MAJOR PREDATORS IN RICE ECOSYSTEMS AND THEIR POTENTIAL IN RICE PEST MANAGEMENT

BY

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DECLARATION

I hereby declare that this thesis entitled **"Major predators in rice ecosystems and their potential in rice pest management"** 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 **"Major predators in rice ecosystems and their potential in rice pest management"** is a record of research work done independently by Mrs. K.S. Premila (97-21-05) 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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CONTENTS

LIST OF TABLES

LIST OF TABLES CONTINUED

LIST OF TABLES CONTINUED

LIST OF TABLES CONTINUED

LIST OF FIGURES

LIST OF PLATES

LIST OF ABBREVIATIONS

DAT	-	Days after transplanting
DAS	-	Days after sowing
CSRC	-	Cropping Systems Research Centre
RRS	-	Rice Research Station
RE	-	Rice Ecosystem
NRE	-	Non Rice Ecosystem
m^2	-	Metre Square
BPH	-	Brown Planthopper
WBPH	-	White backed Planthopper
GLH	-	Green Leafhopper
ZLH	-	Zigzag Leafhopper
KAU	-	Kerala Agricultural University
viz.	-	Namely
cm	-	Centimetre
%	-	Per cent
LC	-	Lethal Concentration
ml	-	Millilitre
HAT	-	Hours after treatment
log	-	Logarithm
^0C	-	Degree Celsius
et al.	-	And others
No.	-	Number
CD	-	Critical Difference
Fig.	-	Figure
ppm	-	Parts per million
spp.	-	Species
kg	-	Kilogram
ha	-	Hectare
var.	-	Variety
EW	-	Emulsifiable Water

INTRODUCTION

1. INTRODUCTION

Protection of crops from pest damage has been the prime concern of farmers since the origin of agriculture. In the ancient times, the natural enemies prevailing in the agro-ecosystems were relied on for reducing pest activity. Whenever the population of an insect increased, the self-regulatory mechanism of nature acted as a moderating check preventing injurious species from multiplying excessively. As agriculture progressed, mechanical and cultural methods followed by plant based products were tried for pest suppression. Subsequently, with intensification of agriculture a number of insecticides were introduced to contain the pests. The spectacular results achieved with the agrochemicals and the concomitant increase in production paved the way for a large-scale adoption of exclusively pesticide based pest control strategies. However, the plethora of problems brought in its wake and the deepening concern for human health and environment once again tilted the balance in favour of biological control. Currently, biological approach for suppression of pest is on the upsurge and forms the core of sustainable pest management strategies. As opined by Coppel and Mertins (1977) "returns from successful biological programmes can be higher than those of other successful agricultural technology research programmes both in terms of quantity and quality of produce".

In a strict sense, biological control involves the use of beneficial organisms for reducing pest density. The two important groups of bio-agents predominating in agro-ecosystems are the predators and parasitoids. Having co-evolved with the plants and their arthropod pests, they have established a set of interactions, which influence the population level of any one or all of them. Realising the potential of this method of pest regulation, the biotic agents have been exploited for pest management even from the early days. The first successful example of classical biological control is that of the coccinellid beetle *Rodolia cardinalis* Mulsant, a predator controlling the cotton cushion scale *Icerya purchasi* Maskell in California in 1888 and even prior to this, ants were released by Chinese citrus growers for the control of noxious pests (Doutt, 1964). Despite these attempts, utilization of predators for pest control was on a low key over the years. The host specific parasitoids were widely explored in pest management based on the contention that monophagous entomophages are biologically well adapted to its host and tend to play an efficient regulatory role (Coppel and Mertins, 1977). However, with increase in of global temperature and the practice of comprehensive pest management gaining importance, it has been felt that the superior environmental adaptive ability, general feeding habit, voracity and searching capacity of a predator could be advantageously exploited for pest control. Moreover, unlike the parasitoids, which appear after the host, predators are already there in an undisturbed agricultural landscape thus forming the first line of defence against the intruding pest.

The situation prevailing in the rice ecosystem, which represents one of the richest natural enemy fauna, is all the more conducive for the exploitation of predators for pest control. The entomophage community in the rice ecosystem consists largely of a wide range of insect predators, spiders and parasitoids. They have existed in the environment since antiquity keeping insect pests below damaging levels. The paradox in rice insect pest management is that when natural biological control works, these natural enemies are taken for granted resulting in their mismanagement.

Over the past 30 years the dominant pest control strategy in tropical rice had been the use of resistant varieties and chemical insecticides which brought about a telling change in the status of pest and natural enemies. General predators dominated in the rice fields, which generated an increased interest in their utilization for the regulation of rice pests (IRRI, 1976, 1977 and 1978). Studies conducted by Settle *et al.* (1996) indicated that species rich, abundant and well distributed population of generalist predators supported by detritus-feeding and plankton-feeding neutrals can be found early in the season in rice fields. These predators are capable of suppressing the later developing pest population thereby lending stability to rice ecosystems. Thus unlike the parasitoids, predators could play a crucial role in regulating pest population in rice fields. Conservation of these potential bio-agents through habitat management would be an economically and ecologically ideal method of control of pests of rice, the staple food of millions of people in Asia, Africa and Latin America.

However, predators of rice pests are among the least studied arthropods. In the past, reports of their activity were largely anecdotal and studies were mostly confined to the construction of species lists. The quantitative information generated has been meagre. For successful exploitation of the benefits of the natural enemy in a comprehensive pest management system, their role in pest suppression must be quantified and predicted. Very limited information is available on the biological characters, feeding preference and predatory potential of the important predators in rice ecosystem of Kerala. Hence the present investigation was taken up with a view:

1. To identify potential predators in rice ecosystem.
2. To explore the changes in species composition and status of pests in rice ecosystem
3. To determine the suitability of natural prey for mass culturing of dominant predators in the laboratory.
4. To evaluate the predatory efficiency of the dominant ones
5. To assess the impact of insecticides on the predators

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The stability and sustainability of rice ecosystems are dependent on the inter and intra-specific competitions of their arthropod diversity. Time to time, the community ecology changes in relation to the cultivation practices adopted and fluctuations in the environment. Recently, these changes have been phenomenal with predators dominating among the natural enemies. The predators prevalent in the rice ecosystems in Kerala, their potential in managing pests of rice, effect of insecticides and the present status of pests and other natural enemies in rice ecosystem were studied in the present investigation. Literature relevant to the different aspects of the study is reviewed in this chapter.

2.1 ARTHROPOD COMMUNITY IN RICE ECOSYSTEMS

The arthropod community in rice ecosystems can broadly be categorised as entomophages, phytophages and neutrals based on feeding guild. Globally, tremendous shift has been observed in the composition and status of arthropod community in rice ecosystems during the last two decades which alone is reviewed here.

2.1.1 Entomophages

The inherent large and diverse population of natural enemies in rice ecosystems protects the crop from the damage of herbivores. The occurrence and abundance of entomophages is dependent on the pests prevalent in an ecosystem. Comparatively higher population of predators have been reported in the rice ecosystems in the last two decades.

2.1.1.1 Insect Predators

The tettigonid, *Conocephalus* sp. was observed predating on egg masses of the predominant pest *Leptocorisa oratorius* (Fabricius) in the rice fields of West Malaysia (Manley, 1985). It was also found to prey on leafhoppers, planthoppers and early instar nymphs of grasshoppers in China (Deng and Jin, 1995).

Thirteen species of dragonflies were identified as important predators of pests of rice in China (Zhang, 1986). The most abundant predators in rice fields in Bangladesh were the carabid *Ophionea ishii ishii* Habu and *Microvelia douglasi atrolineata* Bergroth (Kamal *et al.*, 1987). *Paederus fuscipes* Curtis and *Ophionea indica* (Thunberg) were the important predators of *Nilaparvata lugens* (Stal) and *P. fuscipes* occurring from 40 days after transplanting (DAT) to ripening of the crop and their peak period of activity was during 60-68 DAT. The carabid beetle *O. indica* appeared 35-75 DAT in winter-spring and erratically in summer–autumn with the peak at 40 DAT in Mekong Delta of Vietnam (Luong Minh Chau, 1987). The coccinellid, *Micraspis crocea* Mulsant was found to be abundant during outbreaks of *N. lugens* in Philippines (Shepard and Rapusas, 1989). *Cyrtorhinus lividipennis* Reuter, *Micraspis discolor* (Fabricius), *Harmonia octomaculata* (Fabricius) and *P. fuscipes* were the major predators recorded from the rice fields of Sri Lanka (Rajendram and Devarajah, 1990). Similarly, *M. douglasi atrolineata,* the mesoveliid, *Mesovelia vittigera* Horvath and *C. lividipennis* were the most abundant species of insect predators in the irrigated rice fields of Philippines where homopteran pests were dominant (Heong *et al.*, 1991). Predator diversity and evenness was significantly lower in Los Banos than in Cabunteian in Philippines and the dominant insect predators were mostly heteropterans (*M. douglasi atrolineata* and *C. lividipennis*). Peak population of the predators was observed at a later stage of crop growth (Heong *et al.*, 1992).

In India, large population of *C. lividipennis, Nabis capsiformis* Germar, *Gonatopus* sp. and *P. fuscipes* were observed in the rice fields of Madhya Pradesh (Upadhyay and Diwakar, 1983). Peak incidence of the predaceous coccinellid *Brumoides suturalis* (Fabricius) was seen to coincide with the maximum population level of *Sogatella furcifera* (Horvath) in the rice fields in Delhi (Garg and Sethi, 1984). *P. fuscipes*, *Menochilus sexmaculatus* (Fabricius), *Coccinella septempunctata* Linnaeus and *Scymnus* sp. were present in large numbers during summer in Chhattishgarh region (Bhardwaj *et al.*, 1986). The predator complex of monsoon rice pests of Madhya Pradesh included *Agriocnemis pygmaea* (Rambur), *P. fuscipes* and *C. lividipennis* (Bhardwaj and Pawar, 1987 a). In a survey conducted in Tamil Nadu, *C. lividipennis* was observed to be the most abundant predator reaching to 18 to 65 nymphs per hill at 50 DAT (Peter, 1988) while *P. fuscipes* was found at population densities of 5 to 20 beetles per m^2 (Rajendran and Gopalan, 1988). Survey carried out at an experimental farm in Madurai, Tamil Nadu, revealed that eight species of predatory coccinellids fed on *N. lugens*, *S. furcifera* and *Nephotettix* spp. Of the coccinellids, *M. sexmaculatus* accounted for 43 per cent, *Sticholotis* sp. for 25 per cent and *Scymnus* sp. for 10 per cent of the total population (Parasuraman, 1989). Two coleopteran and one hemipteran insect were seen preying on *S. furcifera* in Ludhiana (Bhathal *et al.*, 1990).

In the rice ecosystem of Kottarakkara in Kollam district of Kerala, the predators of planthoppers like *Ophionea nigrofasciata* Schmidt-Goebel, *M. douglasi atrolineata, Micraspis* sp. and *Agriocnemis* sp. were present abundantly (Nandakumar and Pramod, 1998). Survey conducted in three taluks of Thiruvananthapuram district revealed high population of *Agriocnemis* sp. in Neyyattinkara and Nedumangadu taluks and *Crocothemis* sp. in Chirayinkil taluk throughout the cropping season. High population of *C. lividipennis* was observed at 40 DAT in the three taluks. *M. crocea* was observed at 40 DAT in Chirayinkil taluk (Ajayakumar *et al.*, 2002).

2.1.1.2 Spider Predators

One of the most abundant and potential predators in rice ecosystems are the spiders. As they have a wide host range, they play an important role in suppressing population of hoppers, dipterans and lepidopterans in paddy fields (Kamal *et al.*, 1992).

Studies from tropical Asian countries showed that Thailand and Malaysia had the highest number of reported spider species being 60 and 30 respectively, followed by India (25), Indonesia (24) and Burma (14). A few species of spiders were reported from the Philippines (12), Sri Lanka (9) and Bangladesh (8) (Barrion and Litsinger, 1980). Survey of the spider fauna in Philippine rice agro-ecosystem revealed the existence of a wide array of species with 51 taxa comprising 34 genera under 16 families. It was further observed that both *Lycosa pseudoannulata* (Boesenberg et Strand) and *Callitrichia formosana* (Oi) were the dominant species prevalent in irrigated wetland (Barrion and Litsinger, 1981). Similarly, *L. pseudoannulata* and *Tetragnatha* sp. were the important predators observed in the rice fields of Mekong Delta, Vietnam. *L. pseudoannulata* occurred throughout the crop cycle and the peak period of occurrence was at tillering and *Tetragnatha* spp. appeared upto 70 DAT (Luong Minh Chau, 1987).

One hundred and sixty seven species in 28 families of spiders were identified in rice fields in China, which significantly reduced the number of delphacids, cicadellids and pyralids. Three peaks in spider numbers were observed in May, July and October and the cultivation practices, application of chemicals, rainfall and typhoons affected the population of the spiders (Xu *et al.*, 1987). 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 in the first crop and were more prevalent than orb-web spiders. The hunting spiders were dominated by *L. pseudoannulata.* Fifty eight to sixty eight per cent of the fauna in the rice fields of Northern California were observed to be *Pardosa ramulosa* (Mc Cook) and the flooded paddy served as a refuge for the semi aquatic *P. ramulosa* during the day in summer months (Oraze *et al.*, 1988). Sixty three species of spiders were reported from paddy fields in Thailand and among them spiders of genus *Tetragnatha* were found most abundant (Vungsilabutr, 1988).

Thirteen spider species were seen in five rice growing sites of Philippines. The species of *Tetragnatha, Pardosa pseudoannulata* (Boesenberg et Strand) and members of the family Linyphiidae were dominant (Heong *et al.*, 1990). Studies on population dynamics of spiders in rice fields in Jiangsu, China showed that there were 73.10 to 93.50 spiders per 100 hills at transplanting and 325.50 to 543.20 spiders per 100 hills at the grain filling stage. The spider fauna was composed of 45.60 per cent erigonids, 24.20 per cent lycosids, 10.80 per cent clubionids, 10.20 per cent theridiids and 9.20 per cent of others (Qi, 1990). The spiders *P. pseudoannulata, C. formosana* and three species of *Tetragnatha* were the other dominant group of natural enemies in irrigated rice fields of Philippines next to heteropteran predators (Heong *et al.*, 1991 and 1992). Thirty nine species of spiders belonging to 28 genera and 10 families were recorded from paddy fields of Bangladesh (Kamal *et al.*, 1992). The dominant spiders in central Java, Indonesia were web spiders and hunting spiders (Settle, 1994).

The abundance of spiders in rice fields has also been reported from India. Among the various species of Araneae seen in rice fields of Chhattishgarh region, *Lycosa* sp. was present in large numbers and the spiders were observed to contribute to rice pest control from the nursery stage until harvest (Bhardwaj and Pawar, 1987 b). In a survey conducted in Ludhiana,13 species of Araneae were recorded preying on the delphacid *S. furcifera,* of which five species were web spinners and eight species were hunting spiders (Bhathal *et al.*, 1990).

Twenty species of spiders were observed in the genera *Tetragnatha, Neoscona, Oxyopes, Phidippus* and *Pardosa* in the rice ecosystem in Jammu region. Population of the spiders was noticed to increase gradually with the growth of rice plants (Thakur *et al.,* 1995). Twenty one spider groups under 16 genera belonging to 10 families were seen in the rice fields in the Eastern Coastal belt of South India (Anbalagan and Narayanasamy, 1996). Investigations on the predatory spider complex in different rice ecosystems revealed that *L. pseudoannulata, Marpissa mandali* Tikader, *Oxyopes javanus* Thorell, *Argiope catenulata* (Doleschall) and *Tetragnatha javana* (Thorell) were the most prevalent ones in the rice fields of Tamil Nadu and Pondicherry (Geethavishwanathan *et al.*, 1996). *Tetragnatha* sp. and *Oxyopes* sp. were dominant in irrigated rice fields of Jalandhar, Punjab. Spiders belonging to the families Araneidae, Clubionidae, Metidae, Oxyopidae, Salticidae, Thomisidae and Tetragnathidae were recorded from the rice ecosystems of Punjab (Kaur *et al.*, 2001).

L. pseudoannulata, Oxyopes sp., *Tetragnatha maxillosa* (Thorell), *Phidippus* sp., *Atypena* sp. and *Araneus* sp. were seen in the rice ecosystem of Kottarakkara in Kollam district of Kerala (Nandakumar and Pramod, 1998). The number and species diversity of predatory spiders in Kuttanadu was measured from August 1999 to February 2001. Of the 22 species of spiders collected, eight species were hunting spiders and 14 species were web builders. The hunting spider group comprised of the families Lycosidae, Salticidae and Oxyopidae. Among the web builders, *Tetragnatha listeri* Sundevall was found to be the most abundant spider species in the rice ecosystem of Kuttanadu forming 11.98 per cent of the total collected species (Sudhikumar and Sebastian, 2001). Moderate levels of *L. pseudoannulata* and *T. maxillosa* were recorded throughout the cropping season in three taluks of Thiruvananthapuram district (Ajayakumar *et al.*, 2002).

2.1.1.3 Parasitoids

Unlike predators, parasitoids are host specific. As such their occurrence and intensity is highly dependent on the prevalence of their hosts. With the dominance of the sucking pests in the last two decades, fewer parasitoids have been observed in rice ecosystems (Pasalu, 2003).

One hundred and fourteen species of parasitoids were recorded in the rice fields in Beibei, China, 14 from *Scirpophaga incertulas* (Walker), 18 from *Chilo suppressalis* (Walker), 10 from *Sesamia inferens* (Walker), 26 from *Cnaphalocrocis medinalis* (Guenee), 20 from *Parnara* sp., 13 from *Naranga aenescens* Moore, three from *Mycalesis gotama* Moore, three from *Nephotettix cincticeps* (Uhler) and seven from delphacids (Zhao, 1986). The tachinids *Beekia* sp., *Gymnoclyta* sp., *Mormidaa* sp. and *Oebalus ypsilongriseus* (Degeer) were observed in rice fields of Puerto Rico (Franquí *et al.*, 1988). The main parasitoids collected from rice fields in Pakistan were *Trichogramma* sp., *Apanteles angustibasis* (Gahan) and *Brachymeria* sp. and a low population of twelve species of parasitoids (Ahmed *et al.*, 1989).

Goniozus spp., *Elasmus brevicornis* Westwood, *Macrocentrus* sp. and *Argyrophylax* sp. were recorded from larvae of *C. medinalis* in rice fields in Sri Lanka (Rajapakse, 1990). Pipunculid flies were reported to be important parasitoids of the nymphs and adults of *N. cincticeps* in Japan (Morakote and Yano, 1990) and *N. virescens* in Indonesia (Suzuki and Raga, 1992). *Anagrus nilaparvatae* Pang et Wang and *Anagrus* sp. were dominant in Guangdong, China, with densities of 440 to 690 and 930 to 1425 per 10 hills of rice at peak occurrence in October and June respectively. *A. nilaparvatae* had a wide host range parasitising the eggs of the delphacids *Toga* sp., *Nilaparvata* sp., *Sogatella panicicola* (Ishihara), *Thecophora propinqua* (Adams), *S. furcifera* and *N. lugens*. Parasitism of *S. furcifera* and *N. lugens* eggs reached 40.30 to 92.60 and 20.00 to 60.00 per cent respectively (Li and He, 1991). Egg parasitism by species of *Oligosita* and A*nagrus* ranging from 10 to 70 per cent was reported by Wada *et al.* (1991) in paddy fields of Muda area, West Malaysia. Mymarid parasitism was responsible for the mortality of three planthoppers on the winter crop, the mean parasitism rates being 20.60, 32.80 and 53.20 per cent for *N. lugens*, *S. furcifera* and *Laodelphax striatellus* (Fallen) respectively (Suzuki *et al.*, 1994).

Parasitisation of nymphs of *N. virescens* by *Gonatopus* sp. reached very high levels in July (Upadhyay, 1983). In a survey conducted in Andhra Pradesh, ten egg parasites, seven nymphal - adult parasites and a hyperparasite of *N. lugens, S. furcifera* and *Nephotettix* sp. were found (Bentur and Kalode, 1985). The mymarid, *Anagrus* sp. and the trichogrammatid, *Oligosita* sp. were the most common egg parasitoids of *N. lugens* while *Gonatocerus* sp. and *Paracentrobia* sp. attacked eggs of *N. virescens* and *Nephotettix nigropictus* (Stal). Dryinids, pipunculids and strepsipterans parasitised the nymphs and adults of delphacids and cicadellids in Andhra Pradesh (Gupta and Pawar, 1989). The parasitoids *Echthrodelphax fairchildi* Perkins, *Haplogonatopus apicalis* Perkins, *Pseudogonatopus hospes* Perkins and a species of the genus *Pseudogonatopus* were found attacking *N. lugens* and *S. furcifera* in Madhya Pradesh (Yadav and Pawar, 1989). Males and females of the strepsipteran *Halictophagus bipunctatus* Yang was reported to parasitise *N. virescens* in West Bengal (Das *et al.*, 1990). Seven parasitoids were seen parasitising natural population of *C. medinalis* in Karaikal region, Pondicherry, of which *Goniozus* sp. and *Elasmus johnsoni* Howard were the most effective with the parasitism ranging from 4.00 to 22.00 per cent (Manisegaran *et al.*, 1997). Two larval parasitoids *viz., Bracon hispae* (Viereck) and *Chrysonotomyia* sp. were recorded from the larvae of rice hispa and the percentage of parasitism was 30.70 and 9.30 per cent respectively in a survey conducted at Jorhat district of Assam (Bhattacharyya *et al.*, 2000).

Stenobracon sp., *Xanthopimpla* sp., *Charops brachypterum* Cameron, *Cotesia* sp. and *Opius* sp. were the commonly seen parasitoids in the rice ecosystem of Kottarakkara in Kollam district of Kerala

(Nandakumar and Pramod, 1998). Sizeable population of *Cotesia flavipes* Cameron and *Tetrastichus schoenobii* Ferriere were seen at 60 DAT in the rice ecosystems of Neyyattinkara, Nedumangadu and Chirayinkil taluks of Thiruvananthapuram district of the state (Ajayakumar *et al.*, 2002).

2.1.2 Neutrals

The 'other insects' (non-pests and non-beneficial) in the rice fields is a highly ignored group. Few researchers have reported the importance of these groups. The chironomids seen in rice ecosystems was lumped as "root feeders" under phytophagous insects by Heong *et al.* (1991). Intensive surveys conducted in Indonesia indicated that, early in the crop season, natural enemies especially the generalist predators have abundant sources of food in the form of detritivores (mostly larvae and adults of specific families in Diptera and Coleoptera) together with members of Culicidae and Chironomidae (Settle, 1994). Of the total number of species catalogued from low land irrigated rice in Indonesia, detritivores and plankton feeders represented an important contribution to the total diversity (18.95 per cent). The true midges outnumbered the mosquitoes. Nineteen species of Ephydridae and five species of Collembola were among the dominant groups of detritivores recorded (Settle *et al.*, 1996).

Studies on plant-herbivore-natural enemy interaction in a natural rice ecosystem in Thiruvananthapuram district of Kerala, indicated that the high population of general predators (95 per cent of the natural enemy population) seen existing on detritivores and filter feeders even before the herbivores appeared, kept the pest under check upto the vegetative phase (Nalinakumari and Hebsybai, 2002).

2.1.3 Phytophages

Remarkable changes have occurred in the status of insect pests in rice tracts due to the unbridled use of synthetic insecticides. Sucking pests were seen to be the major ones in most of the rice fields. Resurgence of

N. lugens (Heinrichs and Mochida, 1984 and Kenmore *et al.*, 1984), *Nephotettix* spp. (Dahal and Neupane, 1990) and *S. furcifera* (Luo *et al.*, 1990 and Ambikadevi *et al.*, 1998) was reported from several parts of the world.

The rice midge *Cricotopus sylvestris* (F.), the shore fly *Ephydra macellaria* Eggar and the green bug *Schizaphis graminum* (Rondani) were the most prevalent pest in the rice ecosystems of Ukraine in SSR, USSR (Kazanok, 1986). The planthopper, *Sogatodes oryzicola* (Muir) was identified as the principal insect pest of rice in Cuba. Other important pests included the rice stink bug, *Oebalus insularis* Stal and the fall army worm *Spodoptera frugiperda* (Smith) (Meneses, 1986). The white fly *Aleurocybotus* sp. was found to be a potential pest in West Africa attacking rice from seedling to flowering stage (Alam, 1989). The total number of *N. lugens* and *S. furcifera* which remained below 10 per hill in 1985-86, was seen to be much higher in 1986-87 in West Java, Indonesia (Holdom *et al.*, 1989).

The leafhoppers, *N. virescens* and *N. nigropictus* were seen to dominate (13.80 to 41.00 per cent) the rice fields and nurseries in three districts of Nepal (Dahal and Neupane, 1990). Delphacids, cicadellids, leaf rollers, leaf caterpillars and thrips, prevailed in the rice fields of China (Luo *et al.*, 1990). *N. lugens, S. furcifera, N. virescens* and *N. nigropictus* were recorded as major pests of rice in Sri Lanka and the species described as minor pests were *L. oratorius, Scotinophara lurida* (Burmeister), *Nezara viridula* (Linnaeus), *Tanymecus* sp. and *Aulacophora* sp. (Rajendram and Devarajah, 1990). Studies on the arthropod community associated with irrigated rice grown in Philippines also indicated that the phytophage species were mainly homopterans and was dominated by the cicadellids, *N. virescens* and *N. nigropictus* and the delphacids, *N. lugens* and *S. furcifera* (Heong and Aquino, 1990 and Heong *et al.*, 1991). Twenty two species of Delphacidae and 34 species of

Cicadellidae occurred on rice in South and South East Asia, of which the genera *Nephotettix, Recilia, Nilaparvata, Sogatella* and *Laodelphax* were important pests (Wilson and Claridge, 1991).

Displacements of conventional major pests by sucking pests were also seen in different parts of India. The plant and leafhoppers, *N. lugens* and *Nephotettix* spp. became troublesome pests in rice growing tracts of Warangal causing hopper burns and spreading a plant virus disease (Rao *et al.*, 1982).

