.14	21.35	91.29	62.14	3.03	1
March -4	32.5	23.13	94.86	65.29	0	0
April-1	32.67	21.77	96.17	70	0.16	1

APPENDIX III

Correlation of different weather parameters with the population of spiders, pests, neutrals and insect natural enemies

Virippu season

Weather parameters	Spiders	Insect natural enemies	Pests	Neutrals
RH morning	-0.3 51	-0.484	-0.170	-0.395
RH evening	-0.091	0.215	-0.040	-0.298
T maximum	-0.058	+0.181	+0.226	-0.172
T minimum	-0.039	-0.134	-0.060	-0.103
Rainfall	-0.244	-0.404	-0.158	-0.265
No. of Rainy days	-0.204	-0.384	-0.139	-0.197

Mundakan season

Weather parameters	Spiders	Insect natural enemies	Pests	Neutrals
RH morning	-0.402	0.189	-0.506	-0.028
RH evening	+0.094	-0.176	+0.023	-0.061
T maximum	+0.002	+0.033	+0.278	-0.145
T minimum	-0.348	-0.205	-0.421	+0.150
Rainfall	-0.485	-0.397	-0.513*	-0.13 8
No. of Rainy days	-0.495	-0.236	-0.521*	-0.102

* Significant at t 5% level

DOCUMENTATION AND PREDATORY POTENTIAL OF SPIDERS IN RICE ECOSYSTEM AND IMPACT OF INSECTICIDES ON SPIDERS

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ABSTRACT

The survey conducted to document the spiders in the paddy fields of Thiruvananthapuram district during the Virippu and Mundakan seasons of 2005-'06, brought out sixty five species of spiders, which fall into two major groups, hunters and web builders and belonged to eleven families and seven foraging guilds. The species composition of hunters was more than the web building spiders, although the latter was numerically dominant. The dominant guild was orb web weavers. Araneidae was the family with more species composition, followed by Tetragnathidae and Salticidae. The predominant genus being *Tetragnatha*, and species, *Tetragnatha mandibulata* Walckenaer. The other dominant species were *Tetragnatha maxillosa* Thorell, *Argiope anasuja* Thorell, *Neoscona rumpfi* Tikader & Biswas, *Telamonia dimidiata* Simon, *Bianor carli* Reimoser, *Oxyopes javanus* Thorell, *Peucetia viridana* Stoliczka, *Pardosa pseudoannulata* Böesenberg & Strand and *Thomisus projectus* Tikader. Seventeen species of spiders were reported for the first time from the rice fields of Kerala, and it included the three dominant spiders, *viz., N. rumpfi, B. carli* and *T. projectus.* Spiders were also observed in the field bunds and border weeds, and from the webs built among plants, in between the plants and on individual leaves.

The seasonal occurrence of spiders during the Virippu and Mundakan seasons did not show any remarkable difference. Among the eleven families, six were more populated *viz.*, Tetragnathidae, Araneidae, Salticidae, Lycosidae, Oxyopidae and Thomisidae. The predominant family was Tetragnathidae. The vegetative and reproductive stages of the crop harboured more spiders and the highest population was recorded during the reproductive stage. The crop growth stages had significant influence over the spider population, where as the weather parameters had no correlation.

The ten spiders showed a definite preference for the different hoppers, bugs and lepidopterans when evaluated for their prey preference. The spiders *A. anasuja,*

P. viridana, T. dimidiata and *T. projectus* broadened their preference to the orthopteran and coleopteran pests. The predatory potential of the spiders showed that the spiders which consumed more number of prey insects per day in a mixed diet took comparatively lower numbers when the prey insects were provided individually. *A. anasuja* was the most potential predator and *P. viridana* was the spider with highest rate of hyper predation and the most cross predated insect predator was *C. lividipennis*. The parasitoids were not consumed by the spiders.

The topical application of chemicals recorded higher mortality of spiders than when released on the treated plants. Among the chemicals, imidacloprid 0.005 per cent proved to be safer and triazophos 0.05 per cent more toxic. Azadirachtin 0.004 per cent had more toxicity among the neem formulations. In the field, better recolonization of spiders was noticed in the neem products treated plots than the synthetic pesticides, imidacloprid proved to be the safest chemical for the spiders and all the insect natural enemies and was quite promising for the pests.

From the results obtained, it can be concluded that pest management will be effectively executed in the field by these potential predators, which are abundant and had specific adaptations which overpowered the other natural enemies in the rice fields. In a naturally balanced rice ecosystem, in a pesticide free environment, these carnivores can survive and when assembled into groups, they could contribute to significant reductions in pest numbers, which have a positive effect on crop production and is beneficial to farmers. Imidacloprid 0.005 per cent could be utilized for pest control when infestation is severe without harming the spider fauna. Hence, conservation biological control could be practiced along with spider mediated IPM.