Infestation by *S. furcifera* resulted in 10 to 40 per cent loss of grains in 1000 ha of rice field in Punjab (Saini *et al.*, 1982). *S. furcifera* recognised as a minor pest of rice three decades ago was found to slowly gain importance as a serious threat to the rice cultivation in India (Kalode, 1983). Severe loss due to the pest infestation was also reported from Haryana (Kushwaha and Singh, 1986) and Karnataka (Gubbaiah *et al.*, 1987). *Stenchaetothrips biformis* (Bagnall) was observed to be severe in the July to November crop in Northern Telengana zone of Andhra Pradesh. Incidence of the thrips was high following a period of prolonged dry spell after the onset of monsoon (Reddy *et al.*, 1987). Among the four species of bugs *Dolycoris indicus* Westwood, *Menida histrio* (Fabricius), *Scotinophara coarctata* Fabricius and *Cletus signatus* Walker were recorded during the milky stage of rice in Manipur, *C. signatus* was the major pest causing 10 to 40 per cent infestation (Singh and Singh, 1987).

Among the severe pests damaging basmati rice in Jammu, *N. virescens, N. nigropictus, Haplothrips ganglbaueri* Schmutz and *Oligonychus oryzae* Hirst debilitated the crop by sucking cell sap. (Roshansingh *et al.*, 2000). The two gundhi bugs, *C. signatus* and *L. oratorius* were of major importance on rice at grain filling stage in Meghalaya (Rao and Shylesha, 2002 a and 2002 b). In a study made to find the rank abundance of pests and predators in a rice field at Kovur village, Kancheepuram district of Tamil Nadu, 16 groups of insect pests were observed on rice plants, the major ones being the white backed planthopper and brown planthopper. The other pests observed included the white leafhopper, zigzag leafhopper, orange bug, thrips, leaf folder, stem borer, skipper, yellow hairy caterpillar, cutworms, hispa and flea beetle (ERI, 2003).

A few reports indicated similar changes in pest status in the rice ecosystems of Kerala. In a survey conducted in the rice fields of Rice Research Station, Moncompu, the black bug *Scotinophara* sp. was found to feed on plant sap from leaf sheath around the base of plants (KAU, 1980-81 and KAU, 1981-82). The hoppers *viz.*, *N. virescens, N. nigropictus, Recilia dorsalis* (Motschulsky), *Exitianus indicus* Distant and *Cofana spectra* (Distant) coming under Cicadellidae, *N. lugens* and *S. furcifera* belonging to Delphacidae and *Nisia nervosa* (Motschulsky) under Menoplidae were observed to be the important sucking pests of paddy in Thrissur and Palghat districts of Kerala (KAU, 1983-84 and KAU, 1984-85). The population of gall midge, green leafhopper and leaf folder was found to be high during August in a study conducted at Regional Agricultural Research Station, Pattambi (KAU, 1987-90). Heavy incidence of thrips in the seedling stage and brown planthopper at tillering stage and moderate incidence of leaf folder and rice bug was reported from Kuttanadu (KAU, 1995-96). Survey conducted during Rabi 1996-97 from seven padasekharams in Kuttanadu indicated greater infestation by gall midge and green leafhopper than stem borer (KAU, 1997-98).

White backed planthopper reached the level of a major pest during Rabi, 1997-98 resulting in severe crop loss in many locations of Kuttanadu, an endemic area for *N. lugens* (Ambikadevi *et al.*, 1998). Leafhoppers were seen to dominate the phytophage population in a survey conducted in six rice growing areas of Thrissur district of Kerala and planthoppers and plant bugs were the next important group of pests found in varying densities (Beevi *et al.*, 2000).

2.1.4 Arthropod Community in Adjoining Vegetation

Adjoining vegetation serve as refuge for a number of arthropods seen in rice ecosystems. Often the species are maintained on these vegetation.

Considerable number of *C. lividipennis* were observed on the weed *Cyperus difformis* L. during November 1985 to January 1986 in Andhra Pradesh in India (Bentur and Kalode, 1987). High population of *P. fuscipes, O. indica* and *Zelotes* sp. was observed on the bunds of rice fields in Mekong Delta of Vietnam. Population of the spiders *L. pseudoannulata, Tetragnatha nitens* (Audouin), *T. javana, Tetragnatha virescens* Okuma, *Clubiona japonicola* (Boesenberg et Strand) and *C. formosana* was also high in the field bunds (Luong Minh Chau, 1987).

After crop harvest, population of spiders in border weeds increased due to migration of insects from the rice field in Jammu (Thakur *et al.*, 1995).

2.2 REARING OF PREDATORS

Mass culturing of any bio-control agent is essential for its effective use in the field. Though voluminous literature is available on the rearing of important parasitoids, only few studies have been conducted on the rearing of predators of rice pests.

2.2.1 Insect Predators

Various host insects have been evaluated for their suitability in rearing *C. lividipennis* in the laboratory by different workers. According to Rajendram and Devarajah (1986) *N. lugens* was a suitable prey for rearing the predator. The developmental period of eggs lasted for 7.36 days and nymphal development took 11.72 days and adult males and females had longevities of 16.47 and 12.33 days respectively when reared on the prey. Mean fecundity was 30.08 eggs/female. Suitability of the eggs of *N. lugens* for rearing *C. lividipennis* has also been reported (Manti and Shepard, 1990 a; Geetha *et al.*, 1992 and Chen *et al.*, 1994).

Eggs of *Corcyra cephalonica* (Staint) was considered to be the next suitable diet. The eggs of *C. cephalonica* when pasted on rice pseudostem to serve as oviposition substrate, increased the culturing efficiency to a tune of about 10 to 25 per cent (Manti, 1991). When the predator was reared for six successive generations on eggs of *Corcyra* observations on the biological parameters showed a significant increase in fecundity (26.00 to 94.80 eggs per female) in the first four generations compared to the parent generation (11.00 to 62.00 eggs per female) (Manimaran and Manikavasagam, 2000).

When *C. lividipennis* was reared on eggs of *Drosophila melanogaster* Meigen, *C. cephalonica, N. lugens, S. furcifera* and *Nephotettix* sp. it was observed that 82.40, 62.30, 66.70, 53.00 and 31.30 per cent of mirid nymphs passed through five instars on the five prey species respectively. Nymphal duration varied from 12.30 days on *N. lugens* to 14.82 days on *D. melanogaster* (Geetha *et al.*, 1992).

M. crocea survived and developed successfully on pollen and *N. lugens*, when reared on flowering rice panicles and second and third instar nymphs of *N. lugens* (Shepard and Rapusas, 1989).

2.2.2 Spider Predators

Predatory spiders are in general opportunistic feeders while a few are selective in their feeding habit. Attempts have been made to rear spiders in the laboratory by several research workers.

In China, a new technique was developed for mass rearing spiders using the host insects like fruit flies, houseflies and ephydrids as prey (Wang and Zhou, 1984). The natural prey *N. lugens* followed by artificial medium prepared with a base of dog biscuits (bone soup, liver meat and wheat meal) was seen to be superior for culturing the spider, *L. pseudoannulata* (Rajendran, 1987).

A mass rearing method for *L. pseudoannulata* was successfully developed using two new cage designs and mixtures of *D. melanogaster* larvae and *N. lugens* nymphs as prey in China. The rearing cages were simple and cheap and minimised cannibalism. Rearing was over thirty times faster than using test tubes. Maintaining over 10,000 spiderlings required only 40 man-hours per week (Thang *et al.*, 1990).

Rearing *L. pseudoannulata* upto the third instar on nymphs of *N. lugens* and then with the grubs of *Tribolium castaneum* (Herbst) was seen to be best for the spider, taking minimum time to reach adulthood with high fecundity and high per cent of individuals reaching the adult stage compared to the other preys used (Ganeshkumar and Velusamy, 1995).

2.3 EFFICIENCY OF PREDATORS IN SUPPRESSING HOPPER PESTS OF RICE

2.3.1 Searching Capacity

2.3.1.1 Insect Predators

Studies on population, habitats, searching ability, numerical and functional response of *P. fuscipes* and serological tests conducted in laboratory and field in China indicated that *P. fuscipes* was the third most important predator of rice pests, after wolf spider *L. pseudoannulata* and other spiders (Gu *et al.*, 1989).

The searching capacity of *Rhynocoris fuscipes* (Fabricius) increased with increasing prey density. The considerable number of prey consumed by the predator per day at higher prey density than at lower density reflected the predator's biocontrol potential (Ambrose and Antoclaver, 1995).

2.3.1.2 Spider Predators

Experiments showed that *Achaearanea tepidariorum* (Koch) selected sites for web building by a series of movements that were random with respect to the distribution of its prey. When selected sites failed to yield an adequate supply of prey they were quickly abandoned. On the other hand, when adequate supplies of food were forthcoming at a site, random movement ceased and the site was systematically searched by filling the area with web (Turnbull, 1964).

Studies on the catching function of 19 species of spiders in paddy fields in China with serological method indicated that the prey included *C. medinalis, S. incertulas, Naranga aenescens* Moore, *Nephotettix bipunctatus* Distant, *Empoasca subrufa* (Motschulsky) and *C. spectra* (Tang and Zhou, 1983). Wolf spiders were seen to aggregate at higher densities of *N. lugens* (60 per 5 tillers per cage) increasing the chances of encountering each other. At low hopper densities (5,10 and 20 per 5 tillers per cage), the spiders dispersed to about one spider per plant (Heong and Rubia, 1990). The functional response of *L. pseudoannulata* to one day-old females of the yellow stem borer was studied in the laboratory on 13 and 35 day old TN-1 rice plants and rice stubbles. The spider searched for the pest more efficiently on 13 day old plants as at this stage there was less foliage and the search area was smaller than on 35 day old plants with more than ten tillers and denser leaves. It was also possible that the pest could hide better in the older plants and the predation was lowest in stubbles (Rubia *et al.*, 1990).

2.3.2 Feeding Potential

2.3.2.1 Insect Predators

The feeding potential of *C. lividipennis* has been investigated by several scientists. Pophaly *et al.* (1978) reported that 20.00 to 99.70 per cent mortality of early nymphal instars of leaf and planthoppers was due to predation by

C. lividipennis. Under glasshouse conditions, the predatory efficiency seemed to be greater on eggs of planthoppers than that of leafhoppers. Luo and Zhuo (1986) accounted 40.00 to 60.00 per cent predation on the eggs of *N. lugens* and *S. furcifera* by *C. lividipennis* under field conditions. Salim and Heinrichs (1986) reported that the feeding rate of *C. lividipennis*, *P. fuscipes* and *Synharmonia octomaculata* (F.) on *S. furcifera* ranged from 1.40 to 2.40 per day. Adults of the predator when fed on first and fourth instar nymphs of *N. lugens* in greenhouse in Tamil Nadu consumed on an average 5.89 and 2.79 first and fourth instar nymphs per day respectively (Rajendran *et al.,* 1987). When fed on eggs of *N. lugens*, females had higher daily and total consumption than males. Egg consumption by both females and males was highest one day after the mirid emerged. Egg consumption by mirid females was relatively high during the first week and then decreased. Total life time consumption by females was 143.68 ± 17.00 eggs and that of males was 61.23 ± 12.70 eggs. Average consumption per day was about 8.98 ± 1.06 for females and 2.36 ± 0.49 for males (Manti and Shepard 1990 a and 1990 b).

The feeding rate of the adult *C. lividipennis* was higher on *C. cephalonica* eggs (5.40 eggs per day) than on eggs of *N. lugens* (4.42 eggs per day) (Anitaram and Lakkundi, 2000).

The average feeding potential of first, second, third and fourth instar grubs of the coccinellid beetle *Cheilomenes sexmaculata* (Fabricius) was 19.00 ± 15.00, 47.10 ± 3.30, 77.70 ± 7.60 and 76.40 ± 12.90 individuals respectively in the case of *Melanaphis indosacchari* David and 18.50 ± 2.20, 25.80 ± 12.70, 57.50 ± 16.80 and 77.80 ± 18.50 individuals respectively in the case of *Melanaphis sacchari* Zehnt (Easwaramoorthy *et al.*, 1998).

2.3.2.2 Spider Predators

Feeding efficiency of *L. pseudoannulata* has been estimated to be 24 nymphs or adults of *N. lugens* per day (IRRI, 1975) and 15.20 planthopper adults per day (Samal and Misra, 1975). While highest feeding activity of *L. pseudoannulata* on *S. furcifera* (5.90 per day) was observed by Salim and Heinrichs (1986) compared with *C. lividipennis*, *S. octomaculata* and *P. fuscipes*, Luong Minh Chau (1987) recorded maximum feeding on *N. lugens* (8.50 nymphs per day). Shortest developmental period of spiderlings and highest survival rate and fecundity of the spider were obtained when a mixture of larvae of *Drosophila* and nymphs of *N. lugens*, were given as compared to that of spiderlings fed with each prey separately (Thang *et al.*, 1988).

Ge and Chen (1989) studied the predation by *Theridion octomaculatum* (Boesenberg et Strand), an important predator of rice hoppers (Delphacidae), in the laboratory and field in China. The spider could attack 0.25 to 1.88 individuals of *N. lugens* per day. The functional response of the predator to *N. lugens* was simulated with Hollings II and sigmoid III type models in the laboratory. The functional response model became a typical sigmoid III type when the space and complexity of the experimental arena were increased. It was suggested that the population ratio between the spider and *N. lugens* in the field fluctuated with the density and age structure of the population of the pest and the economic threshold for its control.

The feeding efficiency of six predatory spiders, *viz.*, *Salticus scenicus* (Clerck), *Pardosa birmanica* Simon, *Oxyopes pande* Tikader, *Thomisus* sp., *Neoscona nautica* (L. Koch) and *Cassinoides indica* L. on white backed planthopper was studied under greenhouse condition. *S. scenicus* was found to be the most efficient predator consuming 4.95 nymphs of white backed planthopper per day followed by *O. pande* (3.76), *P. birmanica* (3.67), *Thomisus* sp. (3.45) *N. nautica* (2.55) and *C. indica* (1.83) (Bhathal and Dhaliwal, 1990). Rubia *et al.* (1990) reported that *L. pseudoannulata* fed on a variety of prey, including hoppers, collembolans, flies and the mirid predator *C. lividipennis*. According to them the consumption of prey by individual spiders increased with prey density.

Studies on the predation of *Atypena formosana* (Oi) on brown planthopper and green leafhopper indicated that the spider attacked many of the nymphs within 24 hours with more second instars than third instars being eaten. The attack rate was highest for the second instars, the handling time was lowest for the nymphs of green leafhopper, while the handling times for the second and third instar brown planthopper did not differ significantly (Sigsgaard and Villareal, 1999).

2.3.3. Prey Preference

2.3.3.1 Insect Predators

The mirid, *C. lividipennis* has been reported as an important egg and nymphal predator of *N. lugens* by many workers (IRRI, 1979, 1998 and Sivapragasam, 1983). More number of eggs of *N. lugens* (IRRI, 1988), *S. furcifera* and *Nephotettix* sp. were consumed by the mirid compared to the nymphs and adults of the pests (Pophaly *et al.*, 1978). Similar observations were made by Sivapragasam and Asma (1985) who found that the female, male and nymphs of *C. lividipennis* consumed 22.00,18.00 and 6.00 eggs of *N. lugens* per day respectively and eggs were preferred compared to nymphs and adults of the pest. Between first instar nymphs and adults of *N. lugens*, the predator preferred first instar nymphs for consumption (Ganeshkumar and Velusamy, 1996 a).

Singh and Devi (1996) tested the food preference of *Coccinella septempunctata* (Linn.) on four aphid species *viz.*, *Aphis gossypii* Glover, *Aphis craccivora* Koch, *Brevicoryne brassicae* (Linn.) and *Lipaphis erysimi* (Kalt.) in the laboratory. Adults of the predator consumed more aphids than their grubs and the order of prey preference was *A. gossypii* followed by *A. craccivora*, *L. erysimi* and *B. brassicae*.

2.3.3.2 Spider Predators

Feeding on mixed prey consisting of five species resulted in higher fecundity of the spider *L. pseudoannulata* as compared to feeding on rice leafhopper only (Suzuki and Kiritani, 1974). Similarly, the spider fed with a mixture of the adults of *Drosophila*, *Musca* and white fly and larvae of

Musca had a higher survival rate than those provided with *Drosophila* alone (Gavarra and Raros, 1975).

Oxyopes sp. had a greater preference for *N. virescens* (39.23 per cent) followed by *S. furcifera* (19.19 per cent) and *N. lugens* (14.40 per cent) in a mixed population and the preference was attributed to the habitat of the spiders. On the other hand, *Pardosa* preferred *N. lugens* (41.04 per cent) to *S. furcifera* (30.79 per cent) and *N. virescens* (14.05 per cent) (Chiu, 1979).

Nirmala (1990) and Ganeshkumar (1994) have also reported that *Pardosa* which inhabits the lower parts of the rice plant where planthoppers are seen had a distinct preference for *N. lugens* and *S. furcifera* than *N. virescens*. *Tetragnatha* preferred significantly more *N. virescens* (16.23 per cent) to *S. furcifera* (11.08 per cent) and *N. lugens* (10.44 per cent).

Laboratory experiments conducted at the Soil and Water Management Research Institute, Thanjavur, Tamil Nadu to assess the prey preference of three common rice dwelling spiders on rice pests showed that *Pardosa* sp. was the most efficient predator. It had greater preference for *N. lugens* (14.31) followed by *S. furcifera* (10.96). *Tetragnatha* sp. and *Oxyopes* sp. consumed more of *Nephotettix* sp. being 5.69 and 7.29 respectively (Samiayyan and Chandrasekharan, 1998).

2.3.4 Hyperpredation

Most entomophagous predators are general feeders and often prey upon each other. Intraspecific and interspecific predation had been noted in immature stages of *L. pseudoannulata* and *C. lividipennis*. When 10 *C. lividipennis, S. octomaculata* or *P. fuscipes* were caged with one *L. pseudoannulata*, the spider killed 60.00 per cent of *C. lividipennis* but no *S. octomaculata* or *P. fuscipes*. Except for the spider, no predator was cannibalistic. When one spider was caged with ten each of *C. lividipennis* and *S. furcifera*, *C. lividipennis* had 41.00 per cent mortality and

S. furcifera only 27.00 per cent (Salim and Heinrichs, 1986). When left on the caged rice plant, the spider *L. pseudoannulata* killed three mirids per day (IRRI, 1987). Rajendran (1987) reported that the spider fed on an average of 5.22 adult mirids per day. Both male and female spiders attacked all stages of *C. lividipennis*. An adult spider could consume as many as 22.00 mirids per day (Heong, 1989).

Heong and Rubia (1990) examined the possibility of 'mutual interference' in adult female of *L. pseudoannulata* (encountering other spiders, which may lead to decreased prey searching efficiency, aggression, cannibalism and outward dispersal) preying on *N. lugens* in the laboratory. Mutual interference appeared to intensify with increased prey density. Some cannibalism was also observed.

Studies conducted on the cross predation between *Oxyopes javanus* Thorell and *C. lividipennis* showed that two *C. lividipennis* adults consumed 23.60 $\pm$ 10.98 eggs or 5.99 $\pm$ 2.26 emerging *O. javanus* spiderlings in the absence of their mother. However, *C. lividipennis* did not devour nymphs of its own species indicating the absence of cannibalism. Adults of *O. javanus* were found to feed readily on nymphs and adults of *C. lividipennis* (Ganeshkumar and Velusamy, 1996a).

2.4 TOXICITY OF INSECTICIDES TO PREDATORS

Distinct differences in the toxicity of various insecticides to predators in the rice ecosystem have been reported.

2.4.1 Insect Predators

Application of 0.20 per cent diazinon at fortnightly intervals in rice fields at Dacca, Bangladesh caused 59.10 per cent reduction of population of *C. lividipennis* (Chowdhary and Alam, 1979). Similarly, of the ten insecticides tested in the laboratory, the synthetic pyrethroids cypermethrin, fluvalinate and fenvalerate were highly toxic to *C. lividipennis*. Methomyl and etofenprox were relatively harmless.

Fenobucarb, chlorpyrifos, furathiocarb and monocrotophos showed moderate toxicity (Srinivas and Pasalu, 1990). Chlorpyrifos, BPMC and buprofezin when evaluated for their relative potency on *N. lugens* and its egg predator, *C. lividipennis* indicated that chlorpyrifos and BPMC were 2.75 and 1.25 times less toxic to *C. lividipennis* than to *N. lugens*. Buprofezin on the other hand was > 2500 times less toxic to *C. lividipennis* than to *N. lugens* (Suvaparp, 1992). However, methyl parathion when sprayed 14 and 38 DAT at 0.75 kg a.i. per ha (Arida *et al.*, 1997) and acephate (Ganeshkumar and Velusamy, 2000) had no significant effect on the population of *C. lividipennis.*

Similarly, phorate and carbofuran (1kg a.i./ha) granular application and quinalphos spray (0.05 per cent) were relatively safe to *M. douglasi atrolineata* (Jhansilakshmi *et al.*, 1998).

Trials on selective toxicity of insecticides to *C. lividipennis* and *M. douglasi atrolineata* revealed that cypermethrin and deltamethrin were highly toxic to these predators on contact. Deltamethrin was toxic to *C. lividipennis* and *M. douglasi atrolineata* when they were fed on treated *N. lugens*. Endosulfan and ethylan were not very toxic to these predators. Of the commercially available insecticides, acephate, BPMC, carbophenothion and endosulfan were less toxic to natural enemies (Fabellar and Heinrichs, 1984).

Studies on the mortality of two cricket predators of rice *viz.*, *Metioche vittaticolis* (Stal) and *Anaxipha longipennis* (Serville) after applying commonly used insecticides like monocrotophos 30 EC, MIPC 50 WP, chlorpyrifos 20 per cent + BPMC 11 per cent EC, methyl parathion 50 EC, azinophosethyl 40 EC, BPMC 50 EC (fenobucarb), cypermethrin 5 EC, methomyl 20 EC, endosulfan 35 EC @ 0.40 kg a.i. per ha indicated that both species were highly susceptible to all insecticides except azinophosethyl and endosulfan (Bandong and Litsinger, 1986). Similarly, Rubia and Shepard (1987) studied the toxicity of five commonly used insecticides to *M. vitatticolis*, in rice fields in Philippines in the laboratory. On the basis of the LD_{50} 24 hours after treatment, the decreasing order of toxicity of the compounds was cypermethrin> carbosulfan > monocrotophos > fenobucarb > buprofezin. Buprofezin was not toxic and did not affect nymphal moulting of *M. vittaticolis*. Low population of mirids was observed in plots treated with monocrotophos at 0.75 kg a.i. per ha than in plots treated with neem, 48 days after treatment (Kareem *et al.*, 1988).

In field trials, three commercial products of cypermethrin (Summerin 10 EC, Agromethrin 10 EC, Peskil 10 EC) and one product each of alpha cypermethrin (Fastac 2 EC), diazinon 60 EC, malathrin (Pesnon 57 EC), fenitrothion (Novathion 50 EC) and phosphamidon (Dimecron 100 WSC) caused low mortalities (33.00 to 40.00 per cent) of the coccinellid *M. discolor*, a predator of *N. virescens* (Rabbi *et al.*, 1993)

Acephate, chlorpyriphos and monocrotophos were observed to be safe to *P. fuscipes* (Ganeshkumar and Velusamy, 2000).

2.4.2 Spider Predators

Fourteen insecticides (four carbamates, six organo phospahates, gamma BHC, methomyl, cartap and chlordimeform) were tried for their relative toxicity to *L. pseudoannulata* in Japan. Of the carbamate compounds tested, carbaryl and the organophosphate compounds, fenitrothion, pyridafenthion and tetrachlorvinphos compounds were least toxic to *Lycosa* whereas chlordimeform, was highly toxic to *Lycosa*. Very low doses of cartap caused paralysis in *Lycosa* and these spiders were immobilized for upto 15 days. Gamma BHC and methomyl were very toxic (Takahashi and Kiritani, 1973). Similarly, among eight insecticides tested for their relative toxicity to *L. pseudoannulata,* buprofezin had the least adverse effect from contact with treated plant surfaces or from ingestion of treated delphacids. Acephate, propaphos and fenobucarb reduced the growth and predation of the spider to some extent.

Mexacarbate, cypermethrin and endosulfan were safe to *L. pseudoannulata* only when the spider was placed on treated plants one to three days after treatment (Thang *et al.*, 1987).

Of the thirty five insecticides used on rice in Asia, BHC, monocrotophos, decamethrin, azinophosmethyl, MTMC, BPMC, chlorpyrifos and fenvalerate consistently reduced the number of spiders *viz.*, *L. pseudoannulata, Tetragnatha* sp. and *Araneus* sp. (Reissig *et al.*, 1982). Studies on influence of commonly used insecticides on predatory populations indicated that acephate, chlorpyriphos and monocrotophos were safer to *L. pseudoannulata* and *T. javana* whereas phorate and carbofuran was found to be more toxic to the predators (Ganeshkumar and Velusamy, 1996 b and 2000).

Application of carbofuran (0.50 kg and 1.00 kg a.i. per ha) and phorate (1.00 kg and 2.00 kg a.i. per ha) reduced the population of spiders in rice fields of Kerala (KAU, 1981-82).

Isocarb, metolkarb and methamidophos also caused 14.40 per cent mortality of Araneae in China. Quinalphos and deltamethrin were more toxic to spiders, the mortality per cent ranged from 49.70 to 82.70 (Zhang *et al.*, 1988). Different formulations of quinalphos applied @ 1.00 and 0.50 kg a.i. per ha revealed that dust formulation was more toxic to spider predators of *N. lugens* followed by EC formulations when applied at 55 and 70 DAT. The mortality of spider complex was 54.55 and 62.55 per cent when quinalphos dust was used, it was only 30.77 per cent and 33.45 per cent in granular formulation (Mandal and Somchoudhary, 1994). Application of methyl parathion 0.75 kg a.i. per ha at 14 and 30 DAT was seen to reduce the population of spiders (Arida *et al.*, 1997).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Survey was undertaken to assess the occurrence and distribution of predators in the rice ecosystems of Kerala. Laboratory studies were conducted in the Department of Entomology, College of Agriculture, Vellayani to locate suitable prey for mass rearing the dominant predators identified in the survey. Searching capacity, feeding potential, prey preference and hyper predatory activity of the major predators and relative toxicity of insecticides to these predators were also determined.

3.1 STUDIES ON ARTHROPOD COMMUNITY IN RICE ECOSYSTEMS

Three heterogeneous rice ecosystems receiving different levels of pesticides as detailed below were selected for the study

- Kuttanadu rice fields of Alappuzha district where pesticides were applied at high levels.
- Double cropped rice fields of Thiruvananthapuram district where pesticides were applied moderately (need based application).
- Pokkali rice fields of Ernakulam district where no pesticides were applied and fish culture was practised along with rice cultivation.

Six padasekharams were identified in each of the ecosystem (Table 1) and from each padasekharam, three fields were selected at random for the study. The occurrence of predators was assessed at 30, 50 and 70 days after transplanting/sowing (DAT/DAS) during two consecutive seasons of the crop through different methods.

Table 1. Padasekharams selected for the survey

Rice ecosystems	Sl. No.	Name of Padasekharams	Rice variety/ Season
Kuttanadu	1	Ramankari	
	2	Nedumudi	Jyothi
	3	Moncompu	Puncha crop of 1998-1999
	4	Alappuzha	and 1999-2000
	5	Champakulam	
	6	Kainakari	
Double cropped	7	Ulloor	
	8	Anad	Jyothi
	9	Punchakari	Virippu and Mundakan
	10	CSRC Karamana	season of 1999-2000
	11	Upaniyoor	
	12	Athiyannoor	
Pokkali	13	Chellanam	Vyttila 4
	14	RRS Vyttila	Pokkali crop of 1999 and
	15	Cheranallur	2000
	16	Chalikkavattam	
	17	Kumbalangi	
	18	Kannamali	

3.1.1 Assessment by Sweepnet

The insects/spiders in the rice ecosystem (RE) and non-rice ecosystem (NRE) were collected with a sweepnet adopting the method of Reissig *et al.* (1986).

The insects/spiders collected were transferred to a polythene bag. One end of a long cotton strip moistened with chloroform was introduced into the polythene bag without touching the sides and the other end was placed at the open end of the polythene bag and tied with a rubber band. After 10 minutes, the cotton strip was removed and the dead insects/ spiders were brought to the laboratory, sorted and grouped as predators (insects and spiders), parasitoids, neutrals and pests based on feeding guild. Each of the arthropod was further identified based on the taxonomic characters. The number of adults and immature stages of each insect/ spider was counted and recorded together.

3.1.2 Assessment by Direct Counting

Twenty hills were selected at random from each padasekharam in Kuttanadu ecosystem and double-cropped ecosystem of Thiruvananthapuram. The leaves and stems of the plants were examined by moving diagonally from one corner to the opposite corner of the selected padasekharams of the ecosystem. The predators, parasitoids, neutrals and pests present on the rice plants were counted and recorded. Such assessment through direct counting was not done in the Pokkali rice ecosystem due to the flooded condition of the fields.

3.1.3 Assessment by Visual Counting

An area of 20 m^2 was demarcated in each of the padasekharam and the insects flying above the rice canopy were observed and recorded visually from all the selected padasekharams.

3.1.4 Assessment by Sieving Water

The population of aquatic insects in Pokkali rice ecosystem alone was recorded through this method. Thirty litres of water was sieved through a muslin cloth and the insects trapped in the cloth were counted and grouped as predators and pests. As sufficient water was not available in the fields of Kuttanadu and double cropped fields of Thiruvananthapuram, assessment by this method was not done in these ecosystems.

3.2 IDENTIFICATION OF SUITABLE PREY FOR REARING OF PREDATORS

3. 2.1 Maintenance of Field Population of Predators and Prey

A rice field of 200 m^2 was selected in the Instructional Farm, College of Agriculture, Vellayani, and planted with seedlings of rice (variety Jaya) for periodical collection of the insect predators *viz.*, the mirid *C. lividipennis* and the coccinellid, *M. discolor* and spiders, *T. maxillosa* and *L. pseudoannulata* and their prey brown planthopper (BPH), *N. lugens*, white backed planthopper (WBPH), *S. furcifera*, green leafhopper (GLH), *Nephotettix* sp. and zigzag leafhopper (ZLH), *R. dorsalis* for maintaining the stock culture. The crop was maintained as per the package of practices recommendations of Kerala Agricultural University (KAU, 1996) without adopting any plant protection measures.

3.2.2 Mass Rearing of Prey Insects

3.2.2.1 Raising of Rice Plants

Clay pots (15 x 15 cm) were filled with uniform quantity of clayey soil collected from rice fields and planted with 25 day old rice seedlings (variety Jaya) at the rate of two seedlings per pot. The plants were maintained as per the package of practices recommendations of Kerala Agricultural University (KAU, 1996). Water level in each pot was maintained at 2 cm height throughout the crop period. One week after transplanting, the plants were covered with cylindrical cages (13 x 45 cm) of transparent mylar film of 250 micron thickness. Each cage (Plate 1) was provided with a voil cloth lined ventilation (5 x 10 cm). The distal end of the cage was covered with close mesh nylon net and tightened around the cage with a rubber band. The caged plants were maintained inside the insectary at room temperature.

Plate 1   Potted plants covered with mylar film cage

Plate 2 Potted plants inside polyethylene cage

3.2.2.2 Rearing of N. lugens

Gravid female hoppers of *N. lugens* were collected from the rice field maintained as described in 3.2.1. and released on rice plants raised in clay plots mentioned in 3.2.2.1 for oviposition. Emerging nymphs were maintained on the same plants till the outer leaves showed yellowing. The plants were then cut at the base with a blade and the nymphs were gently tapped onto other fresh caged rice plants. The different stages of the prey insects were fed on rice plants continuously to ensure sufficient stock culture.

3.2.2.3 Rearing of S. furcifera

Rearing of *S. furcifera* was done as in 3.2.2.2

3.2.2.4 Rearing of Nephotettix sp.

Rearing of *Nephotettix* sp. was done as in 3.2.2.2

3.2.2.5 Rearing of R. dorsalis

Rearing of *R. dorsalis* was done as in 3.2.2.2

3.2.3 Mass Culturing of Predators

3.2.3.1 C. lividipennis

Twenty mirid bugs collected from the field were released on seedlings of rice var. Jaya raised in pots as described under 3.2.2.1. The emerging nymphs were maintained till development into adults. Further multiplication of the predator was done as per the procedure of Rajendran (1987). This ensured sufficient number of mirid bugs of uniform age and size for the various laboratory studies.

3.2.3.2 M. discolor

Fifty adult beetles of *M. discolor* were collected from the field and transferred to rice plants infested with nymphs of *N. lugens* maintained inside mylar film cages as described in 3.2.2.1. The eggs laid by the beetles were collected daily along with the substratum and transferred to other fresh rice plants. This process was repeated to ensure sufficient culture of the predator for the various laboratory studies.

3.2.3.3. T. maxillosa

The adult female spiders of *T. maxillosa* were collected from the rice plants maintained in the field and released on rice seedlings raised in pots as described under 3.2.2.1. The natural prey, *N. lugens* was introduced periodically into the cages as food. After emergence, the spiderlings were released individually to potted rice plants using a camel hair brush in order to avoid cannibalism. Adequate number of the nymphs and adults of *N. lugens* were released daily into the cage according to the stage of the spiderling. Further multiplication of the predator was done following the procedure of Rajendran (1987). This served as stock culture of the predator.

3.2.3.4 L. pseudoannulata

The spider was reared as described in 3.2.3.3.

3.2.4 Determination of Suitability of Different Prey for Rearing Predators

Suitability of different prey for rearing the insect predators *viz.*, *C. lividipennis* and *M. discolor* and the spider predators, *T. maxillosa* and *L. pseudoannulata* was determined through assessment of duration of different instars, adult longevity and number of prey consumed when reared on different prey. The first instar nymphs of the three prey *viz.*, *N. lugens, S. furcifera* and *Nephotettix* sp. were tested for their suitability to *C. lividipennis*. The developmental period, adult longevity and number of prey consumed by different instars and adults of *M. discolor* were studied on its eggs and second instar nymphs of *N. lugens* and *S. furcifera*. The prey tested for the spiders, *T. maxillosa* and *L. pseudoannulata* were *N. lugens, S. furcifera* and *Nephotettix* sp. The nymphs of the prey were given to the spiders upto the fourth instar and adults from the fifth instar to adult and during adulthood. The number of prey consumed was recorded daily and the total number consumed by each instar was worked out to determine the feeding preference during the developmental period.

3.2.4.1 C. lividipennis

Twenty adult mirid bugs were collected from the stock culture as detailed in 3.2.3.1 and released on 'Jaya' rice plants infested with first instar nymphs of *N. lugens* and observed for oviposition. The days on which the oviposition punctures were seen on the rice leaf sheath and the first instar nymphs emerged were noted to determine the egg period of *C. lividipennis*. One newly emerged nymph of the mirid bug was transferred to a rice seedling raised in mylar film cages as described in 3.2.2.1 and provided with 15 first instar nymphs of *N. lugens*. The mirids were maintained till death to study the duration of the different instars, adult longevity and number of prey consumed. The number of the prey was maintained at 15 per plant by introducing the number consumed every day. The predators were transferred to fresh plants as and when required. Five such replications were maintained. The total number of the prey consumed by different instars and adults was determined from the daily observations.

The developmental period, adult longevity and feeding preference of *C. lividipennis* when reared on first instar nymphs of *S. furcifera* and *Nephotettix* sp. were also studied as detailed above.

3.2.4.2 M. discolor

Twenty adult females of *M. discolor* were collected from the stock culture maintained as detailed in 3.2.3.2 and the beetles were allowed to oviposit in petridishes lined with moist filter paper. The freshly laid eggs were immediately separated along with the substratum and placed in fresh petridishes for hatching. The eggs were observed daily and the period from egg laying to hatching was recorded as egg period. The newly emerged individual grubs were introduced into petridishes supplied with 15 eggs of *M. discolor* at the rate of one grub per petridish. Similarly, the first instar grubs were transferred to rice seedlings infested with 15 second instar nymphs of *N. lugens* and *S. furcifera*. Observations were taken daily to determine the days taken to complete each larval instar, pupal stage, adult longevity and number of prey consumed during the developmental period. The number of prey was maintained at 15 per plant by replacing the number consumed daily. Five replications were maintained for each treatment.

The period from the day of adult emergence till its mortality was taken as adult longevity. The total number of the prey consumed by different instars and adults was determined from the observations taken daily.

3.2.4.3 T. maxillosa

A pair of freshly emerged spiders (male and female) were released onto rice plants infested with *N. lugens* maintained in cages as described in 3.2.2.1. Five such cages were set up to serve as replications. Immediately after the appearance of egg sac, the females were transferred to similar individual rearing cages. The emergence of spiderlings was observed daily. The incubation period was assessed by noting the number of days taken for the emergence of the spiderlings. Newly emerged first instar spiderlings were then transferred to rice plants in mylar film cages at the rate of one spiderling per plant. Five replications were maintained. Fifteen nymphs of *N. lugens* were supplied to the spiderlings up to the fourth instar and adult *N. lugens* were given to the subsequent instars and adult spiders. The number of *N. lugens* was maintained uniformly at 15 per pot throughout the period of study by replenishing with the required number of prey every day. The number of prey consumed during each instar and by adults was noted. The duration of each instar and total nymphal period were recorded by observing the cages daily. Each instar of a spiderling was identified based on the presence of moulted skin or exuvium either on the plant or inside the cage.

The newly moulted adult spiders were maintained in cages with 15 *N. lugens* infested rice plants (3.2.2.1) to determine their longevity. The cages were observed daily and replenished with adult *N. lugens* to maintain the number at 15 in each cage till the death of the spider. The longevity of the adult spider was assessed by recording the date of emergence and mortality of the spider.

The duration of different instars and longevity of adult *T. maxillosa* and number of prey consumed when reared on *S. furcifera* and *Nephotettix* sp. were also studied as described above.

3.2.4.4 L. pseudoannulata

The developmental period, adult longevity and number of prey consumed by *L. pseudoannulata* when reared on *N. lugens*, *S. furcifera* and *Nephotettix* sp. were determined as detailed in 3.2.4.3.

3.3 EVALUATION OF PREDATORY EFFICIENCY

The potential of *C. lividipennis*, *M. discolor*, *T. maxillosa* and *L. pseudoannulata*, in suppressing the population of hoppers was studied by assessing their searching capacity, feeding potential, prey preference and hyperpredatory activity. The plants were raised in cylindrical clay pots (30 x 30 cm) filled with clayey soil and were planted with six seedlings of 25 day old rice seedlings of Jaya and maintained as described in 3.2.2.1. One week after planting, the seedlings were confined in a cylindrical polyethylene cage (30 cm diameter x 45 cm height) the top portion of which was covered with perforated polyethylene sheet (Plate 2). These plants were maintained in the insectary.

3.3.1 Assessment of Searching Capacity

Searching capacity of *C. lividipennis*, *M. discolor*, *T. maxillosa* and *L. pseudoannulata*, when supplied with a mixed population of *N. lugens*, *S. furcifera*, *Nephotettix* sp. and *R. dorsalis* was determined by following the procedure of Nicholson and Bailey (1935) with slight modification as detailed below.

3.3.1.1 C. lividipennis

The searching capacity of adult *C. lividipennis* was studied with the first instar nymphs of the prey insects *viz*., *N. lugens*, *S. furcifera, Nephotettix* sp. and *R. dorsalis.* Ten numbers of each prey species were collected from the stock culture and released on rice plants raised in pots as described in 3.3. One *C. lividipennis,* starved for 24 hours was released in a cage. Five such cages were maintained as replications.

The number of prey surviving attack after 24 hours was recorded, and the searching capacity was worked out as the "area of discovery" using the formula:

$$A = 1/p \log N/S$$

Where,

A – Area of discovery of a natural enemy

p – Number of searching natural enemies

N _ Number of prey initially present

S – Number of prey surviving attack

3.3.1.2. M. discolor

The searching capacity of adult *M. discolor* was studied as mentioned in 3.3.1.1 with the second instar nymphs of prey insects.

3.3.1.3 T. maxillosa

The searching capacity of adult *T. maxillosa* was studied as described in 3.3.1.1 using the adults of the prey insects.

3.3.1.4 L. pseudoannulata

The searching capacity of adult *L. pseudoannulata* was studied as described in 3.3.1.1 using the adults of the prey insects.

3.3.2 Assessment of Feeding Potential

The feeding potential of *C. lividipennis* was studied with the first instar nymphs of *N. lugens, S. furcifera* and *Nephotettix* sp. For *M. discolor*, the prey tested were its eggs and second instar nymphs of *N. lugens* and *S. furcifera*. The feeding potential of both sexes of *T. maxillosa* and *L. pseudoannulata* was determined by supplying the adults of *N. lugens, S. furcifera* and *Nephotettix* sp.

3.3.2.1 C. lividipennis

The experiment was conducted in caged potted plants as detailed in 3.3. Fifteen first instar nymphs of *N. lugens* collected from the stock culture were introduced into a cage and five such replications were maintained. Adults of *C. lividipennis* collected from the stock culture were starved for 24 hours and released in each cage at the rate of one mirid per cage. The number of prey consumed by the mirid daily in each replication was recorded up to seven days. The number of prey insects was maintained at 15 per cage daily by releasing the required number each day. The mean number of nymphs of *N. lugens* consumed by a single mirid per day in each replication was calculated.

Feeding potential of *C. lividipennis* using first instar nymphs of *S. furcifera* and *Nephotettix* sp. was studied as described above.

3.3.2.2 M. discolor

Feeding potential of *M. discolor* was studied on the eggs of *M. discolor* and second instar nymphs of *N. lugens* and *S. furcifera* as described in 3.3.2.1.

3.3.2.3 T. maxillosa

The feeding potential of both sexes of *T. maxillosa* was determined by supplying with the adults of *N. lugens, S. furcifera* and *Nephotettix* sp. as described in 3.3.2.1.

The experiment was conducted in caged potted plants as detailed in 3.3. Fifteen adult *N. lugens* collected from the stock culture were introduced into a cage and five such replications were maintained. Adult females of *T. maxillosa* of uniform age collected from the stock culture were starved for 24 hours and released in each cage at the rate of one spider per cage. The number of prey consumed by the spider daily in each replication was recorded up to seven days. The number of prey insects was maintained at 15 per cage, daily by releasing the required number each day. The mean number of *N. lugens* consumed by a single female spider per day in each replication was calculated. The feeding potential of adult male spider was determined similarly.

The feeding potential of male and female *T. maxillosa* using *S. furcifera* and *Nephotettix* sp. was studied as detailed above.

3.3.2.4 L. pseudoannulata

Feeding potential of male and female *L. pseudoannulata* was assessed following the procedure described in 3.3.2.3.

3.3.3 Assessment of Prey Preference

The prey preference of insect predators and spider predators was determined by supplying with a mixed population of the respective prey as detailed below.

3.3.3.1 C. lividipennis

The prey preference of one day old adult mirid bug, *C. lividipennis* was studied with a mixed population of the first instar nymphs of *N. lugens, S. furcifera* and *Nephotettix* sp. Five prey of each species were introduced into a cage containing rice plants raised as described in 3.3. One adult *C. lividipennis* collected from the stock culture was starved for 24 hours and released in a cage. Five replications were maintained. The population of the prey was maintained uniformly at 15 per cage throughout the period of study by replacing the number of dead prey with live ones daily after each observation. The number of prey insects consumed by the mirid was recorded daily for seven days.

3.3.3.2 M. discolor

Prey preference of adult *M. discolor* was studied with the mixed population of the eggs of *M. discolor* and second instar nymphs of *N. lugens* and *S. furcifera* as in 3.3.3.1.

3.3.3.3 T. maxillosa

The prey preference of both sexes of *T. maxillosa* was determined by supplying with the mixed population of the adults of *N. lugens, S. furcifera* and *Nephotettix* sp. as described in 3.3.3.1

3.3.3.4 L. pseudoannulata

Prey preference of the male and female adults of *L. pseudoannulata* was assessed as described in 3.3.3.3.

3.3.4 Assessment of Hyperpredatory Activity

The experiment was conducted in the lines as suggested by Guillebeau and All (1989). Ten predators commonly seen in the rice ecosystem as listed below were selected for the study:

1. *Crocothemis* sp.
2. *Agriocnemis* sp.
3. *Polytoxus fuscovitattus*
4. *Tetragnatha maxillosa*
5. *Oxyopes* sp.
6. *Lycosa pseudoannulata*
7. *Atypena formosana*
8. *Ophionea nigrofasciata*
9. *Cyrtorhinus lividipennis*
10. *Micraspis discolor*

Each one of the predators starved for 24 hours served as the searching predator while the non starved predators acted as the prey. One searching predator was released in a cage containing rice plants raised in clay pots as described in 3.3. Five numbers of a prey were introduced into the cage and were observed for hyperpredatory activity. The number of prey consumed was recorded after 24 hours. Two replications were maintained. Such searching predator plus prey predator combinations were tested for hyperpredatory activity for each of the predator selected for the study and percentage of prey consumed was worked out.

3.4 DETERMINATION OF TOXICITY OF INSECTICIDES TO MAJOR PREDATORS

The relative toxicity of the insecticides carbaryl, phosphamidon, monocrotophos, quinalphos and methyl parathion to the adults of *C. lividipennis, M. discolor, T. maxillosa, Agriocnemis* sp. and *O. nigrofasciata* was assessed in terms of LC_{50}. Ten graded concentrations of the technical material of each insecticide as detailed below were prepared in acetone.

Stock solution –

One gram technical material in 25 ml acetone 4% - (A)

5.00ml A	+	95 ml EW	-	0.20 %	(B)
50.00ml B	+	50 ml EW	-	0.10 %	(C)
50.00ml C	+	50 ml EW	-	0.05 %	(D)
50.00ml D	+	50 ml EW	-	0.025 %	(E)
50.00ml E	+	50 ml EW	-	0.0125 %	(F)
50.00ml F	+	50 ml EW	-	0.006 %	(G)
50.00ml G	+	50 ml EW	-	0.003 %	(H)
50.00ml H	+	50 ml EW	-	0.0015 %	(I)
50.00ml I	+	50 ml EW	-	0.0007 %	(J)
50.00ml J	+	50 ml EW	-	0.0003 %	(K)

One ml. of each concentration of the insecticide was taken in a petridish and rotated for a few seconds for uniform spread over the entire area of the dish and dried under a fan for ten minutes. Ten adults of the test insect/spider of uniform size and age were released per petridish and observed for mortality, 24 and 48 hours after treatment (HAT). Moribund insects/spiders were treated as dead. Petridishes treated with acetone served as control. Five replications were maintained.

3.5 STATISTICAL ANALYSIS

The data thus obtained were subjected to probit analysis (Finney, 1981). Regression equations were calculated for each insecticide and LC_{50} values were computed.

Data relating to each experiment were analysed by applying the appropriate method of analysis.

RESULTS

4. RESULTS

Rice is the only one crop cultivated in standing water. As such, the ecosystem is unique with a diversity of fauna and flora. Biotic and abiotic stresses lead to change in the dynamic system. Of late, the preponderance of predators has been observed in rice ecosystems. Results of the present study conducted to identify the major predators in the rice ecosystems of Kerala, their potential in managing hoppers and their sensitivity to insecticides are presented hereunder:

4.1 STUDIES ON ARTHROPOD COMMUNITY IN RICE ECOSYSTEMS

4.1.1 Arthropod Abundance During First Season

4.1.1.1 Rice Ecosystem of Kuttanadu

Predators occurring at 30 DAT

The insect predators *viz*., *C. lividipennis*, *Agriocnemis* spp. and dragonflies were the major predators seen at 30 DAT in Kuttanadu rice ecosystem (Table 2). These predators were observed in all the six locations. The mean number of *C. lividipennis* observed were 5.00, 5.33, 1.67, 1.67, 11.33 and 7.00 per 10 sweeps and 1.10, 3.20, 0.60, 0.60, 1.60 and 0.60 per hill respectively at Ramankari, Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari respectively. While the mean population of *Agriocnemis* spp. ranged from 2.67 to 5.67 per 10 sweeps, the population of dragonflies assessed visually ranged from 0.67 to 2.67 per 20 m^2, the maximum number of the predator was recorded from Moncompu.

Among the spider predators, *Tetragnatha* spp. was recorded from five locations. The population of *Tetragnatha* spp. in sweep net collection varied from 1.00 to 2.67 per 10 sweeps and 0.20 to 1.10 per hill when assessed through direct count. *L. pseudoannulata* (0.20 per hill) was seen only at Ramankari and Moncompu while *A. formosana* was seen in all the locations except Champakulam (0.33 to 1.67 per 10 sweeps) and (0.00 to 0.30 per hill). At Alappuzha, a mean number of 0.30 *A. formosana* was assessed per hill through direct count method.

Table 2 Incidence of entomophages and neutrals in the rice ecosystem of Kuttanadu at 30 DAT (Season I)

Entomophages/ Neutrals	Locations																							
	Ramankari				Nedumudi				Moncompu				Alappuzha				Champakulam				Kainakari			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN
Insect predators *C. lividipennis*	5.00± 2.00	1.10± 1.10		5.00± 2.00	5.33± 2.52	3.20± 2.67		5.00± 2.65	1.67± 1.53	0.60± 0.70		1.67± 1.53	1.67± 1.53	0.60± 0.70		1.00± 1.73	11.33± 3.00	1.60± 1.07		4.33± 2.52	7.00± 5.57	0.60± 1.07		3.67± 2.52
Agriocnemis spp.	5.00 ± 3.61	0.00		2.67± 1.15	4.67± 4.04			3.67± 1.53	4.33± 1.53			3.67± 1.53	2.67± 1.53			0.67± 1.15	5.67± 3.06			2.67± 3.06	5.33± 3.21			2.33± 0.58
Euscyrtus sp.				1.00± 1.00				0.33± 0.58				2.00± 2.00				3.00± 2.65								1.67± 1.53
Dragonflies			1.67± 2.08				0.67± 1.15				2.67± 3.06				0.67± 1.15				2.33± 2.52				1.67± 1.53	
Spiders *Tetragnatha* spp.	1.00± 1.00	0.40± 0.52				1.10± 1.29		0.33± 0.58				0.67± 1.15	2.67± 3.06	0.40± 0.52			2.00± 1.73	0.40± 0.52			1.00± 1.00	0.20± 0.42		
L. pseudoannulata		0.20± 0.42								0.20± 0.42														
A. formosana	0.67± 0.58			0.67± 1.15	1.67± 0.58				0.33± 0.58				0.67± 0.15	0.30± 0.48		0.33± 0.58					0.33± 0.58			
Parasitoids *Tetrastichus* sp.													12.00± 5.00								1.67± 1.53			
Neutrals/others Culicids	3.67± 1.53			22.33± 3.51	1.67± 1.53			18.33± 4.04	0.67± 1.15			22.00± 5.57	2.00± 1.00			19.00± 8.00				13.67± 4.51	1.00 ± 1.73			19.33± 3.21
Chironomids	3.67± 2.08			1.33± 1.53	1.33± 2.31			1.67± 0.58	0.67± 1.15			0.67± 1.15	2.00± 3.46							1.33± 1.53				
Houseflies				1.33± 1.53				1.67± 0.58				1.33± 0.58				2.67± 0.58								

RE – Rice ecosystem NRE – Non rice ecosystem SN-Sweep net (per 10 sweeps) DC-Direct count (per hill) VC-Visual counting (per 20 m^2)

Both *C. lividipennis* and *Agriocnemis* spp. were seen in the adjoining non rice habitat. The population of these predators was almost similar to that seen in the rice ecosystem. While the population of *C. lividipennis* ranged from 1.00 to 5.00 per 10 sweeps, population of *Agriocnemis* spp. ranged from 0.67 to 3.67 per 10 sweeps. Besides these two predators, *Euscyrtus* sp. was also seen in the non rice ecosystem at Ramankari (1.00 per 10 sweeps), Nedumudi (0.33 per 10 sweeps), Moncompu (2.00 per 10 sweeps), Alappuzha (3.00 per 10 sweeps) and Kainakari (1.67 per 10 sweeps). Among the spiders, the population of *Tetragnatha* spp. and *A. formosana* ranged from 0.33 to 0.67 per 10 sweeps.

Parasitoids occurring at 30 DAT

The only parasitoid recorded from Kuttanadu rice ecosystem at 30 DAT was *Tetrastichus* sp. and it was seen in sweep net samples taken from Alappuzha (12 per 10 sweeps) and Kainakari (1.67 per 10 sweeps). No parasitoid was seen in the adjoining vegetation.

Neutrals occurring at 30 DAT

Other insects seen in the ecosystem included culicids and chironomids. The population of culicids ranged from 0.67 to 3.67 per 10 sweeps in the rice fields and 13.67 to 22.33 per 10 sweeps in the non rice habitat. Population of chironomids ranged from 0.67 to 3.67 per 10 sweeps in rice ecosystem and 0.67 to 1.33 per 10 sweeps in the non rice ecosystem. Houseflies were seen only in non rice ecosystem, its population ranging from 1.33 to 2.67 per 10 sweeps.

Pests occurring at 30 DAT

The hemipterans *N. lugens, Nephotettix* spp. and *C. spectra* and the lepidopteran, *C. medinalis* were the four pests seen infesting rice at 30 DAT (Table 3). While incidence of *N. lugens*, *C. medinalis* and *Nephotettix* spp. was seen in all the six locations surveyed, *C. spectra* occurred only at Nedumudi. Among the four pests, *N. lugens* was the predominant species. The mean number of *N. lugens* recorded from Ramankari, Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari were 66.33, 59.00, 35.67, 40.33, 49.00 and 38.67 per 10 sweeps and 4.90, 6.90, 6.00, 7.90, 3.70 and 0.90 per hill respectively. This

Table 3. Incidence of pests in the rice ecosystem of Kuttanadu at 30 DAT (Season I)

Pests	Locations																	
	Ramankari			Nedumudi			Moncompu			Alappuzha			Champakulam			Kainakari		
	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE
	Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment		
	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN
N. lugens	66.33± 28.50	4.90± 2.51		59.00± 13.89	6.90± 4.07		35.67± 5.03	6.00± 1.83		40.33± 11.50	7.90± 2.51		49.00± 34.87	3.70± 1.70		38.67± 8.33	0.90± 0.74	
C. medinalis	8.00± 4.58	0.40± 0.52		11.33± 4.51	0.70± 0.82		11.00± 8.00	0.70± 0.67		10.67± 4.51	0.90± 0.74		13.00± 8.54	0.50± 0.61		3.00± 2.65	0.20± 0.42	
Nephotettix spp.	4.67± 2.89		1.00± 1.73	10.67± 3.21		2.00± 2.00	4.67± 2.52		1.33± 2.31	2.33± 1.53		1.00± 1.00	8.33± 7.09	0.30± 0.48	3.33± 1.53	8.67± 2.08	0.50± 0.71	2.33± 2.52
C. spectra					0.50± 0.85													
M. histrio									0.33± 0.58						0.33± 0.58			
O. chinensis						0.67± 1.15			1.00± 1.73						0.67± 1.15			

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill)

was followed by *C. medinalis,* the mean number of the pest being 8.00, 11.33, 11.00, 10.67, 13.00 and 3.00 per 10 sweeps and 0.40, 0.70, 0.70, 0.90, 0.50 and 0.20 per hill in the above six locations respectively. Population of *Nephotettix* spp. was low, the mean number being 4.67, 10.67, 4.67, 2.33, 8.33 and 8.67 per 10 sweeps in Ramankari, Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari respectively and 0.30 and 0.50 per hill at Champakulam and Kainakari respectively when recorded through direct count. *C. spectra* was recorded only from Nedumudi through direct count (0.50 per hill).

Among the pests seen in the rice ecosystem, only the green leafhopper *Nephotettix* spp. was recovered from the adjoining non rice habitat. The pest was seen in all the six locations surveyed. The mean number of hoppers per 10 sweeps ranged from 1.00 to 3.33. The population of other pests in the non rice habitat *viz.*., *M. histrio* in Moncompu (0.33 per 10 sweeps) and Champakulam (0.33 per 10 sweeps) and *O. chinensis* in Nedumudi (0.67 per 10 sweeps), Moncompu (1.00 per 10 sweeps) and Champakulam (0.67 per 10 sweeps) was negligible.

Predators occurring at 50 DAT

Five insect predators were observed at 50 DAT of which *Agriocnemis* spp. and dragonflies were noted in six locations, *C. lividipennis* in five, *M. discolor* in four and *P. fuscovittatus* in three locations (Table 4). While substantial number of *Agriocnemis* spp. was observed in sweep net collections in all the locations (the mean population ranging from 3.00 to 41.00 per 10 sweeps.), the predator could be observed through direct count only at Nedumudi (0.50 per hill). The mean number of dragonflies observed in the six locations ranged from 1.33 to 3.00 per 20 m^2, the mean number recorded at each location being 3.00 (Ramankari), 2.67 (Nedumudi), 1.67 (Moncompu), 1.33 (Alappuzha), 2.33 (Champakulam) and 2.00 (Kainakari) per 20 m^2.

The mean number of *C. lividipennis* recorded from Ramankari, Nedumudi, Moncompu, Champakulam and Kainakari were 6.67, 21.67, 8.00, 2.33 and 13.67 per 10 sweeps and 0.60, 3.80, 0.70, 0.20 and 0.80 per hill respectively. Mean population of *M. discolor* ranged from 0.67 to 7.33 per 10 sweeps. Only a few

Table 4 Incidence of entomophages and neutrals in the rice ecosystem of Kuttanadu at 50 DAT (Season I)

Entomophages / Neutrals	Ramankari				Nedumudi				Moncompu				Alappuzha				Champakulam				Kainakari			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN
Insect predators *C. lividipennis*	6.67 ± 6.35	0.60± 1.26		4.00± 3.00	21.67 ± 6.03	3.80± 2.53		3.67± 1.53	8.00± 3.00	0.70± 0.82		7.00± 3.61				4.33± 1.53	2.33± 1.53	0.20± 0.42		5.00± 2.00	13.67± 3.06	0.80± 0.78		5.00± 3.61
Agriocnemis spp.	13.67± 3.06			1.67± 2.07	12.00 ± 4.36	0.50± 0.71		3.00± 1.00	17.67± 3.51			1.00± 1.73	3.00± 1.00			2.00± 2.00	9.33± 5.86			1.33± 1.53	41.00± 4.58			2.33± 1.53
M. discolor	5.00 ± 3.00	0.20 ± 0.42		0.33 ± 0.58		0.10 ± 0.32			7.33 ± 1.73	0.50 ± 0.71		0.33 ± 0.58				1.00 ± 1.73	0.67 ± 1.15				2.33 ± 1.53			0.33 ± 0.58
P. fuscovittatus	0.67 ± 0.58								2.67 ± 1.53											1.67 ± 2.08	2.33 ± 0.58			
Dragonflies			3.00± 1.00				2.67± 1.53				1.67± 1.53				1.33± 1.15				2.33± 2.08				2.00± 2.00	
Spiders *Tetragnatha* spp.	11.00± 3.00	0.50± 0.71		0.67± 1.15				2.00± 2.65	1.67 ± 0.58	0.30± 0.48		1.33± 1.53	1.00± 1.00			0.33 ± 0.58	2.00± 2.00	0.30± 0.48		1.00 1.00	2.67± 1.53	0.30± 0.48		0.67± 1.15
L. pseudoannulata					1.33 ± 1.15				1.33 ± 1.15															
A. formosana	1.33± 2.31								0.30± 0.48			1.00 ± 1.73				0.33± 0.58								2.00 ± 3.46
Parasitoids *Tetrastichus* sp.	2.67 ± 3.79																							
Telenomus sp.	3.67 ± 2.08																							
Neutrals/ others Culicids	4.33± 2.52			17.33± 6.03	2.33± 0.58			18.67± 1.53	2.00± 3.46			17.33± 7.76	2.00± 1.00			19.00± 6.00	3.67± 1.53			15.33± 4.04				16.33± 4.51
Chironomids	2.33± 1.15				3.67± 1.53				2.00± 1.00			0.67± 1.15	2.33± 1.53			0.67 ± 1.15	3.33± 1.53			0.33± 0.58	3.33± 2.52			

RE – Rice ecosystem NRE – Non rice ecosystem SN-Sweep net (per 10 sweeps) DC-Direct count (per hill) VC-Visual counting (per 20 m^2)

beetles (0.10 to 0.50 per hill) were observed through direct count at three locations. The mean number of *P. fuscovittatus* recorded from the three locations *viz.*, Ramankari, Moncompu, and Kainakari through sweep net collections was 0.67, 2.67, and 2.33 per 10 sweeps respectively.

Tetragnatha spp., *L. pseudoannulata* and *A. formosana* were the three spiders observed at 50 DAT. *Tetragnatha* spp. was recorded from all the locations surveyed except Nedumudi. More numbers of the spider was observed in sweep net collections (1.00 to 11.00 per 10 sweeps) than by direct count (0.30 to 0.50 per hill) at three locations *viz.*, Ramankari, Moncompu and Champakulam. While *L. pseudoannulata* was seen only at Nedumudi (1.33 per 10 sweeps) and Moncompu (1.33 per 10 sweeps), *A formosana* was recorded from Ramankari (1.33 per 10 sweeps) and Moncompu (0.30 per 10 sweeps).

Most of the predators present in the rice ecosystem were recorded from the non rice ecosystem too. They included *C. lividipennis* (3.67 to 7.00 per 10 sweeps), *Agriocnemis* spp. (1.00 to 3.00 per 10 sweeps), *M. discolor* (0.33 to 1.00 per 10 sweeps) and *P. fuscovittatus* (1.67 per 10 sweeps). The spiders observed were *Tetragnatha* spp. (0.33 to 2.00 per 10 sweeps) and *A. formosana* (0.33 to 2.00 per 10 sweeps). While *Tetragnatha* spp. was recorded from all the six locations, *A. formosana* was seen only in three locations.

Parasitoids occurring at 50 DAT

Two parasitoids, *Tetrastichus* sp. (2.67 per 10 sweeps) and *Telenomus* sp. (3.67 per 10 sweeps) were observed at 50 DAT. Both the parasitoids were seen only at Ramankari.

Neutrals occurring at 50 DAT

The other insects seen in the rice ecosystem included the culicids and the chironomids. Mean population of culicids observed in five padasekharams ranged from 2.00 to 4.33 per 10 sweeps and chironomids from 2.00 to 3.67 per 10 sweeps. None of these species could be recorded through direct count.

Population of culicids was higher in the adjoining nonrice fields than in the rice ecosystem, the mean population ranging from 15.33 to 19.00 per 10 sweeps. However, the mean population of chironomids seen in the nonrice fields of Moncompu, Alappuzha and Champakulam was low (0.33 to 0.67 per 10 sweeps).

Pests occurring at 50 DAT

Besides *N. lugens*, *C. medinalis*, *Nephotettix* spp., *C. spectra*, *M. histrio* and *O. chinensis* which were observed at 30 DAT, *S. furcifera* and *L. acuta* were also recorded at 50 DAT (Table 5). The white backed planthopper *S. furcifera* was the predominant pest, the mean population recorded per 10 sweeps from Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari being 402.67, 348.00, 166.67, 94.67 and 137.33 respectively and through direct count being 7.20, 8.00, 8.70, 4.70 and 5.90 per hill. This was followed by *C. medinalis,* the mean population being 7.00, 11.33, 10.67, 11.67, 18.33 and 25.33 per 10 sweeps and 0.50, 1.80, 1.00, 0.40, 0.20 and 0.90 per hill when recorded from Ramankari, Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari respectively. The mean population of *N. lugens* ranged from 2.33 to 26.00 per 10 sweeps in the six locations surveyed. Through direct count assessment, a mean population of 6.80 *N. lugens* per hill was recorded at Ramankari alone. The mean number of *Nephotettix* spp. collected in sweep net from each of the six locations was 5.67, 12.00, 16.67, 2.33, 3.00, 17.67 per 10 sweeps respectively and the mean number observed per hill at Ramankari, Moncompu, Alappuzha and Kainakari were 0.20, 0.50, 0.20 and 0.70 respectively. The mean number of *L. acuta* collected per 10 sweeps were 0.67, 2.33, 10.00, 0.67 and 0.67 from Ramankari, Nedumudi, Moncompu, Champakulam and Kainakari respectively. The bug was observed at two locations through direct count, the number being 0.30 per hill and 0.60 per hill at Nedumudi and Moncompu respectively. *C. spectra* was observed in three padasekharams. The incidence of the pest was low, the mean population ranging from 0.67 to 2.67 per 10 sweeps and 0.70 per hill (Nedumudi). Mean population of *M. histrio* and *O. chinensis* was also low. The mean number of *M. histrio*

Table 5. Incidence of pests in the rice ecosystem of Kuttanadu at 50 DAT (Season I)

Pests	Locations																	
	Ramankari			Nedumudi			Moncompu			Alappuzha			Champakulam			Kainakari		
	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE
	Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment		
	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN
S. furcifera				402.67± 76.04	7.20± 2.10		348.00± 78.69	8.00± 2.36		166.67± 34.02	8.70± 1.64		94.67± 18.58	4.70± 2.06		137.33± 42.27	5.90± 2.42	
N. lugens	12.00± 2.00	6.80± 0.79	2.67± 3.05	26.00± 6.56		2.33± 1.53	9.33± 2.52		1.33± 2.31	3.67± 3.51		1.33± 0.58	2.33± 2.08		1.33± 2.31	5.00± 2.00		1.00± 1.00
C. medinalis	7.00± 3.00	0.50± 0.71	7.00± 3.00	11.33± 4.04	1.80± 1.03	3.67 ± 1.53	10.67± 6.11	1.00± 0.82	3.33 ± 3.06	11.67± 3.79	0.40± 0.52	2.00 ± 2.00	18.33± 7.77	0.20± 0.42	3.33 ± 2.31	25.33± 4.04	0.90± 0.99	3.00± 2.00
L. acuta	0.67± 0.58			2.33 ± 1.53	0.30 ± 0.48		10.00± 2.00	0.60 ± 0.84					0.67 ± 1.15			0.67 ± 0.58		
Nephotettix spp.	5.67± 1.53	0.20± 0.42	1.33± 1.53	12.00± 4.00		3.00± 3.61	16.67± 5.51	0.50 ± 0.71	3.33± 3.21	2.33± 1.53	0.20± 0.42	0.33± 0.58	3.00± 3.00		1.33± 1.53	17.67± 4.51	0.70± 0.82	1.67± 1.53
C. spectra				2.67± 2.31	0.70± 0.82		2.00 ± 2.00						0.67± 1.15					
M. histrio	0.67± 0.58						1.00± 1.00									0.67± 0.58		
O. chinensis				0.67± 0.58			2.33± 1.15			0.33± 0.58			0.33± 0.58			1.33± 1.15		

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill)

collected were 0.67, 1.00 and 0.67 per 10 sweeps from Ramankari, Moncompu and Kainakari respectively. By sweep net collection, *O. chinensis* was recorded from 10 sweeps from Nedumudi (0.67), Moncompu (2.33), Alappuzha (0.33), Champakulam (0.33) and Kainakari (1.33).

Among the pests in the rice ecosystem, *N. lugens*, *C. medinalis* and *Nephotettix* spp. were recorded from the adjoining non rice habitat too. The mean number of *N. lugens* per 10 sweeps ranged from 1.00 to 2.67, *C. medinalis* 2.00 to 7.00 and *Nephotettix* spp. 0.33 to 3.33. The three pests were observed in all the six locations surveyed.

Predators occurring at 70 DAT

The insect predators *viz.*, *C. lividipennis*, *Agriocnemis* spp., *M. discolor*, *P. fuscovittatus* and dragonflies were observed in all the six locations (Table 6). *C. lividipennis* was the dominant predator recorded, the mean number collected by 10 sweeps from Ramankari, Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari being 69.33, 114.67, 15.00, 10.00, 5.00 and 7.00 respectively. Comparatively, lower population of the predator was observed through direct count. The mean number of the mirid observed in the six locations was 2.60, 8.20, 0.80, 0.90, 0.20 and 0.60 per hill respectively. Similarly, a mean number of 17.00, 8.33, 17.33, 4.67, 7.00 and 6.00 per 10 sweeps of *Agriocnemis* spp. was recorded from these locations respectively. The damselfly was not observed through direct count. The mean population of *M. discolor* was 42.00, 52.67, 4.00, 15.00, 10.33 and 15.33 per 10 sweeps and 1.40, 2.60, 0.20, 0.70, 0.50 and 0.70 per hill by direct count respectively and that of *P. fuscovittatus* was 17.67, 14.67, 14.67, 15.00, 11.33 and 3.67 per 10 sweeps respectively. *P. fuscovittatus* was not observed in direct count method. At 70 DAT, dragonflies were visually counted and recorded from all the six locations and the mean number seen were 2.67, 2.00, 3.33, 4.33, 3.00 and 1.00 per 20 m^2 in the respective six locations.

Tetragnatha spp. and *A. formosana* were the two spiders observed at 70 DAT. *A. formosana* was recorded from all the six locations and the mean population ranged from 0.67 to 7.00 per 10 sweeps and 0.20 to 1.00 per hill.

Table 6 Incidence of entomophages and neutrals in the rice ecosystem of Kuttanadu at 70 DAT (Season I)

Entomophages / Neutrals	Locations																							
	Ramankari				Nedumudi				Moncompu				Alappuzha				Champakulam				Kainakari			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN
Insect predators *C. lividipennis*	69.33± 9.02	2.60± 1.51		7.67± 1.53	114.67± 13.32	8.20± 2.04		10.33± 1.53	15.00± 3.00	0.80± 0.92		5.33± 3.51	10.00± 2.00	0.90± 0.88		1.67± 1.15	5.00± 2.00	0.20± 0.42		5.00± 2.00	7.00± 3.00	0.60± 0.70		7.00± 3.00
Agriocnemis spp.	17.00± 9.85			1.33± 1.53	8.33± 2.52			2.00± 1.00	17.33± 4.16			5.33± 1.53	4.67± 1.15			2.00± 2.00	7.00± 3.00			1.33± 1.53	6.00± 3.00			1.67± 0.58
M. discolor	42.00± 10.84	1.40± 0.84			52.67± 10.07	2.60± 2.17			4.00± 3.61	0.20± 0.42			15.00± 2.65	0.70± 0.67			10.33± 2.08	0.50± 0.71			15.33± 4.73	0.70± 0.82		
P. fuscovittatus	17.67± 6.51			1.67± 1.53	14.67± 6.03			2.33± 1.53	14.67± 6.03			1.00± 1.00	15.00± 5.57			0.67± 1.15	11.33± 2.52			1.67± 2.08	3.67± 3.06			0.67± 1.15
Dragonflies			2.67± 3.06				2.00± 2.00				3.33± 1.53				4.33± 1.53				3.00± 1.00				1.00± 1.00	
Spiders *Tetragnatha* spp.	1.67± 1.53	0.40± 0.52		1.53± 1.53		0.60± 0.70		0.67± 1.15	12.00± 2.00	0.90± 1.10		0.33± 0.58	0.33± 0.58	0.40± 0.52		1.67± 1.15				0.67± 1.15	2.67± 1.53	0.40± 0.52		2.00± 1.00
A. formosana	5.33± 3.06	0.70± 0.82		2.33± 1.53	4.67± 2.08	1.00± 1.15		1.33± 2.31	1.00± 1.00	0.20± 0.42		1.00± 1.00	1.67± 1.53	0.30± 0.48			7.00± 1.00	0.30± 0.48		0.67± 0.58	0.67± 1.15	0.20± 0.42		0.67± 1.15
Neutrals/ others Culicids				18.33± 7.09				13.33± 4.51				19.33± 3.51				16.67 ± 3.79				15.33± 3.51				19.67± 2.08
House flies				0.33± 0.58				0.67± 1.15				0.67± 1.15												0.33± 0.58
Atractomorpha sp.								0.67± 1.17				0.67± 1.15				1.33± 2.31				0.67± 1.15				

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill) VC - Visual counting (per 20 m^2)

Tetragnatha spp. was observed in four locations only *viz.*, Ramankari, Moncompu, Alappuzha and Kainakari. The mean population of *Tetragnatha* spp. in the four locations varied from 0.33 to 12.00 per 10 sweeps and 0.40 to 0.90 per hill. More number of the spiders were recovered by sweep net collection than by direct count.

Out of the five insect predators seen in rice ecosystem, three were recorded from the nonrice ecosystem also. They were *C. lividipennis*, *Agriocnemis* spp. and *P. fuscovittatus*. As in the rice ecosystem, *C. lividipennis* was the predominant predator seen in the non rice ecosystem and its mean population ranged from 1.67 to 10.33 per 10 sweeps. *Agriocnemis* spp. was also recorded from the six locations, the mean population of which varied from 1.33 to 5.33 per 10 sweeps. The mean number of *P. fuscovittatus* per 10 sweeps ranged from 0.67 to 2.33. The spiders seen in rice fields were also observed in the nonrice habitat. *Tetragnatha* spp. was observed in all the six locations, the mean population ranging from 0.33 to 2.00 per 10 sweeps. The mean population of *A. formosana* ranged from 0.67 to 2.33 per 10 sweeps.

Parasitoids occurring at 70 DAT

No parasitoids were recorded at 70 DAT.

Neutrals occurring at 70 DAT

Culicids, houseflies and *Atractomorpha* sp. were seen only in the nonrice ecosystem at 70 DAT. The mean population of culicids ranged from 13.33 to 19.67 per 10 sweeps. Mean population of houseflies (0.33 to 0.67 per 10 sweeps) and *Atractomorpha* sp. seen in adjoining vegetation of four padasekharams (0.67 to 1.33 per 10 sweeps) was low.

Pests occurring at 70 DAT

The hemipterans recorded at 70 DAT were *S. furcifera*, *L. acuta*, *Nephotettix* spp. and *M. histrio* and the lepidopteran recorded was *C. medinalis*. The rice earhead thrips, *Haplothrips ganglbaueri* Schmutz was also found to infest during this stage (Table 7). While *C. medinalis*,

Table 7 Incidence of pests in the rice ecosystem of Kuttanadu at 70 DAT (Season I)

Pests	Locations																	
	Ramankari			Nedumudi			Moncompu			Alappuzha			Champakulam			Kainakari		
	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE
	Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment		
	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN
S. furcifera	5.67± 0.58			8.00± 4.00	4.90± 1.66					2.33± 2.08								
C. medinalis	7.67± 3.06	1.10± 0.99		8.67± 5.51	0.90± 0.88		10.33± 2.65	0.70± 0.82		5.00± 2.65	0.70± 0.82		10.67± 3.06	1.00± 0.82		7.00± 2.00	0.50± 0.53	
L. acuta	27.33± 5.03	1.00± 0.82	1.00± 1.00	16.33± 4.51	0.80± 0.79	2.00± 1.00	16.33± 4.51	0.40± 0.52	0.33± 0.58	8.67± 5.13	0.40± 0.52	1.67± 1.15	7.33± 1.53	0.80± 0.79	1.67± 1.53	11.00± 6.00	0.40± 0.52	1.00± 1.00
Nephotettix spp.	12.67± 3.06		2.33± 2.51	28.67± 8.50		5.33± 2.08	14.00± 3.61	1.80± 1.48	2.67± 1.53	18.00± 4.00	0.50± 0.71	2.67± 1.15	10.33± 3.05	0.50± 0.53	1.33± 1.15	7.00± 4.00		1.00± 1.00
M. histrio	3.00± 1.00			2.00± 2.00												0.67± 1.15		
H. ganglbaueri	501.33± 18.04	46.10± 20.78		189.67± 12.34	21.10± 5.34		526.67± 162.63	13.60± 6.53		86.67± 6.11	5.10± 2.13		45.33± 6.11	7.00± 3.89		76.00± 8.00	13.90± 3.73	
C. spectra			0.33± 0.58									0.33± 0.58			0.33± 0.58			0.33± 0.58

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill)

L. acuta, *Nephotettix* spp. and *H. ganglbaueri* were seen in all the six locations surveyed, *S. furcifera* occurred only at Ramankari, Nedumudi and Alappuzha. Incidence of *M. histrio* was observed in Ramankari, Nedumudi and Kainakari.

Among the pests observed at 70 DAT, *H. ganglbaueri* was the dominant species. The mean population in the six locations was 501.33 (Ramankari), 189.67 (Nedumudi), 526.67 (Moncompu), 86.67 (Alappuzha), 45.33 (Champakulam) and 76.00(Kainakari) per 10 sweeps and 46.10, 21.10, 13.60, 5.10, 7.00 and 13.90 per hill respectively. This was followed by *Nephotettix* spp., the mean number in the respective locations being 12.67, 28.67, 14.00, 18.00, 10.33 and 7.00 per 10 sweeps. Through direct count the pest was recorded from three locations *viz.* Moncompu (1.80/hill), Alappuzha (0.50/hill) and Champakulam (0.50/hill) only. The mean population of *L. acuta* in each of the six locations was 27.33, 16.33,16.33, 8.67, 7.33 and 11.00 per 10 sweeps and 1.00, 0.80, 0.40, 0.40, 0.80 and 0.40 per hill respectively.

The population of *C. medinalis* ranged from 5.00 to 10.67 per 10 sweeps in the sweep net method and 0.50 to 1.10 per hill in direct count in the six locations surveyed. The mean number of *C. medinalis* noted from Ramankari, Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari were 7.67, 8.67, 10.33, 5.00, 10.67 and 7.00 per 10 sweeps and 1.10, 0.90, 0.70, 0.70, 1.00 and 0.50 per hill respectively. The mean population of *S. furcifera* assessed through sweep net method was 5.67, 8.00 and 2.33 per 10 sweeps in Ramankari, Nedumudi and Alappuzha respectively. Through direct count, a mean population of 4.90 was recorded from Nedumudi alone. Low population of *M. histrio* was recorded from Ramankari (3.00 per 10 sweeps), Nedumudi (2.00 per 10 sweeps) and Kainakari (0.67 per 10 sweeps) through sweep net collection.

Among the pests seen in the rice ecosystem, only the green leafhopper *Nephotettix* spp. and the rice bug, *L. acuta* were observed in the adjoining non rice ecosystem. The population of *Nephotettix* spp. ranged from 1.00 to 5.33 per 10 sweeps and that of *L. acuta* ranged from 0.33 to 2.00 per 10 sweeps. Apart from this, very low population of *C. spectra* was observed at Ramankari, Alappuzha, Champakulam and Kainakari, each location having a mean population of 0.33 per 10 sweeps.

4.1.1.2 Double Cropped Rice Ecosystem of Thiruvananthapuram

Predators occurring at 30 DAT

The predators seen at 30 DAT are given in Table 8. Among the insect predators, *C. lividipennis* was dominant and it was seen in all the locations except at Karamana. The mean population of the predators recorded from Ulloor, Anad, Punchakari, Upaniyoor and Athiyannoor were 19.33, 18.00, 44.00, 8.00 and 15.67 per 10 sweeps and 3.70, 1.20, 4.10, 1.60 and 2.40 per hill respectively. *Agriocnemis* spp. (1.00 to 8.33 per 10 sweeps) and *Euscyrtus* sp. (1.00 to 3.00 per 10 sweeps) were observed in all the six locations surveyed. *M. discolor* (2.00 to 4.00 per 10 sweeps and 0.20 to 0.40 per hill) was seen in all the locations except Punchakari. Very low population of *O. nigrofasciata* was recorded from Anad (1.00 per 10 sweeps) and Athiyannoor (0.33 per 10 sweeps). Comparatively more number of dragonflies were recorded in visual count and the maximum number being recorded from Punchakari (6.00 per 20 m^2). The mean number of dragonflies recorded from the other locations *viz.*, Ulloor, Anad, Karamana, Upaniyoor and Athiyannoor were 4.00, 1.00, 2.67, 1.67 and 2.00 per 20 m^2 respectively.

Tetragnatha spp., *L. pseudoannulata* and *A. formosana* were the three spiders observed at 30 DAT. *Tetragnatha* spp. was observed from all the six locations and it was the dominant predator. The mean population of this spider was 10.00, 4.35, 11.33, 5.00, 17.00, 9.00 per 10 sweeps and 0.80, 0.40, 0.90, 0.80, 0.90 and 1.00 per hill at Ulloor, Anad,

Table 8 Incidence of entomophages and neutrals in the double cropped rice ecosystem of Thiruvananthapuram at 30 DAT (Season I)

Entomophages / Neutrals	Locations																							
	Ulloor				Anad				Punchakari				Karamana				Upaniyoor				Athiyannoor			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN
Insect predators *C. lividipennis*	19.33± 4.93	3.70± 1.30		16.67± 6.03	18.00± 3.61	1.20± 1.28		10.33± 3.51	44.00± 10.58	4.10± 1.48		25.33± 9.71					8.00± 2.00	1.60± 1.26		3.00± 3.61	15.67± 8.02	2.40± 2.01		5.33± 3.51
Agriocnemis spp.	3.67± 1.52				8.33± 2.08				7.00± 3.00				8.33± 4.51				4.00± 1.00				1.00± 1.00			
M. discolor	4.00± 3.61	0.20± 0.41			2.00± 1.00	0.40± 0.50							2.67± 1.15	0.20± 0.42			3.33± 2.52				2.67± 1.53	0.20± 0.42		
O. nigrofasciata					1.00± 1.00																0.33± 0.58			
Euscyrtus sp.	1.00± 1.00			1.00± 1.00	1.67± 1.15			1.33± 0.58	3.00± 1.00			1.33± 1.53	2.00± 1.00			0.67± 0.58	2.33± 0.58				1.67± 0.58			1.00± 1.00
Dragonflies			4.00± 1.00				1.00± 1.00				6.00± 2.65				2.67± 1.15				1.67± 1.53				2.00± 2.64	
Spiders *Tetragnatha* spp.	10.00± 3.00	0.80± 0.77			4.35± 1.53	0.40± 0.68			11.33 2.52	0.90± 0.72			5.00± 2.00	0.80± 0.92			17.00± 2.00	0.90± 0.88			9.00± 2.00	1.00± 0.82		
L. pseudoannulata																	4.00± 2.65				2.33± 0.58			
A. formosana	1.10± 0.85																							
Parasitoids *Apanteles* sp.	1.00± 1.00				1.67± 0.58				2.33± 1.53															
Neutrals/ others Culicids	2.33± 0.58			12.00± 3.61				9.33± 2.52	2.00± 1.00			16.00± 6.00				16.33± 4.51				15.33± 4.16	2.33± 0.58			18.67± 7.51
Camponotus sp.				3.33± 4.16				4.00± 3.00				4.00± 2.65				2.33± 1.53				7.00± 4.00				3.33± 2.52
Atractomorpha sp.								0.67± 1.15								1.67± 0.58				1.33± 0.58				6.33± 1.53

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill) VC - Visual counting (per 20 m^2)

Punchakari, Karamana, Upaniyoor and Athiyannoor respectively. *L. pseudoannulata* was recorded from Upaniyoor (4.00 per 10 sweeps) and Athiyannoor (2.33 per 10 sweeps) and *A. formosana* (1.10 per 10 sweeps) was observed only at Ulloor.

Among the insect predators observed in the rice ecosystem, *C. lividipennis* and *Euscyrtus* sp. were recorded from the adjoining non rice ecosystem too. While the mean population of *C. lividipennis* ranged from 3.00 to 25.33 per 10 sweeps, the number of *Euscyrtus* sp. varied from 0.67 to 1.33 per 10 sweeps.

Parasitoids occurring at 30 DAT

The parasitoid *Apanteles* sp. was seen in three locations *viz.*, Ulloor (1.00 per 10 sweeps), Anad (1.67 per 10 sweeps) and Punchakari (2.33 per 10 sweeps).

Neutrals occurring at 30 DAT

Only culicids were observed in the rice ecosystem of Thiruvananthapuram at 30 DAT. It was also recorded from three locations *viz.*, Ulloor (2.33 per 10 sweeps), Punchakari (2.00 per 10 sweeps) and Athiyannoor (2.33 per 10 sweeps) by sweep net method. The mean population of culicids (9.33 to 18.67 per 10 sweeps), *Camponotus* sp. (2.33 to 7.00 per 10 sweeps) and *Atractomorpha* sp. (0.67 to 6.33 per 10 sweeps) were observed in the non rice fields of Thiruvananthapuram.

Pests occurring at 30 DAT

Three hemipterans and one orthopteran pest were observed in the double cropped rice fields of Thiruvananthapuram at 30 DAT, where need based application of pesticides was done (Table 9). *S. furcifera*, *Nephotettix* spp. and *C. spectra* were the hemipterans and *O. chinensis* was the only orthopteran pest observed. *S. furcifera* was the predominant species, the mean number of *S. furcifera* obtained from Ulloor, Punchakari, Upaniyoor and Athiyannoor being 9.33, 10.67, 17.00 and

Table 9 Incidence of pests in the double cropped rice ecosystem of Thiruvananthapuram at 30 DAT (Season I)

Pests	Locations																	
	Ulloor			Anad			Punchakari			Karamana			Upaniyoor			Athiyannoor		
	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE
	Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment		
	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN
S. furcifera	9.33± 6.11	4.60± 2.60	3.83± 2.32				10.67± 2.52	1.60± 1.39	1.33± 1.53				17.00± 5.00	2.40± 0.84	0.67± 1.15	25.67± 7.09	3.10± 1.66	0.33± 0.58
Nephotettix spp.	3.67± 2.08		7.67± 4.04	6.33± 4.93	4.10± 1.62	5.33± 4.43	4.33± 1.53	0.60± 1.05	4.33± 2.08	8.67± 2.08	0.80± 0.92	7.00± 4.36	5.00± 3.61	0.50± 0.71	6.67± 2.52			8.67± 2.08
C. spectra	1.33± 0.58	0.80± 1.01								3.00± 1.00						0.67± 0.58		
O. chinensis		1.10± 1.17	0.33± 0.58	2.33± 1.53	0.60± 1.05	1.67± 1.53				1.67± 0.58	0.20± 0.42	1.33± 1.15				1.33± 0.58		

RE – Rice ecosystem NRE – Non rice ecosystem SN – Sweep net (per 10 sweeps) DC – Direct Count (per hill)

25.67 per 10 sweeps and 4.60, 1.60, 2.40 and 3.10 per hill respectively. Incidence of *Nephotettix* spp. was seen in all the locations except Athiyannoor. The mean number recorded from Ulloor, Anad, Punchakari, Karamana and Upaniyoor were 3.67, 6.33, 4.33, 8.67 and 5.00 per 10 sweeps and through direct count 4.10, 0.60, 0.80 and 0.50 per hill respectively except Ulloor.

O. chinensis was seen in three locations *viz.*, Anad, Karamana and Athiyannoor. The mean number obtained were 2.33, 1.67 and 1.33 per 10 sweeps respectively. Through direct count, 1.10, 0.60 and 0.20 *O. chinensis* per hill were recorded from the three locations respectively.

C. spectra was observed in Ulloor, Karamana and Athiyannoor only. Incidence of *C. spectra* was negligible. Through sweep net 1.33, 3.00 and 0.67 per 10 sweeps were recorded respectively and the hopper was noted by direct count only from one location (Ulloor- 0.80 per hill).

Among the pests observed in the rice ecosystem, *S. furcifera* (0.33 to 3.83 per 10 sweeps), *Nephotettix* spp. (4.33 to 8.67 per 10 sweeps) and *O. chinensis* (0.33 to 1.67 per 10 sweeps) were recorded from the adjoining non rice fields.

Predators occurring at 50 DAT

The insect predators recorded at 50 DAT included *C. lividipennis*, *Agriocnemis* spp., *M. discolor*, *Euscyrtus* sp. and dragonflies (Table 10). Among these, *Agriocnemis* sp. was recorded from all the six locations. The mean number recorded from each of the locations surveyed were 10.33 (Ulloor), 3.00 (Anad), 4.00 (Punchakari), 6.67 (Karamana), 1.67 (Upaniyoor) and 1.00 (Athiyannoor) per 10 sweeps. Incidence of *M. discolor* was observed at four locations *viz.*, Anad, Punchakari, Upaniyoor and Athiyannoor, the mean population being 1.33, 3.00, 0.67 and 1.33 per 10 sweeps respectively and 0.50 per hill at Ulloor, 0.20 per hill at Punchakari and 0.40 per hill at Karamana through direct count. *C. lividipennis* was noted at three locations, the mean number recorded

Table 10 Incidence of entomophages and neutrals in the double cropped rice ecosystem of Thiruvananthapuram at 50 DAT (Season I)

Entomophages / Neutrals	Locations																							
	Ulloor				Anad				Punchakari				Karamana				Upaniyoor				Athiyannoor			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN
Insect predators *C. lividipennis*	4.00± 1.00																22.00± 15.52	2.10± 1.73			15.33± 7.09	1.70± 1.25		
Agriocnemis spp.	10.33± 3.06				3.00± 1.00				4.00± 2.65				6.67± 4.04				1.67± 0.58				1.00± 1.00			
M. discolor		0.50± 0.71			1.33± 1.53				3.00± 2.65	0.20± 0.42				0.40± 0.70			0.67± 0.58				1.33± 1.53			
Euscyrtus sp.				0.67± 1.03								0.33± 0.58	1.33± 0.58			0.33± 0.58	0.67± 1.15			1.00± 1.00	0.67± 0.58			0.67± 1.15
Dragonflies			0.67± 1.15				1.00± 1.00				2.00± 2.00				0.67± 1.15				0.67± 1.15				0.67± 1.58	
Spiders *Tetragnatha* spp.	5.33± 2.08	0.20± 0.42			2.00± 1.00	0.50± 0.71			2.33± 2.08	0.60± 0.70			6.67± 2.08	0.80± 1.03			4.00± 3.61	1.20± 1.03			2.67± 1.15	0.70± 0.82		
L. pseudoannulata	0.30± 0.48				1.00± 1.00																			
Parasitoids *Apanteles* sp.	3.33± 3.51				5.33± 3.21								7.33± 4.51				4.33± 2.52				1.00± 1.15			
Neutrals/ others Culicids	3.33± 2.31			9.00± 3.00	2.33± 4.04			11.67± 5.03				8.33± 2.52				18.33± 4.50				13.33± 4.04				14.00± 5.57
Chironomids	2.33± 2.08											2.33± 0.58				1.67± 1.53								
Camponotus sp.				3.67± 3.51				2.33± 1.53				1.67± 1.53								2.33± 2.08				1.33 ± 1.53
Atractomorpha sp.								2.33± 0.58				2.33± 1.53				2.33± 0.58				0.33± 0.58				2.00 ± 2.00

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill) VC - Visual counting (per 20 m^2)

being 4.00, 22.00 and 15.33 per 10 sweeps at Ulloor, Upaniyoor and Athiyannoor respectively. Through direct count, 2.10 and 1.70 *C. lividipennis* per hill were recorded from Upaniyoor and Athiyannoor respectively. *Euscyrtus* sp. was recorded from Karamana, Upaniyoor and Athiyannoor, the mean population being 1.33, 0.67 and 0.67 per 10 sweeps respectively. Population of dragonflies was low, the mean number recorded being 0.67 per 20 m^2 each in four locations *viz.*, Ulloor, Karamana, Upaniyoor and Athiyannoor. The mean number observed at Anad and Punchakari were 1.00 and 2.00 per 20 m^2 respectively.

Tetragnatha spp. and *L. pseudoannulata* were the two spiders recorded at 50 DAT. *Tetragnatha* spp. was the dominant spider and it was recorded from all the six locations surveyed, the mean population ranging from 2.00 to 6.67 per 10 sweeps and 0.20 to 1.20 per hill. Low population of *L. pseudoannulata* was observed at Ulloor (0.30 per 10 sweeps) and Anad (1.00 per 10 sweeps).

Euscyrtus sp. alone was observed from the nonrice habitat. The mean population of the insect predator was 0.67, 0.33, 0.33, 1.00 and 0.67 per 10 sweeps at Ulloor, Punchakari, Karamana, Upaniyoor and Athiyannoor respectively.

Parasitoids occurring at 50 DAT

Apanteles sp. was the only parasitoid observed in the double cropped rice fields of Thiruvananthapuram at 50 DAT. The mean number obtained through sweep net collections from Ulloor, Anad, Karamana, Upaniyoor and Athiyannoor were 3.33, 5.33, 7.33, 4.33 and 1.00 per 10 sweeps respectively.

Neutrals occurring at 50 DAT

Besides pests and natural enemies, culicids and chironomids were noted in the rice ecosystem of Thiruvananthapuram. Culicids were seen in two locations *viz.*, Ulloor (3.33 per 10 sweeps) and Anad (2.33 per 10 sweeps). Chironomids (2.33 per 10 sweeps) were obtained from Ulloor only.

Culicids were seen in all the locations in nonrice habitat, the mean population being 8.33 to 18.33 per 10 sweeps. Chironomids were recorded from two locations *viz.*, Punchakari (2.33 per 10 sweeps) and Karamana (1.67 per 10 sweeps). Other neutrals observed were *Camponotus* sp. (1.33 to 3.67 per 10 sweeps). *Atractomorpha* sp. was recorded from five locations *viz.*, Anad (2.33 per 10 sweeps), Punchakari (2.33 per 10 sweeps), Karamana (2.33 per 10 sweeps), Upaniyoor (0.33 per 10 sweeps) and Athiyannoor (2.00 per 10 sweeps).

Pests occurring at 50 DAT

The pests observed at 50 DAT from the double cropped rice fields of Thiruvananthapuram district included *C. medinalis*, *L. acuta*, *Nephotettix* spp., *C. spectra*, *M. histrio* and *O. chinensis* (Table 11). The green leafhopper, *Nephotettix* spp. was the dominant pest, incidence of which was recorded in all the six locations surveyed. The mean number of *Nephotettix* spp. collected from Ulloor, Anad, Punchakari, Karamana, Upaniyoor and Athiyannoor were 22.00, 5.33, 14.67, 11.67, 12.33 and 19.00 per 10 sweeps and 5.60, 0.60, 1.50, 1.40, 1.10 and 1.50 per hill respectively. The mean population of *C. spectra* ranged from 1.00 to 3.00 per 10 sweeps in all the locations except Karamana *viz.*, Ulloor (1.00), Anad (2.33), Punchakari (3.00), Upaniyoor (1.00) and Athiyannoor (1.00). Through direct count a mean of 0.20 and 0.50 per hill was noted from Punchakari and Ulloor respectively. *L. acuta* was observed from five locations *viz.*, Ulloor (1.00 per 10 sweeps), Punchakari (1.67 per 10 sweeps), Karamana (1.67 per 10 sweeps), Upaniyoor (3.33 per 10 sweeps) and Athiyannoor (1.00 per 10 sweeps). The mean number of *C. medinalis* recorded through sweep net from Punchakari, Upaniyoor and Athiyannoor was 2.67, 2.67 and 1.00 per 10 sweeps respectively. Similarly, low population of *M. histrio* (0.30 to 0.67 per 10 sweeps) and *O. chinensis* (0.33 to 3.00 per 10 sweeps) were noted in the respective three locations.

Table 11 Incidence of pests in the double cropped rice ecosystem of Thiruvananthapuram at 50 DAT (Season I)

Pests	Locations																	
	Ulloor			Anad			Punchakari			Karamana			Upaniyoor			Athiyannoor		
	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE
	Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment		
	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN
C. medinalis							2.67± 1.15						2.67± 2.52		1.00± 1.00	1.00± 1.15		0.33± 0.58
L. acuta	1.00± 1.00						1.67± 1.15			1.67± 1.53			3.33± 4.93			1.00± 1.15		
Nephotettix spp.	22.00± 9.17	5.60± 2.22	3.67± 1.53	5.33± 2.52	0.60± 0.70		14.67± 4.93	1.50± 1.51	4.00± 3.61	11.67± 4.51	1.40± 1.43		12.33± 3.06	1.10± 1.29	3.33± 4.16	19.00± 11.36	1.50± 1.35	1.33± 1.15
C. spectra	1.00± 1.00	0.50± 0.71		2.33± 0.58			3.00± 2.00	0.20± 0.42					1.00± 1.00			1.00± 1.00		
M. histrio	0.30± 0.48									0.33± 0.58			0.67± 1.15					
O. chinensis	1.00± 1.00		0.33± 0.58			1.33± 1.15				3.00± 1.00	0.20± 0.42					0.33± 0.58		

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill)

Only very few pests were seen in the nonrice fields at 50 DAT. This included the green leafhopper, *Nephotettix* spp., the small rice grass hopper, *O. chinensis* and *C. medinalis*. The mean number of green leaf hoppers ranged from 1.33 to 4.00 per 10 sweeps in the four locations where it was observed. *O. chinensis* was recorded from two locations *viz.*, Ulloor (0.33 per 10 sweeps) and Anad (1.33 per 10 sweeps) only. *C. medinalis* was seen in the adjoining vegetation of Upaniyoor (1.00 per 10 sweeps) and Athiyannoor (0.33 per 10 sweeps).

Predators occurring at 70 DAT

More number of insect predators were recorded at 70 DAT from the double cropped rice ecosystem of Thiruvananthapuram (Table 12). They were *C. lividipennis*, *Agriocnemis* spp., *M. discolor*, *O. nigrofasciata*, *P. fuscovittatus* and *Euscyrtus* sp. Among these *M. discolor* was the dominant predator, its occurrence in the six locations being 6.67 (Ulloor), 3.00 (Anad), 3.33 (Punchakari), 7.67 (Karamana), 7.00 (Upaniyoor) and 6.00 (Athiyannoor) per 10 sweeps. Through direct count it was observed in four locations *viz.*, Anad (0.40 per hill), Punchakari (0.20 per hill), Karamana (0.60 per hill) and Athiyannoor (1.10 per hill). This was followed by *Euscyrtus* sp., the mean number recorded from Ulloor, Anad, Punchakari, Karamana, Upaniyoor and Athiyannoor being 1.33, 1.00, 0.33, 0.67, 0.67 and 2.00 per 10 sweeps respectively. *Agriocnemis* sp. was recorded from all locations (0.33 to 1.33 per 10 sweeps) except Ulloor. *P. fuscovittatus* was observed from five locations (0.33 to 0.67 per 10 sweeps) except Anad. *C. lividipennis* occurred in three locations *viz.*, Ulloor (1.00 per 10 sweeps), Anad (3.67 per 10 sweeps) and Punchakari (3.33 per 10 sweeps). Negligible population (0.33 per 10 sweeps) of *O. nigrofasciata* was recorded from Anad and Karamana at 70 DAT.

Tetragnatha spp. and *L. pseudoannulata* were recorded at 70 DAT from Thiruvananthapuram. *Tetragnatha* spp. was observed in all the six locations. The mean number of *Tetragnatha* spp. recorded were 5.33,

Table 12 Incidence of entomophages and neutrals in the double cropped rice ecosystem of Thiruvananthapuram at 70 DAT (Season I)

Entomophages/ Neutrals	Locations																							
	Ulloor				Anad				Punchakari				Karamana				Upaniyoor				Athiyannoor			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN
Insect predators *C. lividipennis*	1.00± 1.73				3.67± 2.08				3.33± 0.58															
Agriocnemis spp.					0.33± 0.58				0.33± 0.58				0.67± 0.58				1.33± 1.53				0.33± 0.58			
M. discolor	6.67± 3.51				3.00± 1.00	0.40± 0.70			3.33± 2.31	0.20± 0.42			7.67± 1.15	0.60± 0.84			7.00± 8.66				6.00± 4.58	1.10± 1.52		
O. nigrofasciata					0.33± 0.58								0.33± 0.58											
P. fuscovittatus	0.67± 0.58								0.33± 0.58				0.33± 0.58				0.33± 0.58				0.67± 1.15			
Euscyrtus sp.	1.33± 1.53			1.67± 1.53	1.00± 1.00			3.67± 4.04	0.33± 0.58			2.00± 2.00	0.67± 0.58			2.67± 1.15	0.67± 1.15			0.33± 0.58	2.00± 1.73			0.67± 1.15
Dragonflies																								
Spiders *Tetragnatha* spp.	5.33± 4.07	1.00± 0.82		0.67± 1.15	2.33± 2.08	0.30± 0.48			3.33± 3.21	1.10± 0.99			7.67± 1.53	0.40± 0.70		0.33± 0.58	2.33± 1.53	0.20± 0.42			3.67± 3.21	1.00± 133		
L. pseudoannulata													0.67± 1.15				0.67± 0.58				1.00± 1.00			
Parasitoids *Apanteles* sp.	7.67± 3.06				1.67± 1.53				2.33± 2.51				5.67± 2.52				4.33± 2.31				1.67± 1.53			
Neutrals/ others Culicids.				9.33± 2.51				11.33± 3.51				15.00± 3.61				12.33± 4.16				15.33± 6.62				17.67± 5.51
Camponotus sp.				4.33± 5.13				3.00± 3.61								5.00± 5.57				3.00± 3.00				
Atractomorpha sp.													0.33± 0.58								1.00± 1.00			

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill) VC - Visual counting (per 20 m^2)

2.33, 3.33, 7.67, 2.33 and 3.67 per 10 sweeps and 1.00, 0.30, 1.10, 0.40, 0.20 and 1.00 per hill from Ulloor, Anad, Punchakari, Karamana, Upaniyoor and Athiyannoor respectively. *L. pseudoannulata* was noted in three locations only *viz.*, Karamana (0.67 per 10 sweeps), Upaniyoor (0.67 per 10 sweeps) and Athiyannoor (1.00 per 10 sweeps).

Euscyrtus sp. was the only insect predator seen in the non rice fields at 70 DAT, the population of which varied from 0.33 to 3.67 per 10 sweeps. The population of *Euscyrtus* sp. in the nonrice habitat was more than that of its occurrence in rice ecosystem.

Tetragnatha spp. was also recorded from the nonrice fields of Thiruvananthapuram, the population noted from the two locations *viz.*, Ulloor and Karamana were 0.67 and 0.33 per 10 sweeps respectively by sweep net method.

Parasitoids occurring at 70 DAT

The parasitoid *Apanteles* sp. alone was observed in all the six locations, its population ranging from 1.67 to 7.67 per 10 sweeps.

Neutrals occurring at 70 DAT

Atractomorpha sp. was recorded in the rice ecosystems of two locations *viz.*, Karamana (0.33 per 10 sweeps) and Athiyannoor (1.00 per 10 sweeps) at 70 DAT. Culicids and *Camponotus* sp. were observed from the adjoining nonrice fields. The culicid population varied from 9.33 to 17.67 per 10 sweeps and its occurrence was noted in all the six locations surveyed. The black ant *Camponotus* sp. was observed in four locations *viz.*, Ulloor (4.33 per 10 sweeps), Anad (3.00 per 10 sweeps), Karamana (5.00 per 10 sweeps) and Upaniyoor (3.00 per 10 sweeps).

Pests occurring at 70 DAT

C. medinalis, *L. acuta*, *Nephotettix* spp., *C. spectra*, *M. histrio* and *O. chinensis* observed at 50 DAT were seen at 70 DAT too (Table 13). Except *O. chinensis,* all the other pests were recorded from all the six

Table 13 Incidence of pests in the double cropped rice ecosystem of Thiruvananthapuram at 70 DAT (Season I)

Pests	Locations																	
	Ulloor			Anad			Punchakari			Karamana			Upaniyoor			Athiyannoor		
	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE
	Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment		
	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN
C. medinalis	8.67± 3.06			15.00± 4.58			15.67± 4.16			10.33± 4.51			16.00± 3.00			15.00± 6.56		
L. acuta	19.67± 18.17	0.20± 0.42		22.00± 17.08	3.90± 2.73		4.00± 1.73	0.60± 0.84		12.33± 12.70	2.40± 1.95		12.33± 14.57	0.90± 1.37		9.67± 6.03	0.30± 0.67	
Nephotettix spp.	52.00± 17.44	8.80± 3.36	1233± 3.51	29.67± 11.93	5.40± 3.37	12.67 5.69	20.33± 14.98	2.40± 2.07	10.33± 4.16	28.00± 9.16	3.70± 1.77	10.33± 4.04	20.33± 14.98	2.20± 2.20	12.33± 4.16	25.33± 9.29	2.20± 1.75	10.00± 3.00
C. spectra	0.67± 0.58			0.67± 1.15			1.00± 1.00			0.67± 1.15			0.20± 0.42			1.67± 1.53		
M. histrio	4.33± 2.08		1.00± 1.73	1.67± 1.53		1.00± 1.73	5.33± 4.04			7.00± 6.24	1.10± 1.10	0.33± 0.58	2.00± 1.00		0.33± 0.58	3.33± 0.58		0.67± 1.15
O. chinensis	1.33± 2.31	0.60± 0.70	0.67 1.15				1.33± 1.15		1.00± 1.00	1.00± 1.00		0.67± 0.58	0.67± 0.58		0.33± 0.58	0.67± 1.53		

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill)

locations. As at 50 DAT, *Nephotettix* spp. was the dominant pest at 70 DAT too. The mean number of *Nephotettix* spp. observed at Ulloor, Anad, Punchakari, Karamana, Upaniyoor and Athiyannoor was 52.00, 29.67, 20.33, 28.00, 20.33 and 25.33 per 10 sweeps and 8.80, 5.40, 2.40, 3.70, 2.20 and 2.20 per hill respectively. This was followed by *L. acuta*, the mean number recorded being 19.67, 22.00, 4.00, 12.33, 12.33 and 9.66 per 10 sweeps and 0.20, 3.90, 0.60, 2.40, 0.90 and 0.30 per hill from each of the above locations. The mean number of *C. medinalis* recorded was 8.67 (Ulloor), 15.00 (Anad), 15.67 (Punchakari), 10.33 (Karamana), 16.00 (Upaniyoor) and 15.00 (Athiyannoor) per 10 sweeps in the six locations. Incidence of *C. spectra* varied from 0.20 to 1.67 per 10 sweeps in the six locations surveyed and that of *M. histrio* ranged from 1.67 to 7.00 per 10 sweeps and the same was recorded from one location (Karamana 1.10 per hill) only through direct count. The incidence of *O. chinensis* was very low and the same varied from 0.67 to 1.33 per 10 sweeps and through direct count it was recorded only from Ulloor (0.60 per hill).

Nephotettix spp. (10.00 to 12.67 per 10 sweeps), *M. histrio* (0.33 and 1.00 per 10 sweeps) and *O. chinensis* (0.33 to 1.00 per 10 sweeps) were the pests observed in the nonrice fields at 70 DAT.

4.1.1.3 Rice Ecosystem of Pokkali

Predators occurring at 30 DAT

Though few in number, several species of insect predators were noted in Pokkali rice ecosystem. They were *C. lividipennis*, *Agriocnemis* spp., *M. discolor*, *O. nigrofasciata*, *L. fossarum*, *Microvelia* sp. and dragonflies (Table 14). The incidence of *C. lividipennis* was recorded from Cheranallur (3.67 per 10 sweeps) alone. The occurrence of *Agriocnemis* spp. in the six locations varied from 0.33 to 2.33 per 10 sweeps. *M. discolor* was noted in four locations only *viz*., Vyttila, Chalikkavattam, Kumbalangi and Kannamali, the population ranging from 0.33 to 0.67 per 10 sweeps. *O. nigrofasciata* was recorded from all the six locations

Table 14. Incidence of entomophages and neutrals in the rice ecosystem of Pokkali at 30 DAT (Season I)

Entomophages/ Neutrals	Locations																							
	Chellanam				Vyttila				Cheranallur				Chalikkavattam				Kumbalangi				Kannamali			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN
Insect predators *C. lividipennis*									3.67± 1.53															
Agriocnemis spp.	2.00± 1.00				1.33± 0.58				0.67± 0.58				0.33± 0.58				1.33± 0.58				2.33± 0.58			
M. discolor					0.67± 0.58								0.67± 0.58				0.33± 0.58				0.67± 0.58			
O. *nigrofasciata*	3.67± 1.53				8.67± 1.53				1.33± 0.58				0.67± 0.58				0.67± 0.58				0.33± 0.58			
Euscyrtus sp.				2.00± 1.00				3.33± 2.08				1.67± 0.58				2.33± 1.53				1.33± 1.15				2.33± 1.53
Dragon flies	1.67± 2.08		3.33± 2.31		1.67± 1.53		2.33± 1.53		2.00± 2.00		2.00± 1.00		1.00± 1.00		3.00± 1.00		2.00± 2.00		3.67± 2.08		1.00± 1.00		2.33± 1.53	
Dragonfly naiads		2.33± 1.53				2.33± 0.58				3.33± 1.53				1.33± 0.58				2.33± 0.58				1.67± 0.58		
L. fossarum		5.00± 1.00				5.67± 1.53				4.67± 1.53				6.33± 3.06				5.67± 2.08				4.67± 3.79		
Microvelia sp.		3.00± 1.00				5.33 1.53				4.67± 1.53				4.33± 2.52				4.67± 1.53				6.33± 2.08		
Spiders *Tetragnatha* spp.	6.33± 1.53				8.33± 1.53								2.33± 0.58				6.00± 1.00				3.00± 1.00			
Neutrals/ others Culicids	1.67± 1.53			11.33± 4.51	2.67± 0.58			10.33± 2.52	1.67± 0.58			13.00± 5.29				11.33± 4.73	1.33± 0.58			11.00± 3.00	2.33± 1.15			3.00± 2.00
Atractomorpha sp.				0.67± 1.15								1.67± 1.15				0.67± 0.58				1.00± 1.00				2.33± 0.58
Camponotus sp.				1.00± 1.00								2.67± 2.08				3.00± 2.00				5.00± 2.65				5.67± 3.06
Solenopsis sp.				3.00 3.00								4.67± 2.52				3.00± 1.00				4.33± 2.52				2.00± 2.00

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) VC-Visual counting (per 20 m^2) SW – Sieving water (30 L) surveyed and the mean population ranged from 0.33 to 8.67 per 10 sweeps. Dragonflies too were seen in the six locations surveyed, mean population of which ranged from 1.00 to 2.00 per 10 sweeps. Visual counting of dragonflies in the six locations showed a range between 2.00 and 3.67 per 20 m^2, the mean number recorded from Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali were 3.33, 2.33, 2.00, 3.00, 3.67 and 2.33 per 20 m^2 respectively. The population of dragon fly naiads was low with a mean population ranging from 1.33 to 3.33 per 30 litres of water.

The mean population of the water strider, *L. fossarum* (assessed by sieving water) was 5.00, 5.67, 4.67, 6.33, 5.67 and 4.67 per 30 litres of water at Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali respectively. The mean population of the ripple bug, *Microvelia* sp. was 3.00, 5.33, 4.67, 4.33, 4.67 and 6.33 per 30 litres of water respectively in the above locations.

Tetragnatha spp. was the only spider observed at 30 DAT, the mean population was 6.33, 8.33, 2.33, 6.00 and 3.00 per 10 sweeps at Chellanam, Vyttila, Chalikkavattam, Kumbalangi and Kannamali respectively.

Euscyrtus sp. was the only insect predator recorded from the non rice ecosystem of Pokkali at 30 DAT. The predator was noted in all the six locations and the mean population ranged from 1.33 to 3.33 per 10 sweeps.

Parasitoids occurring at 30 DAT

No parasitoids were observed in the Pokkali ecosystem at 30 DAT.

Neutrals occurring at 30 DAT

Only culicids (1.33 to 2.67 per 10 sweeps) were observed in the rice ecosystem at this crop stage.

Along with culicids, *Atractomorpha* sp., *Camponotus* sp. and *Solenopsis* sp. were seen in the nonrice habitat. While culicids (3.00 to 13.00 per 10 sweeps) were seen in all the six locations, *Atractomorpha* sp. (0.67 to 2.33 per 10 sweeps), *Camponotus* sp. (1.00 to 5.67 per 10 sweeps) and *Solenopsis* sp. (2.00 to 4.67 per 10 sweeps) were seen in five locations.

Pests occurring at 30 DAT

Very few pests were observed in the rice ecosystem of Pokkali at 30 DAT. The four pests recorded were *C. medinalis*, *D. armigera*, *Nephotettix* spp. and *O. chinensis*. Incidence of *C. medinalis* was seen in three locations *viz*., Chellanam, Cheranallur and Chalikkavattam. The mean population in each of the location being 0.67, 1.33 and 1.00 per 10 sweeps respectively (Table 15). *D. armigera* occurred at two locations, Chellanam (1.33 per 10 sweeps) and Kumbalangi (2.83 per 10 sweeps). *Nephotettix* spp. was recorded from Vyttila and Cheranallur, the mean population being 1.33 and 2.67 per 10 sweeps respectively. *O. chinensis* was observed from all the locations except Kannamali. Among the four pests, *O. chinensis* had a comparatively higher mean population which ranged from 0.33 to 3.00 per 10 sweeps, in the five locations, the mean number in each location being 1.00 (Chellanam), 3.00 (Vyttila), 1.67 (Cheranallur), 0.33 (Chalikkavattam) and 1.00 (Kumbalangi) per 10 sweeps.

O. chinensis was the only pest noted in the adjoining non rice habitat of Pokkali ecosystem at 30 DAT. The grasshopper was seen in five locations and its population ranged from 0.67 to 2.33 per 10 sweeps.

Predators occurring at 50 DAT

The insect predators found in the Pokkali rice ecosystem at 50 DAT were *C. lividipennis*, *Agriocnemis* sp., *M. discolor*, dragonflies, *L. fossarum* and *Microvelia* sp. (Table 16). *M. discolor* was the predominant predator

Table 15. Incidence of pests in the rice ecosystem of Pokkali at 30 DAT (Season I)

Pests	Locations											
	Chellanam		Vyttila		Cheranallur		Chalikkavattam		Kumbalangi		Kannamali	
	RE	NRE	RE	NRE	RE	NRE	RE	NRE	RE	NRE	RE	NRE
	Method of assessment		Method of assessment		Method of assessment		Method of assessment		Method of assessment		Method of assessment	
	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN
C. medinalis	0.67± 1.15				1.33± 0.58		1.00± 1.73					
D. armigera	1.33± 0.58								2.83± 0.58			
Nephotettix spp.			1.33± 1.15		2.67± 0.58							
O. chinensis	1.00± 1.00	1.33± 0.58	3.00± 1.00	1.67± 1.53	1.67± 0.58	0.67± 0.58	0.33± 0.58		1.00± 1.00	1.67± 1.15		2.33± 0.58

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps)

Table 16. Incidence of entomophages and neutrals in the rice ecosystem of Pokkali at 50 DAT (Season I)

Entomophages/ Neutrals	Locations																							
	Chellanam				Vyttila				Cheranallur				Chalikkavattam				Kumbalangi				Kannamali			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN
Insect predators																								
C. lividipennis									1.00± 1.73				1.00± 1.73				0.33± 0.58				0.33± 0.58			
Agriocnemis spp.	0.67± 1.15				0.67± 1.15								0.33± 0.58											
M. discolor	3.67± 2.08			1.33± 0.58	2.00± 1.73			1.33± 1.15	0.67± 0.58			1.33± 0.58	1.67± 1.15			1.00± 1.00	1.33± 0.58			0.67± 0.58				1.00± 1.00
Dragonflies	0.33± 0.58		2.33± 1.53				3.00± 1.00				3.67± 1.53				1.33± 0.58				2.33± 1.53				2.67± 0.58	
Dragonfly naiads		2.33± 0.58				2.33± 1.53				2.33± 0.58				3.00± 1.00				1.67± 1.15				1.67± 0.58		
L. fossarum		4.33± 2.31				3.67± 1.53				4.00± 2.65				2.33± 1.53				4.00± 1.00				4.33± 1.53		
Microvelia sp.		5.67± 1.53				2.67 ± 0.58				4.33± 1.53				5.33± 1.15				5.33± 1.53				3.00± 1.00		
Spiders																								
Tetragnatha spp.	2.67± 3.05				2.33± 1.52			1.00± 1.00	1.00± 1.00			1.00± 1.00	2.00± 2.00			0.67± 1.15	3.00± 2.65			1.67± 1.53	1.67± 1.15			0.33± 0.58
A. formosana	0.67± 1.15			0.67± 1.15	0.67± 1.15			0.67± 0.58													0.33± 0.58			
Neutrals/ others																								
Culicids				16.00 ± 2.65				25.67 ± 6.11				20.00 ± 7.94					16.33 ± 4.51			23.00 ± 9.64				22.00 ± 5.57
Solenopsis sp.				3.00± 3.00																2.33± 4.04				2.00± 2.00

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) VC - Visual counting (per 20 m^2) SW – Sieving water (30 L)

and it was found in all the six locations. The mean population of *M. discolor* ranged from 0.67 to 3.67 per 10 sweeps. Only low population of *C. lividipennis* was seen at Cheranallur, Chalikkavattam, Kumbalangi and Kannamali, the mean number of the predator per 10 sweeps ranging from 0.33 to 1.00. *Agriocnemis* spp. was seen at Chellanam, Vyttila and Chalikkavattam and its mean population varied from 0.33 to 0.67 per 10 sweeps. Very low population of dragonflies (0.33 per 10 sweeps) was recorded from Chellanam alone by sweep net method. However, through visual counting this predator was seen in all the six locations, the mean population ranging from 1.33 to 3.67 per 20 m^2. The mean population of dragonfly naiads varied from 1.67 to 3.00 per 30 litres of water, through sieving water.

The mean population of *L. fossarum* ranged between 2.33 and 4.33 per 30 litres of water in the six locations surveyed at 50 DAT, the mean number recorded being 4.33(Chellanam), 3.67(Vyttila), 4.00(Cheranallur), 2.33(Chalikkavattam), 4.00(Kumbalangi) and 4.33 (Kannamali). Similarly, ripple bug was *Microvelia* sp. recorded from the six locations, the mean number of bugs per 30 litres of water being 5.67, 2.67, 4.33, 5.33, 5.33 and 3.00 respectively.

Tetragnatha spp. and *A. formosana* were the two spiders observed. *Tetragnatha* spp. was observed in all the six locations and its population varied from 1.00 to 3.00 per 10 sweeps. *A. formosana* was recorded from three locations *viz*., Chellanam, (0.67 per 10 sweeps), Vyttila (0.67 per 10 sweeps) and Kannamali (0.33 per 10 sweeps).

M. discolor was seen in the adjoining non rice habitat, the level of incidence ranging from 0.67 to 1.33 per 10 sweeps. The occurrence of the spiders, *Tetragnatha* spp. and *A. formosana* in the nonrice habitat was almost similar to that seen in the rice ecosystem of Pokkali. The population of *Tetragnatha* spp. ranged from 0.33 to 1.67 per 10 sweeps in all the locations except Chellanam whereas *A. formosana* was recorded from Chellanam and Vyttila (0.67 each per 10 sweeps) only.

Parasitoids occurring at 50 DAT

No parasitoids were observed in the rice fields of Pokkali at 50 DAT.

Neutrals occurring at 50 DAT

Only culicids were recorded from the rice ecosystem from one location, *viz.*, Kumbalangi (16.33 per 10 sweeps). On the contrary, culicids were seen in the nonrice ecosystem in five locations, its population ranged from 16.00 to 25.67 per 10 sweeps. Besides, the ant *Solenopsis* sp. was also recorded from the non rice habitat at three locations(Chellanam, Kumbalangi and Kannamali), the mean population of which ranged from 2.00 to 3.00 per 10 sweeps.

Pests occurring at 50 DAT

The hemipterans, *S. furcifera*, *N. lugens*, *L. acuta*, *Nephotettix* spp. and *M. histrio* and the lepidopteran *C. medinalis* and the orthopteran *O. chinensis* were the seven pests found to infest Pokkali rice at 50 DAT (Table 17). Among the pests, *L. acuta* was the predominant species, its population in the six locations being 3.33(Chellanam), 6.67(Vyttila), 6.33 (Cheranallur), 6.67 (Chalikkavattam), 8.33 (Kumbalangi) and 7.00 (Kannamali) per 10 sweeps. The mean numbers of *N. lugens* recorded from Cheranallur, Chalikkavattam, Kumbalangi and Kannamali were 4.00, 4.00, 2.33 and 1.67 per 10 sweeps respectively. Similarly, 5.67, 3.00, 1.33, 2.33, 2.67 and 0.33 were the mean numbers of *C. medinalis* recorded per 10 sweeps from the respective locations. This was followed by *Nephotettix* spp., the mean population being 2.56, 2.33, 4.33, 4.67, 2.67 and 2.00 per 10 sweeps respectively in the six locations of Pokkali. Mean number of *O. chinensis* varied from 2.00 to 4.33 per 10 sweeps in the three locations *viz.*, Vyttila, Cheranallur and Chalikkavattam. The population of *S. furcifera* in Kannamali and *M. histrio* in Chalikkavattam was low (0.67 per 10 sweeps).

Table 17. Incidence of pests in the rice ecosystem of Pokkali at 50 DAT (Season I)

Pests	Locations											
	Chellanam		Vyttila		Cheranallur		Chalikkavattam		Kumbalangi		Kannamali	
	RE	NRE	RE	NRE	RE	NRE	RE	NRE	RE	NRE	RE	NRE
	Method of assessment		Method of assessment		Method of assessment		Method of assessment		Method of assessment		Method of assessment	
	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN
S. furcifera											0.67± 1.15	
N. lugens					4.00± 6.93		4.00± 3.46		2.33± 2.08		1.67± 1.53	
C. medinalis	5.67± 1.53	2.33± 0.58	3.00± 1.00	2.00± 1.00	1.33± 0.58	1.33± 1.53	2.33± 0.58	1.67± 1.15	2.67± 1.53	2.00± 1.00	0.33± 0.58	
L. acuta	3.33± 0.58	1.33± 0.58	6.67± 4.04	2.00± 1.00	6.33± 2.08	1.33± 0.58	6.67± 2.08	1.67± 1.53	8.33± 2.52	2.33± 0.58	7.00± 2.00	2.67± 1.53
Nephotettix spp.	2.56± 1.01	1.33± 0.58	2.33± 0.58	1.67± 1.15	4.33± 1.53	2.00± 2.00	4.67± 3.06	3.33± 3.21	2.67± 1.53	2.67± 0.58	2.00± 1.00	1.33± 0.58
M. histrio							0.67± 1.15					
O. chinensis			2.67± 1.53	1.00± 1.00	2.00± 1.00	1.33± 1.53	4.33± 1.53	3.00± 1.00				

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps)

C. medinalis (1.33 to 2.33 per 10 sweeps), *L. acuta* (1.33 to 2.67 per 10 sweeps), *Nephotettix* spp. (1.33 to 3.33 per 10 sweeps) and *O. chinensis* (1.00 to 3.00 per 10 sweeps) were the pests recorded at 50 DAT from the non rice habitat of Pokkali. *L. acuta* and *Nephotettix* spp. were noted in all the six locations. *C. medinalis* was seen in all the locations of non rice ecosystems except Kannamali. *O. chinensis* was observed at Vyttila, Cheranallur and Chalikkavattam.

Predators occurring at 70 DAT

More number of predators were recorded at 70 DAT (Table 18). Among the insect predators, *M. discolor* was predominant, the mean number collected per 10 sweeps being 8.33, 9.00, 7.00, 5.33 and 5.67 at Chellanam, Vyttila, Cheranallur, Chalikkavattam and Kannamali respectively. *Agriocnemis* spp., *P. fuscovittatus*, *Euscyrtus* sp. and dragonflies were recorded from all the six locations surveyed. Among the insect predators, the mirid bug *C. lividipennis* was found to have the mean population of 2.00 and 5.33 per 10 sweeps at Cheranallur and Vyttila respectively. While the mean number of *Agriocnemis* spp. recorded was 2.67, 1.33, 1.67, 3.00, 2.00 and 2.00 per 10 sweeps from Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali respectively and the population was 8.00, 4.33, 5.00, 4.67, 6.33 and 3.00 per 10 sweeps in the case of *P. fuscovittatus*, 2.33, 2.67, 3.67, 2.33, 1.00 and 0.67 per 10 sweeps in the case of *Euscyrtus* sp. A mean number of 2.33, 1.00, 1.33, 1.67, 1.00 and 1.00 per 10 sweeps of dragonflies were recorded through sweep net method. Visual counting of the dragonflies in the six locations showed a range between 1.33 to 2.67 at 70 DAT, the mean number in each of the location being 2.33, 2.00,2.00,1.33,2.67 and 2.33 per 20 m^2. The mean population of naiads of dragonfly ranged from 1.67 to 3.33 per 30 litres of water, the mean number being 2.00, 2.67, 3.00, 1.67, 2.33 and 3.33 per 30 litres of water at Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali respectively.

Table 18. Incidence of entomophages and neutrals in the rice ecosystem of Pokkali at 70 DAT (Season I)

Entomophages/ Neutrals	Locations																							
	Chellanam				Vyttila				Cheranallur				Chalikkavattam				Kumbalangi				Kannamali			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN
Insect predators *C. lividipennis*					5.33± 2.08				2.00± 2.00															
Agriocnemis spp.	2.67± 1.15				1.33± 1.53				1.67± 1.53				3.00± 1.00				2.00± 1.00				2.00± 1.00			
M. discolor	8.33± 3.21				9.00± 1.00				7.00± 2.65				5.33± 2.08								5.67± 1.53			
P. fuscovittatus	8.00± 2.00				4.33± 2.52				5.00± 3.00				4.67± 1.53				6.33± 3.06				3.00± 1.00			
Euscyrtus sp.	2.33± 0.58			1.33± 0.58	2.67± 1.53			0.67± 0.58	3.67± 2.08			1.33± 1.15	2.33± 0.58			1.00± 1.00	1.00± 1.00			0.67± 1.15	0.67± 0.58			0.67± 0.58
Dragonflies	2.33± 2.31		2.33± 0.58		1.00± 1.00		2.00± 1.73		1.33± 1.15		2.00± 1.00		1.67± 1.15		1.33± 0.58		1.00± 1.00		2.67± 1.15		1.00± 1.00		2.33± 0.58	
Dragonfly naiads		2.00± 1.00				2.67± 1.53				3.00± 1.00				1.67± 0.58				2.33± 0.58				3.33± 0.58		
L. fossarum		2.67± 1.15				3.33± 1.53				3.67± 0.58				4.33± 1.53				5.33± 2.08				5.00± 2.65		
Microvelia sp.		5.00± 2.00				5.33± 1.53				5.67± 2.08				5.00± 2.00				4.33± 2.08				4.33± 1.53		
Spiders *Tetragnatha* spp.	4.33± 2.52			1.00± 1.00	5.00± 2.00			1.33± 0.58	5.33± 1.53			2.33± 0.58	4.33± 2.08			1.00± 1.00	5.00± 2.65			1.33± 1.15	3.67± 1.53			1.67± 1.15
Neutrals/ others Culicids				8.33± 3.51				7.00± 3.00				9.33± 3.51				9.33± 4.17				7.67± 8.14				7.33± 4.16
Camponotus sp.				1.67± 1.53								2.33± 0.58				4.67± 4.16				4.67± 3.79				2.33± 2.52
Solenopsis sp.				6.33± 2.08								3.00± 3.00				1.67± 1.53								2.00± 2.00

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) VC - Visual counting (per 20 m^2) SW – Sieving water (30 L)

The mean population of *L. fossarum* ranged from 2.67 to 5.33 per 30 litres of water. The mean number recorded from the respective six locations were 2.67, 3.33, 3.67, 4.33, 5.33 and 5.00. The population of *Microvelia* sp. varied from 4.33 to 5.67 per 30 litres of water and the mean numbers noted were 5.00, 5.33, 5.67, 5.00, 4.33 and 4.33 from the six locations respectively.

The only spider recorded from the rice ecosystem was *Tetragnatha* spp. Notable population of *Tetragnatha* spp. was recorded from all the six locations, the numbers being 4.33, 5.00, 5.33, 4.33, 5.00 and 3.67 per 10 sweeps.

The insect predator *Euscyrtus* sp. alone was noted in the nonrice habitat of Pokkali. It was seen in all the six locations, the mean number per 10 sweeps ranging from 0.67 to 1.33. The spider *Tetragnatha* spp. was also observed from the nonrice habitat, the numbers being 1.00(Chellanam), 1.33 (Vyttila), 2.33(Cheranallur), 1.00(Chalikkavattam), 1.33(Kumbalangi) and 1.67(Kannamali) per 10 sweeps respectively in the six locations surveyed.

Parasitoids occurring at 70 DAT

No parasitoids were observed in the rice ecosystem of Pokkali at 70 DAT.

Neutrals occurring at 70 DAT

Neutrals were not observed in the rice ecosystem of Pokkali at 70 DAT. However, culicids, *Camponotus* sp. and *Solenopsis* sp. were seen in the nonrice ecosystem. Culicids were present in all the six locations and were the dominant species, its mean population ranging from 7.00 to 9.33 per 10 sweeps. *Camponotus* sp. (1.67 to 4.67 per 10 sweeps) was recorded from all the locations except Vyttila and *Solenopsis* sp. was observed from four locations *viz.*, Chellanam (6.33 per 10 sweeps), Cheranallur (3.00 per 10 sweeps), Chalikkavattam (1.67 per 10 sweeps) and Kannamali (2.00 per 10 sweeps).

Pests occurring at 70 DAT

The pests recorded at 70 DAT were *C. medinalis*, *L. acuta*, *Nephotettix* spp., *C. spectra* and *O. chinensis*. Except *C. spectra,* all the four pests were observed in the six locations surveyed in Pokkali rice ecosystem (Table 19). The rice bug, *L. acuta* was the dominant pest, its mean population in the six locations being 13.33 (Chellanam), 8.00 (Vyttila), 4.33 (Cheranallur), 2.67 (Chalikkavattam), 3.00 (Kumbalangi) and 4.33 (Kannamali) per 10 sweeps. This was followed by *Nephotettix* spp., the mean population of which was 5.33, 3.00, 4.33, 4.00, 1.33 and 8.67 per 10 sweeps in the respective six locations. *C. medinalis* had a low population, the numbers ranged from 0.67 to 2.00 per 10 sweeps. *C. spectra* was noted in only one location *viz.*, Vyttila (1.33 per 10 sweeps). The mean population of *O. chinensis* in the five locations where it was observed ranged from 2.33 to 3.00 per 10 sweeps.

Majority of the pests seen in the rice ecosystem was also recorded from the non rice habitat. They included *L. acuta*, *Nephotettix* spp. and *O. chinensis*. The mean number of *L. acuta* per 10 sweeps varied from 1.67 to 4.25, while the mean population of *Nephotettix* spp. ranged from 1.33 to 3.33 per 10 sweeps and the population of *O. chinensis* ranged from 0.67 to 1.67 per 10 sweeps. *L. acuta* and *Nephotettix* spp. were observed from all the six locations surveyed.

4.1.2 Arthropod Abundance During Second Season

4.1.2.1 Rice Ecosystem of Kuttanadu

Predators occurring at 30 DAT

Among the five insect predators seen *C. lividipennis*, *Agriocnemis* spp., *O. nigrofasciata* and dragonflies were prevalent in all the six locations surveyed (Table 20). Excepting Alappuzha, *Euscyrtus* sp. was recorded from all the other locations. Comparatively, the population of *C. lividipennis* was high, the mean number recorded from Ramankari, Nedumudi, Moncompu, Alappuzha,

Table 19. Incidence of pests in the rice ecosystem of Pokkali at 70 DAT (Season I)

Pests	Locations											
	Chellanam		Vyttila		Cheranallur		Chalikkavattam		Kumbalangi		Kannamali	
	RE	NRE	RE	NRE	RE	NRE	RE	NRE	RE	NRE	RE	NRE
	Method of assessment		Method of assessment		Method of assessment		Method of assessment		Method of assessment		Method of assessment	
	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN
C. medinalis	1.00± 1.73		1.00± 1.00		2.00± 2.00		0.67± 0.58		1.67± 1.53		1.67± 2.08	
L. acuta	13.33± 3.21	4.25± 3.10	8.00± 3.00	2.33± 0.58	4.33± 1.53	3.67± 1.53	2.67± 1.15	1.67± 1.53	3.00± 1.00	1.67± 0.52	4.33± 1.53	2.33± 0.58
Nephotettix spp.	5.33± 3.51	1.67± 1.53	3.00± 3.61	2.67± 1.15	4.33± 1.53	1.67± 1.53	4.00± 2.00	2.67± 1.53	1.33± 1.15	1.33± 0.58	8.67± 2.51	3.33± 3.21
C. spectra			1.33± 1.53									
O. chinensis	3.00± 1.73	1.67± 0.58			2.67± 1.53	1.00± 1.00	2.33± 0.58	1.33± 1.15	2.33± 1.53	1.33± 1.15	2.67± 1.53	0.67± 0.58

RE - Rice ecosystem   NRE - Non rice ecosystem . SN - Sweep net (per 10 sweeps)

Table 20 Incidence of entomophages and neutrals in the rice ecosystem of Kuttanadu at 30 DAT (Season II)

Entomophages / Neutrals	Locations																							
	Ramankari				Nedumudi				Moncompu				Alappuzha				Champakulam				Kainakari			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN
Insect predators *C. lividipennis*	17.67± 4.04	1.40± 0.97			28.00± 15.00	6.10± 2.51			25.67± 7.51	2.10± 1.60			17.67± 7.37	1.20± 1.03			24.67± 6.81	2.00± 1.77			20.67± 6.11	2.10± 1.60		
Agriocnemis spp.	5.67± 2.52				7.33± 4.73				6.33± 3.06				5.33± 2.08				8.33± 2.52				5.00± 4.00			
O. nigrofasciata	1.33± 1.15				1.00± 1.73				0.33± 0.58				0.33± 0.58				1.33± 1.15				1.33± 1.53			
Euscyrtus sp.	1.00± 1.00	0.30± 0.48		2.33± 1.53	1.00± 1.00			1.00± 1.00	1.38± 0.58	0.30± 0.48		1.33± 2.31				0.67± 1.15	1.67± 1.53	0.20± 0.42		0.67± 0.58	1.00± 1.00	0.20± 0.42		0.33± 0.58
Dragonflies			1.33± 0.58				1.33± 1.53				2.00± 1.00				2.00± 1.00				1.00± 1.00				1.00± 1.00	
Spiders *Tetragnatha* spp.	1.67± 1.53	0.40± 0.52			4.33± 2.51	0.40± 0.70			2.33± 2.52	0.50± 0.53			4.33± 3.21	0.40± 0.52			6.33± 3.05	0.60± 0.84			3.33± 1.53	0.30± 0.48		
L. pseudoannulata	0.63± 1.15	0.20± 0.42			1.00± 1.00	0.80± 0.79							0.67± 0.58	0.20± 0.42							0.33± 0.58			
A. formosana	7.00± 3.00	0.60± 0.97			4.00± 1.00	0.90± 0.88			5.00± 3.61	1.00± 1.05			4.00± 3.00	0.60± 0.84			2.33± 2.52	0.60± 0.84			3.00± 2.65	0.90± 1.10		
Parasitoids *Tetrastichus* sp.	11.33 ± 2.52				6.33± 3.06				5.00± 2.00				17.17± 6.01				12.67± 4.04				19.00± 4.00			
Neutrals/ others Culicids				17.00± 4.00				16.00± 2.00				19.00± 4.58				19.00± 2.68				19.00± 4.58				15.33 ± 4.04
Chironomids								1.00± 1.73				1.00± 1.00				2.33± 2.52	7.67± 2.52			2.00± 3.46				1.00± 1.73
Houseflies				2.33± 2.52				3.67± 4.73				5.00± 5.54				3.67± 3.51				1.67± 1.53				1.00± 1.73
Camponotus sp.				6.67± 2.08				2.33± 2.08				2.33± 0.58				1.00± 1.73				1.33± 1.53				4.33± 2.52
Solenopsis sp.				2.33± 1.53				10.00± 7.55				13.00± 9.54				10.00± 6.24				0.67± 1.15				5.67± 3.51

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill) VC - Visual counting (per 20 m^2)

Champakulam and Kainakari were 17.67, 28.00, 25.67, 17.67, 24.67 and 20.67 per 10 sweeps and 1.40, 6.10, 2.10, 1.20, 2.00 and 2.10 per hill. The mean number of *Agriocnemis* spp. observed in each of the location was 5.67, 7.33, 6.33, 5.33, 8.33 and 5.00 per 10 sweeps. Low population of *O. nigrofasciata* was noticed which ranged from 0.33 to 1.33 per 10 sweeps and the population of *Euscyrtus* sp. (1.00 to 1.67 per 10 sweeps) was also low. The mean population of dragonflies ranged from 1.00 to 2.00 per 20 m^2 when estimated through visual count.

Among the spider predators observed, *Tetragnatha* spp. and *A. formosana* were prevalent in all the six locations. The mean population of *Tetragnatha* spp. varied from 1.67 to 6.33 per 10 sweeps and 0.30 to 0.60 per hill and that of *A. formosana* ranged from 2.33 to 7.00 per 10 sweeps and 0.60 to 1.00 per hill. *L. pseudoannulata* was seen at four locations *viz.*, Ramankari (0.63 per 10 sweeps and 0.20 per hill), Nedumudi (1.00 per 10 sweeps and 0.80 per hill), Alappuzha (0.67 per 10 sweeps and 0.20 per hill) and Kainakari (0.33 per 10 sweeps), the population ranged from 0.33 to 1.00 per 10 sweeps.

Only *Euscyrtus* sp. was recorded from the nonrice habitat the population of which ranged from 0.33 to 2.33 per 10 sweeps. No spiders were seen in the adjoining vegetation.

Parasitoids occurring at 30 DAT

Tetrastichus sp. was the only parasitoid recorded at this stage of rice crop. The incidence of the same was noted from all the six locations and the population ranged from 5.00 to 19.00 per 10 sweeps.

Neutrals occurring at 30 DAT

Chironomids alone were seen in the rice ecosystem at Champakulam (7.67 per 10 sweeps). Culicids, chironomids, houseflies, *Camponotus* sp. and *Solenopsis* sp. were found in the nonrice habitat. All these were recorded from all the six locations surveyed. Among the neutrals, culicids recorded a range between 15.33 and 19.00 per 10 sweeps. This was followed by *Solenopsis* sp. (0.67 to 13.00 per 10 sweeps), *Camponotus* sp.

(1.00 to 6.67 per 10 sweeps), house flies (1.00 to 5.00 per 10 sweeps) and chironomids (1.00 to 2.33 per 10 sweeps).

Pests occurring at 30 DAT

At 30 DAT more number of pests were found to infest rice in the second season than in the first season in Kuttanadu rice ecosystem (Table 21). *S. furcifera*, *C. medinalis*, *P. stagnalis*, *D. armigera*, *Nephotettix* spp., *O. chinensis* and *S. litura* were recorded at 30 DAT. The hemipteran pest, *S. furcifera* was dominant and was recorded from all the six locations with a population range of 18.33 to 72.33 per 10 sweeps and 1.00 to 6.10 per hill. The number of *S. furcifera* recorded from Ramankari, Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari were 24.33, 18.33, 69.00, 55.67, 21.00 and 72.33 per 10 sweeps and 1.40, 4.40,1.60, 4.00, 1.00 and 6.10 per hill. This was followed by *Nephotettix* spp., the mean number observed were 28.33, 23.33, 48.00, 23.67, 28.33 and 18.00 per 10 sweeps and 1.30, 4.20, 4.40, 2.60, 1.50 and 1.10 per hill from the respective locations. *C. medinalis*, *D. armigera* and *O. chinensis* were recorded from all the six locations of Kuttanad ecosystem, the population range of each pest being 1.33 to 5.33 per 10 sweeps, 0.67 to 2.67 per 10 sweeps and 0.67 to 3.33 per 10 sweeps and 0.30 to 0.50 per hill respectively. Low population of *P. stagnalis* was observed in all the locations surveyed except Nedumudi and it ranged from 0.33 to 1.33 per 10 sweeps.

Among the pests seen in the nonrice ecosystem, the mean number of *Nephotettix* spp. ranged from 2.60 to 9.67 per 10 sweeps in all the six locations surveyed. Very low (0.33 per 10 sweeps) population of *P. stagnalis* was observed at three locations *viz*., Ramankari, Alappuzha and Kainakari. Apart from this *O. chinensis* (0.33 to 0.67 per 10 sweeps) was also noted in some locations. The mean population of *S. litura* ranged from 0.67 to 2.33 per 10 sweeps.

Predators occurring at 50 DAT

The predators noted in the Kuttanadu rice ecosystem at 50 DAT is given in Table 22. The damsel fly, *Agriocnemis* spp. was observed in all the six locations, the mean number recorded from Ramankari, Nedumudi, Moncompu, Alappuzha

Table 21 Incidence of pests in the rice ecosystem of Kuttanadu at 30 DAT (Season II)

Pests	Locations																	
	Ramankari			**Nedumudi**			**Moncompu**			**Alappuzha**			**Champakulam**			**Kainakari**		
	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE
	Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment		
	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN
S. furcifera	24.33± 7.51	1.40± 1.17		18.33± 13.32	4.40± 2.07		69.00± 16.70	1.60± 1.17		55.67± 9.29	4.00± 1.76		21.00± 7.00	1.00± 0.67		72.33± 6.66	6.10± 2.51	
C. medinalis	2.00± 1.00			5.33± 1.53			1.33± 1.15			1.67± 1.53			2.67± 2.52			1.67± 0.58		
P. stagnalis	1.00± 1.00		0.33± 0.58				0.33± 0.58			1.33± 1.53		0.33± 0.58	1.00± 1.00			1.33± 1.15		0.33± 0.58
D. armigera	0.67± 1.15			2.67± 1.15			1.00± 1.00			2.67± 0.58			1.67± 0.58			2.00± 2.00		
Nephotettix spp.	28.33± 12.50	1.30± 0.95	9.67± 3.06	23.33± 12.85	4.20± 1.87	5.67± 2.52	48.00± 72.29	4.40± 2.22	6.00± 4.36	23.67± 8.50	2.60± 1.35	2.60± 1.35	28.33± 15.14	1.50± 1.08	6.00± 4.58	18.00± 5.57	1.10± 1.10	5.33± 1.53
O. chinensis	3.33± 1.53		0.33± 0.58	0.67± 1.15	0.50± 0.71		1.00± 1.00		0.67± 1.15	0.67± 1.15			1.00± 1.00		0.33± 0.58	1.00± 1.00	0.30± 0.48	0.33± 0.58
S. litura			0.67± 1.15			1.67± 1.53									0.67± 0.58			2.33± 3.21

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct Count (per hill)

Table 22 Incidence of entomophages and neutrals in the rice ecosystem of Kuttanadu at 50 DAT (Season II)

Entomophages / Neutrals	Ramankari				Nedumudi				Moncompu				Alappuzha				Champakulam				Kainakari			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN
Insect predators																								
C. lividipennis	20.67± 20.67																							
Agriocnemis spp.	1.00± 1.73				3.33± 3.51				2.67± 3.06				3.67± 6.35				1.67± 1.53				4.67± 2.52			
M. discolor	0.67± 0.58	0.20± 0.42			8.67± 2.52	0.70± 0.82			6.33± 9.29	0.20± 0.42			1.00± 1.73	0.30± 0.48			0.67± 1.15	0.20± 0.42		0.33± 0.58				
Euscyrtus sp.				1.67± 0.58				0.33± 0.58								0.67± 0.58				0.67± 1.15				0.67± 0.58
Dragonflies			1.33± 1.53				1.00± 1.00				1.33± 1.15				2.33± 2.52				1.00± 1.00				2.33± 1.55	
Spiders *Tetragnatha* spp.	9.33± 8.08	1.30± 0.95		3.67± 3.05	10.67± 3.51	1.70± 1.25		1.00± 1.00	3.67± 4.73	0.60± 0.70		0.67± 1.15	19.00± 7.00	0.70± 0.67			9.00± 4.36	0.90± 0.74			8.00± 5.57	0.90± 0.74		0.33± 0.58
L. pseudoannulata	0.33± 0.58				0.67± 1.15																			
A. formosana	2.33± 2.58	0.30± 0.48		0.67± 0.58	1.67± 1.53	1.10± 1.36		0.33± 0.58	0.67± 1.15				2.67± 3.06	0.30± 0.48		0.67± 1.15	0.67± 1.15	0.20± 0.42				0.40± 0.52		0.67± 1.15
Parasitoids *Tetrastichus* sp.					2.00± 3.46				1.00± 1.73				1.67± 2.89											
Apanteles sp.					1.00± 1.73				0.67± 1.15															
Neutrals/ others Culicids	5.00± 2.65			21.67± 4.51	5.67± 2.08			19.67± 8.02	4.33± 2.08			19.00± 4.58	4.00± 2.65			14.00± 3.07	4.33± 2.08			18.33± 3.05	5.00± 2.00			16.33± 4.04
Chironomids	2.00± 1.00			0.67± 0.58	1.67± 1.53				2.67± 1.33			0.33± 0.58	7.26± 1.53			0.67± 1.15				0.67± 0.58	8.00± 2.65			0.67± 1.15
Houseflies								0.33± 0.58				0.67± 0.58								0.67± 0.58				
Atractomorpha sp.				0.67± 1.15								1.00± 1.00				1.67± 0.58				0.33± 0.58				
Camponotus sp.				4.33± 2.08				1.67± 0.58				3.65± 2.08				5.67± 4.16				4.33± 3.21				2.00± 1.00

RE – Rice ecosystem NRE – Non rice ecosystem SN-Sweep net (per 10 sweeps) DC - Direct count (per hill) VC - Visual counting (per 20 m^2)

Champakulam and Kainakari were 1.00, 3.33, 2.67, 3.67, 1.67 and 4.67 per 10 sweeps respectively. *M. discolor* was recorded from five locations *viz.*, Ramankari, Nedumudi, Moncompu, Alappuzha and Champakulam, the population ranging from 0.67 to 8.67 per 10 sweeps and 0.20 to 0.70 per hill. More number of the predator was seen in Nedumudi (8.67 per 10 sweeps and 0.70 per hill) and Moncompu (6.33 per 10 sweeps and 0.20 per hill). *C. lividipennis* was recorded from Ramankari (20.67 per 10 sweeps) only. The mean number of dragonflies recorded from Ramankari, Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari were 1.33, 1.00, 1.33, 2.33, 1.00 and 2.33 per 20 m^2 respectively.

Three species of spiders were observed in the rice ecosystem, of which *Tetragnatha* spp. was recorded from all the six locations. The mean number of *Tetragnatha* spp. recorded per 10 sweeps was 9.33, 10.67, 3.67, 19.00, 9.00 and 8.00 at Ramankari, Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari respectively. Only a mean number of 1.30, 1.70, 0.60, 0.70, 0.90 and 0.90 *Tetragnatha* spp. per hill were recorded through direct count. *L. pseudoannulata* was seen only at Ramankari (0.33 per 10 sweeps) and Nedumudi (0.67 per 10 sweeps), while *A. formosana* was seen in all the locations except Kainakari. The mean number of *A. formosana* observed in the respective locations were 2.33, 1.67, 0.67, 2.67 and 0.67 per 10 sweeps and 0.30, 1.10, 0.30, 0.20 and 0.40 per hill.

In the non rice fields, *Euscyrtus* sp. was seen in all the locations except in Moncompu, the mean population varied from 0.33 to 1.67 per 10 sweeps. *M. discolor* was seen at Champakulam (0.33 per 10 sweeps). Among the spiders observed in the rice ecosystem of Kuttanad, *Tetragnatha* spp. and *A. formosana* were recorded from the nonrice ecosystem also. The mean population of *Tetragnatha* spp. ranged from 0.33 to 3.67 per 10 sweeps and the population of *A. formosana* varied from 0.33 to 0.67 per 10 sweeps.

Parasitoids occurring at 50 DAT

The parasitoid *Tetrastichus* sp. was seen in three locations. The mean number of the parasitoid recorded from Nedumudi, Moncompu and Alappuzha were 2.00, 1.00 and 1.67 per 10 sweeps respectively. *Apanteles* sp. was seen in Nedumudi (1.00 per 10 sweeps) and Moncompu (0.67 per 10 sweeps).

Neutrals occurring at 50 DAT

Only culicids and chironomids were observed in the rice ecosystem at 50 DAT. Culicids were recorded from all the six locations and its population ranged from 4.00 to 5.67 per 10 sweeps. Chironomids were collected from all locations except from Champakulam, the mean population ranging from 1.67 to 8.00 per 10 sweeps in the five locations.

The neutrals recorded from the nonrice habitat included culicids, chironomids, houseflies, the grasshopper *Atractomorpha* sp. and the black ant *Camponotus* sp. Culicids and *Camponotus* sp. were recovered from all the six locations and chironomids were recorded from five locations. The mean population of culicids ranged from 14.00 to 21.67 per 10 sweeps and that of *Camponotus* sp. varied from 1.67 to 5.67 per 10 sweeps. The mean population of chironomids (0.33 to 0.67 per 10 sweeps), houseflies (0.33 to 0.67 per 10 sweeps) and *Atractomorpha* sp. (0.33 to 1.67 per 10 sweeps) in the nonrice ecosystem was very low.

Pests occurring at 50 DAT

The hemipterans, *S. furcifera* and *Nephotettix* spp. and the lepidopteran *C. medinalis* and *P. stagnalis* were found to infest rice at 50 DAT (Table 23). The incidence of *C. medinalis*, *P. stagnalis* and *Nephotettix* spp. was seen from all the six locations surveyed. *S. furcifera* was observed in all the locations except Ramankari. Among the pests seen at 50 DAT, *S. furcifera* was predominant, the mean number recorded from Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari were 11.00, 38.33, 10.33, 16.33 and 6.33 per 10 sweeps respectively and 0.90, 1.40, 0.80, 0.80 and 0.80 per hill. This was followed by *Nephotettix* spp.,

Table 23 Incidence of pests in the rice ecosystem of Kuttanadu at 50 DAT (Season II)

Pests	Locations																	
	Ramankari			Nedumudi			Moncompu			Alappuzha			Champakulam			Kainakari		
	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE
	Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment		
	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN
S. furcifera				11.00± 19.05	0.90± 1.29		38.33± 42.15	1.40± 1.35		10.33± 17.89	0.80± 0.79		16.33± 7.02	0.80± 0.79		6.33± 5.69	0.80± 0.79	
C. medinalis	1.00± 1.73	0.20± 0.42		3.00± 1.00	0.30± 0.48	1.00± 1.00	1.67± 1.53	0.30± 0.48	0.67± 0.58	2.00± 3.46	0.40± 0.52	1.00± 1.00	2.67± 2.52	0.40± 0.52	1.00± 1.00	2.67± 1.15	0.40± 0.52	0.67± 0.58
P. stagnalis	3.00± 3.00		1.00± 1.00	1.00± 1.73			2.00± 3.46		0.67± 1.15	1.00± 1.73		1.00± 1.00	1.33± 1.15		1.00± 1.00	1.67± 1.53		0.33± 0.58
Nephotettix spp.	20.67± 5.63	2.00± 1.05	10.67± 4.04	37.33± 21.01	5.70± 2.26	11.00± 3.00	26.33± 18.01	2.30± 1.49	12.00± 7.00	22.67± 4.04	1.90± 1.10	4.33± 1.53	30.33± 12.58	1.90± 1.10	4.33± 1.53	21.33± 6.03	1.50± 0.85	5.00± 2.65
O. chinensis			0.33± 0.58			0.20± 0.42			1.00± 1.00									0.67± 1.15

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct Count (per hill)

the mean population of which was 20.67, 37.33, 26.33, 22.67, 30.33 and 21.33 per 10 sweeps and 2.00, 5.70, 2.30, 1.90, 1.90 and 1.50 per hill in Ramankari, Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari respectively. The mean population of *C. medinalis* was 1.00, 3.00, 1.67, 2.00, 2.67 and 2.67 per 10 sweeps and 0.20, 0.30, 0.30, 0.40, 0.40 and 0.40 per hill in the above locations respectively. The occurrence of *P. stagnalis* ranged from 1.00 to 3.00 per 10 sweeps.

Some of the pests seen in the rice ecosystem was recovered from the adjoining non rice habitat also. They were *C. medinalis*, *P. stagnalis* and *Nephotettix* spp. More numbers of *Nephotettix* spp. were noted from the nonrice habitat at 50 DAT, the mean population of which ranged from 4.33 to 12.00 per 10 sweeps. Apart from these, *O. chinensis* was also recorded in the adjoining vegetation, the mean population ranged from 0.20 to 1.00 per 10 sweeps in the respective four locations *viz.*, Ramankari, Nedumudi, Moncompu and Kainakari. The number of *C. medinalis* recorded ranged from 0.67 to 1.00 per 10 sweeps in the respective five nonrice habitats. *P. stagnalis* was observed in four locations, mean population of which ranged from 0.33 to 1.00 per 10 sweeps.

Predators occurring at 70 DAT

The insect predators, *Agriocnemis* spp., *M. discolor* and *O. nigrofasciata*, *Euscyrtus* sp. and dragonflies were noted in the Kuttanadu rice ecosystem (Table 24). *M. discolor* was the dominant predator observed, the mean population of which was 2.33, 7.67, 5.67, 10.67, 9.00 and 11.00 per 10 sweeps and 0.30, 0.80, 0.50, 0.60, 0.80 and 0.40 per hill at Ramankari, Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari respectively. Population of *Agriocnemis* spp. ranged from 1.33 to 2.67 per 10 sweeps in the six padasekharams. Negligible population of *O. nigrofasciata* was recorded from Ramankari and Moncompu (0.33 per 10 sweeps each). The mean number of dragonflies recorded from the respective six locations were 0.33 per 20 m^2 each from Ramankari, Nedumudi and Alappuzha, 0.67 per m^2 from Kainakari and 1.00 per 20 m^2 each from Moncompu and Champakulam.

Table 24 Incidence of entomophages and neutrals in the rice ecosystem of Kuttanadu at 70 DAT (Season II)

Entomophages / Neutrals	Locations																							
	Ramankari				Nedumudi				Moncompu				Alappuzha				Champakulam				Kainakari			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN
Insect predators Agriocnemis spp.	1.67± 1.53				1.33± 0.58			.67± 1.15	2.33± 0.58			1.00± 1.73	1.67± 1.53			0.33± 0.58	.67± 3.79			1.00± 1.00	2.00± 1.73			1.00± 1.00
M. discolor	2.33± 2.08	0.30± 0.48			7.67± 2.52	0.80± 1.03			5.67± 5.68	0.50± 0.71			10.67± 5.13	0.60± 0.84			9.00± 3.61	0.80± 1.03			11.00± 6.24	0.40± 0.52		
O. nigrofasciata	0.33± 0.58								0.33± 0.58															
Euscyrtus sp.				1.00± 1.73				0.33± 0.58				1.33± 1.15				1.33± 1.53				1.67± 2.08				1.00± 1.00
Dragonflies			0.33± 0.58				0.33± 0.58				1.00± 1.00				0.33± 0.58				1.00± 1.73				0.67± 0.58	
Spiders *Tetragnatha* spp.	3.33± 0.58	0.40± 0.52			2.33± 0.58	0.70± 0.82			1.33± 1.53	0.30± 0.48			2.00± 1.00	0.20± 0.42			6.33± 3.79	0.80± 1.03			4.33± 5.13	0.30± 0.48		
L. pseudoannulata													1.00± 1.00				0.67± 1.15							
A. formosana	3.00± 1.00								1.33± 1.53				1.00± 1.73				1.00± 1.00				1.33± 1.15			
Parasitoids *Tetrastichus* sp.					1.67± 1.52				0.67± 1.15								3.00± 3.00				1.00± 1.73			
Neutrals/ others Culicids	3.33± 3.51				2.67± 1.75			12.00± 4.00	2.67± 2.52			15.33± 1.53	5.00± 1.00			18.00± 3.00	4.00± 2.65			12.33± 4.16	6.33± 1.53			17.00± 3.61
Chironomids												0.67± 1.15				0.33± 0.58								1.00± 1.00
Atractomorpha sp.								1.00± 1.00				0.33± 0.58				1.00± 1.73				1.00± 1.00				1.33± 1.53
Houseflies								0.67± 1.15								2.00± 2.00				1.67± 1.53				1.67± 2.08
Camponotus sp.								1.00± 1.00				1.33± 1.53								1.67± 2.08				2.33± 2.06

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill) VC - Visual counting (per 20 m^2)

Tetragnatha spp., *L. pseudoannulata* and *A. formosana* were the three spiders noted. *Tetragnatha* spp. was dominant, the mean number of the predator recorded from Ramankari, Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari being 3.33, 2.33, 1.33, 2.00, 6.33 and 4.33 per 10 sweeps and 0.40, 0.70, 0.30, 0.20, 0.80 and 0.30 per hill. Population of the wolf spider, *L. pseudoannulata* recorded from Alappuzha (1.00 per 10 sweeps) and Champakulam (0.67 per 10 sweeps) was very low. The dwarf spider, *A. formosana* was noted from all locations except Nedumudi, the mean number recorded being 3.00 (Ramankari), 1.33 (Moncompu), 1.00 (Alappuzha), 1.00 (Champakulam) and 1.33 (Kainakari) per 10 sweeps.

Euscyrtus sp. alone was recorded from the nonrice ecosystem, the mean number of crickets per 10 sweeps ranging from 0.33 to 1.67.

Parasitoids occurring at 70 DAT

The parasitoid, *Tetrastichus* sp. was observed from all the locations except Nedumudi and Alappuzha, the mean population ranging from 0.67 to 3.00 per 10 sweeps.

Neutrals occurring at 70 DAT

Only culicids were seen in the rice ecosystem, the mean population ranged from 2.67 to 6.33 per 10 sweeps. The culicid population was more in the nonrice habitat, the mean number ranging from 12.00 to 18.00 per 10 sweeps. Apart from culicids, chironomids, *Atractomorpha* sp., houseflies and *Camponotus* sp. were observed in the nonrice habitat. *Atractomorpha* sp. was recorded from all the six locations, its mean population ranging from 0.33 to 1.33 per 10 sweeps. The incidence of chironomids was noted at three locations and its population varied from 0.33 to 1.00 per 10 sweeps in these padasekharams. Houseflies were seen in four locations, the population ranging from 0.67 to 2.00 per 10 sweeps. The mean population of *Camponotus* sp. ranged from 1.00 to 2.33 per 10 sweeps.

Pests occurring at 70 DAT

Though many pests were seen at 70 DAT in the Kuttanadu rice ecosystem, their population varied widely (Table 25). Among the pests observed, *Nephotettix* spp. was dominant and was found in all the six locations surveyed. The mean number of *Nephotettix* spp. recorded from Ramankari, Nedumudi, Moncompu, Alappuzha, Champakulam and Kainakari were 38.33, 32.00, 56.00, 62.67, 29.33 and 49.00 per 10 sweeps and 3.70, 7.60, 10.30, 5.50, 2.30 and 1.00 per hill respectively. This was followed by *O. chinensis* which was recorded from four locations, the mean population being 0.50, 0.33, 1.00 and 0.33 per 10 sweeps at Nedumudi Moncompu, Alappuzha and Champakulam respectively.

The mean number of *S. furcifera* recorded from Ramankari, Nedumudi and Kainakari was 19.33, 2.33 and 7.33 per 10 sweeps respectively. Very low population of the pest was recorded from Ramankari (0.90 per hill) and Nedumudi (0.20 per hill) through direct count method of population assessment. Similarly, the mean numbers of *C. medinalis* recorded from Nedumudi, Moncompu and Champakulam were 1.67, 1.00 and 1.00 per 10 sweeps respectively. The same pest was recorded through direct count method only from Nedumudi (0.50 per hill). *L. acuta* was recorded from two locations, Moncompu (1.33 per 10 sweeps) and Alappuzha (2.33 per 10 sweeps).

Among the pests seen in the rice ecosystem, only *Nephotettix* spp. and *O. chinensis* were recovered from the adjoining nonrice ecosystem. Additionally, the polyphagous pest *S. litura* was also recorded from nonrice habitat. The green leafhopper, N*ephotettix* spp. (3.67 to 5.00 per 10 sweeps) and the grass hopper *O. chinensis* (0.33 to 2.67 per 10 sweeps) were found in all the six locations, whereas *S. litura* (0.33 to 0.67 per 10 sweeps) was noted only from three locations.

Table 25. Incidence of pests in the rice ecosystem of Kuttanadu at 70 DAT (Season II)

Pests	Locations																	
	Ramankari			Nedumudi			Moncompu			Alappuzha			Champakulam			Kainakari		
	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE
	Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment		
	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN
S. furcifera	19.33± 11.68	0.90± 0.74		2.33± 4.04	0.20± 0.42											7.33± 7.02		
C. medinalis				1.67± 2.89	0.50± 0.85		1.00± 1.00						1.00± 1.73					
L. acuta							1.33± 1.15			2.33± 4.04								
Nephotettix spp.	38.33± 17.50	3.70± 1.77	5.00± 2.00	32.00± 21.00	7.60± 3.72	4.67± 3.79	56.00± 22.27	10.30± 3.53	4.33± 2.52	62.67± 14.74	5.50± 1.84	5.00± 3.00	29.33± 12.67	2.30± 1.83	4.67± 3.79	49.00± 16.09	1.00± 1.05	3.67± 3.06
O. chinensis			1.33± 2.31	0.50± 0.71		2.67± 1.53	0.33± 0.58		1.00± 1.00	1.00± 1.00		1.00± 1.00	0.33± 0.58		0.33± 0.58			1.00± 1.73
S. litura			0.67± 1.15						0.67± 1.15			0.33± 0.58						

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill)

4.1.2.2 Double Cropped Rice Ecosystem of Thiruvananthapuram

Predators occurring at 30 DAT

Very low population of five insect predators *viz., Agriocnemis* spp. *M. discolor, O. nigrofasciata, Euscyrtus* sp. and dragonflies were seen in the rice fields of Thiruvananthapuram where need based application of insecticide was followed (Table 26). While the mean number of *Agriocnemis* spp. recorded from Ulloor, Anad, Karamana and Upaniyoor were 0.67, 0.33, 0.33 and 0.33 per 10 sweeps, the same predator was recorded only at Ulloor (0.30 per hill) through direct count method of assessment. The mean population of *M. discolor* was low, 0.33 per 10 sweeps in each of the locations, Anad and Athiyannoor. *O. nigrofasciata* was recorded from three locations, *viz.,* Ulloor (1.67 per 10 sweeps), Upaniyoor (1.33 per 10 sweeps) and Athiyannoor (0.67 per 10 sweeps). *Euscyrtus* sp. was noted in all the locations except Ulloor and its occurrence ranged between 0.33 to 2.00 per 10 sweeps. The mean population of dragonflies observed by visual count ranged from 1.00 to 2.33 per 20 m^2 at 30 DAT. The highest number was recorded from Ulloor and Punchakari (2.33 per 20 m^2). The mean number of dragonflies recorded from other locations *viz.,* Anad, Karamana, Upaniyoor and Athiyannoor were 1.67, 1.67, 1.33 and 1.00 per 20 m^2 respectively.

The long jawed spider *Tetragnatha* spp. was the major spider predator observed at 30 DAT. The number of *Tetragnatha* spp. recorded were 5.00, 4.67, 5.67, 5.00, 6.00 and 4.33 per 10 sweeps and 1.00, 0.70, 0.50, 0.40, 0.60 and 0.50 per hill from Ulloor, Anad, Punchakari, Karamana, Upaniyoor and Athiyannoor respectively. The other spider seen in the ecosystem was *L. pseudoannulata,* mean population of which was 1.33, 1.00, 0.33, 0.33, 0.33 per 10 sweeps at Ulloor, Anad, Karamana, Upaniyoor and Athiyannoor respectively. The same was recorded through direct count from one location, Ulloor (0.30 per hill) alone.

Table 26 Incidence of entomophages and neutrals in the double cropped rice ecosystem of Thiruvananthapuram at 30 DAT (Season II)

Entomophages / Neutrals	Locations: Ulloor				Anad				Punchakari				Karamana				Upaniyoor				Athiyannoor			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN
Insect predators *Agriocnemis* spp.	0.67± 1.15	0.30± 0.48			0.33± 0.58								0.33± 0.58				0.33± 0.58							
M. discolor					0.33± 0.58																0.33± 0.58			
O. nigrofasciata	1.67± 1.53																1.33± 1.53				0.67± 1.15			
Euscyrtus sp.				0.33± 0.58	1.00± 1.00			0.33± 0.58	0.33± 0.58	1.00± 1.00			2.00± 1.00			0.33± 0.58	1.67± 1.53				0.33± 0.58			
Dragonflies			2.33± 2.08				1.67± 0.58				2.33± 2.52				1.67± 1.15				1.33± 1.15				1.00± 1.00	
Spiders *Tetragnatha* spp.	5.00± 2.00	1.00± 0.82			4.67± 3.79	0.70± 0.82			5.67± 2.08	0.50± 0.71			5.00± 1.73	0.40± 0.52			6.00± 2.65	0.60± 0.70			4.33± 0.58	0.50± 0.71		1.33± 2.31
L. pseudoannulata	1.33± 0.58	0.30± 0.48			1.00± 1.00								0.33± 0.58				0.33± 0.58				0.33± 0.58			
Parasitoids *Tetrastichus* sp.													0.67± 1.15				1.33± 1.53							
Apanteles sp.	2.33± 2.52				1.33± 1.53				1.00± 1.00				1.33± 0.58											
Neutrals/ others Culicids				3.00± 3.61	1.33± 1.53			13.33± 5.51	1.67± 1.15			12.00± 6.24				13.00± 3.61				12.00± 4.58				15.33 ± 3.79
Chironomids				0.33± 0.58				1.67± 1.53								0.67± 1.15				0.33± 0.58				0.33± 0.58
Camponotus sp.				1.67± 1.53				1.67± 1.15				1.33± 2.31								1.00± 1.00				

RE – Rice ecosystem NRE – Non rice ecosystem SN-Sweep net (per 10 sweeps) DC - Direct count (per hill) VC - Visual counting (per 20 m^2)

Among the insect predators, *Euscyrtus* sp. alone was recorded from the non rice fields at 30 DAT. The mean population recorded from the three respective locations *viz.,* Ulloor, Anad and Karamana was 0.33 each per 10 sweeps. *Tetragnatha* spp. alone was recorded from the non rice habitat at 30 DAT. The occurrence (1.33 per 10 sweeps) was noted at Athiyannoor only.

Parasitoids occurring at 30 DAT

Two parasitoids, *Tetrastichus* sp. and *Apanteles* sp. were observed at 30 DAT. *Tetrastichus* sp. was recorded from Karamana (0.67 per 10 sweeps) and Upaniyoor (1.33 per 10 sweeps). The mean population of *Apanteles* sp. was 2.33, 1.33, 1.00 and 1.33 per 10 sweeps at Ulloor, Anad, Punchakari and Karamana respectively.

Neutrals occurring at 30 DAT

Culicids were recorded from the rice ecosystem of Anad (1.33 per 10 sweeps) and Punchakari (1.67 per 10 sweeps) at 30 DAT. Culicids, chironomids and *Camponotus* sp. were recorded from the nonrice habitat. Culicids were recorded from all the six locations, the mean population ranging from 3.00 to 15.33 per 10 sweeps, while the mean population of chironomids ranged from 0.33 to 1.67 per 10 sweeps and the mean number of *Camponotus* sp. ranged from 1.00 to 1.67 per 10 sweeps.

Pests occurring at 30 DAT

The pests seen at 30 DAT in the double cropped rice fields of Thiruvananthapuram were the defoliators, *C. medinalis, D. armigera* and *O. chinensis* and the sap feeder, *Nephotettix* spp. While the incidence of *C. medinalis* and *Nephotettix* spp. was seen in all the six locations surveyed, *O. chinensis* occurred in five locations and *D. armigera* was seen in only two locations (Table 27). Among these pests, *C. medinalis* was the predominant species, the mean number collected through sweep net method were 6.33, 5.33, 4.00, 3.33, 15.67 and 6.00 per 10 sweeps and through direct count being

Table 27 Incidence of pests in the double cropped rice ecosystem of Thiruvananthapuram at 30 DAT (Season II)

Pests	Locations																	
	Ulloor			**Anad**			**Punchakari**			**Karamana**			**Upaniyoor**			**Athiyannoor**		
	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE
	Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment		
	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN
C. medinalis	6.33± 5.51	2.60± 1.17	4.33± 2.08	5.33± 6.11	1.20± 1.22	4.00± 2.65	4.00± 2.00	0.70± 0.67	5.00± 5.57	3.33± 1.53	0.60± 0.70	8.33± 4.16	15.67± 9.07	1.00± 0.82	5.67± 3.51	6.00± 4.00	0.70± 0.82	5.00± 2.65
D. armigera							0.67± 0.58						0.33± 0.58					
Nephotettix spp.	4.33± 1.33		2.00± 2.00	2.00± 2.00		3.33± 3.06	3.00± 2.45	0.60± 0.70	4.00± 2.65	2.00± 2.00		1.33± 1.15	3.67± 2.08	0.40± 0.52	1.69± 0.58	1.67± 1.53		2.33± 0.58
O. chinensis	0.67± 1.15		1.00± 1.00	1.00± 1.73	0.20± 0.42		3.33± 3.51		2.00± 1.09	2.00± 2.00		0.67± 0.58				2.67± 2.89		1.33± 1.53
S. litura			0.67± 1.15			0.33± 0.58			0.67± 1.15			0.67± 0.58			0.67± 0.58			0.33± 0.58

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill)

2.60, 1.20, 0.70, 0.60, 1.00 and 0.70 per hill at Ulloor, Anad, Punchakari, Karamana, Upaniyoor and Athiyannoor respectively. The mean population of *Nephotettix* spp. recorded was 4.33, 2.00, 3.00, 2.00, 3.67 and 1.67 per 10 sweeps in the above locations respectively. Only very few *Nephotettix* spp. (0.60 and 0.40 per hill from Punchakari and Upaniyoor respectively) were recorded by direct count method. The mean number of *O. chinensis* recorded were 0.67, 1.00, 3.33, 2.00 and 2.67 per 10 sweeps from Ulloor, Anad, Punchakari, Karamana and Athiyannoor respectively. The pest was located through direct count, only from Anad (0.20 per hill). The mean population of *D. armigera* recorded was 0.67 per 10 sweeps and 0.33 per 10 sweeps from Punchakari and Upaniyoor respectively.

C. medinalis, *Nephotettix* spp. and *O. chinensis* seen in the rice fields were observed in the non rice fields also. The mean number of *C. medinalis* ranged from 4.00 to 8.33 per 10 sweeps. The mean population of *Nephotettix* spp. ranged from 1.33 to 4.00 per 10 sweeps. At Anad, Punchakari and Athiyannoor, incidence of *Nephotettix* spp. was higher in nonrice habitat than in the rice fields. *O. chinensis* recorded a range between 0.67 and 2.00 per 10 sweeps from the respective locations excepting Upaniyoor. Apart from this, very low population (0.33 to 0.67 per 10 sweeps) of the polyphagous leaf caterpillar, *S. litura* was also noted.

Predators occurring at 50 DAT

Survey conducted in the six padasekharams of double cropped rice fields of Thiruvananthapuram district showed the prevalence of insect predators, *C. lividipennis, Agriocnemis* spp., *O. nigrofasciata, Euscyrtus* sp. and dragonflies at 50 DAT (Table 28). *Agriocnemis* spp. was the dominant insect predator, the mean number recorded being 6.33, 5.33, 8.00, 5.33 and 8.00 per 10 sweeps from Ullor, Anad, Punchakari, Karamana and Athiyannoor respectively. The same predator was recorded through direct count from Ulloor (0.40 per hill) only. *C. lividipennis* occurred at three

Table 28 Incidence of entomophages and neutrals in the double cropped rice ecosystem of Thiruvananthapuram at 50 DAT (Season II)

Entomophages / Neutrals	Locations																							
	Ulloor				Anad				Punchakari				Karamana				Upaniyoor				Athiyannoor			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN
Insect predators																								
C. lividipennis					0.33± 0.58				1.00± 1.73												4.67± 5.69			
Agriocnemis spp.	6.33± 0.58	0.40± 0.70			5.33± 4.04				8.00± 5.29				5.33± 2.08								8.00± 2.65			
O. nigrofasciata	0.33± 0.58				0.67± 0.58												0.33± 0.58							
Euscyrtus sp.	1.00± 1.00			1.00± 1.00					1.00± 1.00			4.33± 1.53	1.00± 1.00			2.33± 0.58				1.00± 1.00				1.00± 1.00
Dragonflies			2.33 ± 0.58				2.33± 1.53				1.67± 1.15				2.33 ± 1.53				2.00± 1.00				2.33± 1.53	
Spiders *Tetragnatha* spp.	1.00± 1.73	0.40± 0.70		1.00± 1.00	0.67± 1.15	0.20± 0.42		1.00± 1.00	1.00± 1.00	0.30± 0.48		1.67± 1.15	1.67± 1.53	0.30± 0.48		2.00± 1.00				1.67± 1.15	3.67± 3.06	0.40± 0.70		2.33± 1.53
L. pseudoannulata		0.60± 0.84			0.67± 0.15					0.20± 0.42								0.30± 0.48			0.67± 0.58	0.40± 0.70		
A. formosana				1.33± 1.53				1.67± 2.08				1.67± 1.15				1.00± 1.00				1.00± 1.73				1.33± 0.58
Neutrals/ others Culicids				19.67± 6.03				17.83± 6.51				12.67± 4.04				18.67± 2.52	0.67± 0.58			16.33± 3.21				17.33± 5.13
Atractomorpha sp.				1.67± 1.53				0.33± 0.58				1.00± 1.73				1.00± 1.00								1.00± 1.00
Camponotus sp.				6.33± 3.79				7.00± 4.00				4.00± 2.00				2.33± 2.50				2.33± 0.58				1.67± 0.58
Chrysomelids				2.67± 3.06								2.67± 1.15								2.67± 2.52				
Solenopsis sp.				10.67± 3.51				5.67± 2.52				5.33± 1.53				6.33± 2.52				8.00± 2.65				6.00± 3.61

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill) VC - Visual counting (per 20 m^2)

locations only, the mean population being 0.33, 1.00 and 4.67 at Anad, Punchakari and Athiyannoor respectively. Very low population of *O. nigrofasciata* (0.33 to 0.67 per 10 sweeps) was recorded from three locations. Mean population of *Euscyrtus* sp. observed at Ulloor, Punchakari and Karamana was 1.00 per 10 sweeps in each of the location. Dragon flies were the only predator observed in visual count. The mean population of dragonflies recorded was 2.33 per 20 m^2 in each of the four locations *viz.*, Ulloor, Anad, Karamana and Athiyannoor. The mean number seen at Punchakari and Upaniyoor were 1.67 and 2.00 per 20 m^2 respectively.

Among the two spiders, *Tetragnatha* spp. and *L. pseudoannulata* observed in the rice ecosystem, *Tetragnatha* spp. was seen in all locations except in Upaniyoor. The number of *Tetragnatha* spp. noted in sweep net collections were 1.00, 0.67, 1.00, 1.67 and 3.67 per 10 sweeps and 0.40, 0.20, 0.30, 0.30 and 0.40 per hill at Ulloor, Anad, Punchakari, Karamana and Athiyannoor respectively. A mean population of 0.67 each per 10 sweeps was noted in the case of *L. pseudoannulata* at Anad and Athiyannoor. Through direct count, the spider was noted in Ulloor (0.60 per hill), Punchakari (0.20 per hill), Upaniyoor (0.30. per hill) and Athiyannoor (0.40 per hill).

Euscyrtus sp. was the only insect predator recorded from the non rice habitat. Except in Anad, its occurrence ranged from 1.00 to 4.33 per 10 sweeps in all the locations. *Tetragnatha* spp. and *A. formosana* were seen in the nonrice habitat in all the six locations. In the nonrice ecosystem the mean population of *Tetragnatha* spp. varied from 1.00 to 2.33 per 10 sweeps and that of *A. formosana* varied from 1.00 to 1.67 per 10 sweeps.

Parasitoids occurring at 50 DAT

Parasitoids were not observed in the double cropped rice fields of Thiruvananthapuram at 50 DAT.

Neutrals occurring at 50 DAT

Low population (0.67 per 10 sweeps) of culicids alone was noted in the rice fields at Upaniyoor.

On the other hand, culicids, *Atractomorpha* sp., *Camponotus* sp., chrysomelids and *Solenopsis* sp. were noted in the adjacent vegetations. Among these, the mean number of culicids varied from 12.67 to 19.67 per 10 sweeps. The population of *Camponotus* sp. and *Solenopsis* sp. ranged from 1.67 to 7.00 and 5.33 to 10.67 per 10 sweeps. The population of *Atractomorpha* sp. ranged from 0.33 to 1.67 per 10 sweeps in all the locations except Upaniyoor. The population of chrysomelids was 2.67 per 10 sweeps each at Ulloor, Punchakari and Upaniyoor respectively.

Pests occurring at 50 DAT

All the pests seen at 30 DAT continued to infest rice when observed at 50 DAT (Table 29). The green leafhopper *Nephotettix* spp. was the dominant pest recorded, its mean population being 17.00, 9.00, 14.33, 14.00, 18.33 and 13.67 per 10 sweeps and 3.40, 1.00, 1.60, 1.20, 2.80 and 1.50 per hill at Ulloor, Anad, Punchakari, Karamana, Upaniyoor and Athiyannoor respectively. The rice leaf roller was found in all the locations except Athiyannoor. The mean number of *C. medinalis* recorded from Ulloor, Anad, Punchakari, Karamana and Upaniyoor were 1.33, 1.00, 2.00, 5.33 and 0.67 per 10 sweeps respectively. Through direct count of assessment, 1.40, 0.30, 0.30, and 0.30 *C. medinalis* (per hill) were recorded from Ulloor, Anad, Punchakari and Karamana respectively. The mean population of *O. chinensis* was 2.33, 2.00, 0.33, 1.33, 0.33 and 0.67 per 10 sweeps in the respective locations. *D. armigera* was recorded from four locations, the mean population ranging from 0.33 to 1.00 per 10 sweeps. Very low population of *L. acuta* (0.33 to 1.00 per 10 sweeps) was also recorded from all the locations except Ulloor.

Table 29 Incidence of pests in the double cropped rice ecosystem of Thiruvananthapuram at 50 DAT (Season II)

Pests	Locations																	
	Ulloor			Anad			Punchakari			Karamana			Upaniyoor			Athiyannoor		
	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE
	Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment		
	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN
C. medinalis	1.33± 1.53	1.40± 1.35		1.00± 1.00	0.30± 0.48		2.00± 1.73	0.30± 0.48		5.33± 5.03	0.30± 0.48		0.67± 0.15					
D. armigera	0.67± 1.15			0.33± 0.58			1.00± 1.00			0.33± 0.58								
L. acuta				0.67± 1.15			0.67± 1.15			0.33± 0.58			1.00± 1.00			1.00± 1.00		
Nephotettix spp.	17.00± 14.73	3.40± 2.50	8.67± 5.51	9.00± 1.73	1.00± 0.82	9.00± 1.73	14.33± 11.37	1.60± 1.35	8.33± 3.06	14.00± 2.31	1.20± 0.92	7.00± 2.00	18.33± 12.09	2.80± 1.75	10.33± 3.21	13.67± 5.69	1.50± 1.35	8.00± 2.00
O. chinensis	2.33± 0.58		1.33± 1.15	2.00± 3.46		2.33± 0.58	0.33± 0.58		2.00± 2.65	1.33± 0.58		1.00± 1.73	0.33± 0.58			0.67± 1.15		1.33± 1.53

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill)

Among the pests, *Nephotettix* spp. and *O. chinensis* were the only two pests noticed in the nonrice habitat. *Nephotettix* spp. was seen in all the six locations and its mean population ranged from 7.00 to 10.33 per 10 sweeps, whereas the mean number of *O. chinensis* ranged from 1.00 to 2.33 per 10 sweeps.

Predators occurring at 70 DAT

The damselfly *Agriocnemis* spp. was the dominant predator recorded at 70 DAT in the rice fields of Thiruvananthapuram (Table 30). The predator was seen in all locations except Upaniyoor, the mean number recorded from Ulloor, Anad, Punchakari, Karamana and Athiyannoor were 4.33, 4.00, 5.67, 2.33 and 2.33 per 10 sweeps respectively. *M. discolor* was observed in all the six locations, its mean population being 1.00 (Ulloor), 2.33 (Anad), 1.33 (Punchakari), 1.00 (Karamana), 2.00 (Upaniyoor) and 1.33 (Athiyannoor) per 10 sweeps. The predator could be sampled through direct count only from two locations, *viz.*, Anad (0.30 per hill) and Upaniyoor (0.60 per hill). Very low population of *O. nigrofasciata* ranging from 0.33 to 1.67 per 10 sweeps was recorded from all the locations except from Karamana. *Euscyrtus* sp. was noted in the sweep net collections obtained from Ulloor (2.33 per 10 sweeps), Punchakari (3.33 per 10 sweeps), Karamana (5.00 per 10 sweeps) and Athiyannoor (3.33 per 10 sweeps). Through direct count of assessment, the predator was recorded from Punchakari (0.30 per hill), Karamana (0.40 per hill) and Athiyannoor (0.60 per hill). The occurrence of dragonflies was not recorded by visual count in 70 DAT observations.

Tetragnatha spp., *L. pseudoannulata* and *A. formosana* were the spiders recorded. *Tetragnatha* spp. was the dominant spider, the mean number recorded was 2.33, 1.33, 1.67, 1.67, 4.33 and 2.67 per 10 sweeps and 1.00, 0.30, 0.50, 0.30, 0.30 and 0.30 per hill from Ulloor, Anad, Punchakari, Karamana, Upaniyoor and Athiyannoor respectively. While the mean population of *L. pseudoannulata* noticed at Ulloor, Karamana

Table 30 Incidence of entomophages and neutrals in the double cropped rice ecosystem of Thiruvananthapuram at 70 DAT (Season II)

Entomophages / Neutrals	Locations																							
	Ulloor				Anad				Punchakari				Karamana				Upaniyoor				Athiyannoor			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN	SN	DC	VC	SN
Insect predators																								
Agriocnemis spp.	4.33± 1.53				4.00± 2.00				5.67± 2.52				2.33± 0.55								2.33± 2.08			
M. discolor	1.00± 1.73			2.00± 1.00	2.33± 0.58	0.30± 0.48		1.00± 1.00	1.33± 0.58			1.67± 0.58	1.00± 1.00			1.33± 0.58	2.00± 2.00	0.60± 0.84		1.67± 1.52	1.33± 1.15			3.33± 1.53
O. nigrofasciata	1.67± 0.58				0.67± 0.58				0.33± 0.58								1.00± 1.00				0.33± 0.58			
Euscyrtus sp.	2.33± 3.21			0.33± 0.58				1.33± 1.58	3.33± 2.31	0.30± 0.48		1.00± 1.00	5.00± 2.00	0.40± 0.70		0.33± 0.58				1.67± 0.58	3.33± 2.52	0.60± 0.84		0.33± 0.58
Dragonflies																								
Spiders *Tetragnatha* spp.	2.33± 1.53	1.00± 0.82		1.67± 0.58	1.33± 1.15	0.30± 0.48		1.33± 1.53	1.67± 1.53	0.50± 0.71		2.33± 1.53	1.67± 0.58	0.30± 0.48		1.33± 1.15	4.33± 1.53	0.30± 0.48		2.83± 1.72	2.67± 0.58	0.30± 0.48		
L. pseudoannulata	0.33± 0.58	0.40± 0.70											1.33± 2.31								0.67± 0.58			
A. formosana					1.00± 1.00	0.30± 0.48		2.33± 1.53				0.33± 0.58				1.67± 1.15				0.33± 0.58				1.00± 1.00
Parasitoids *Apanteles* sp.	2.33± 2.52				1.00± 1.00				2.33± 2.08				2.67± 3.06								2.33± 4.04			
Neutrals/ others Culicids				16.33± 4.04				18.33± 7.51				18.00± 4.58				10.67± 3.51				7.33± 2.08				18.00± 5.57
Atractomorpha sp.				2.33± 0.58				2.33± 2.31				0.67± 0.58				1.67± 0.58				2.00± 1.00				0.67± 0.58
Camponotus sp.				3.00± 1.00				2.33± 0.58				2.00± 1.75				1.67± 1.53				4.33± 2.52				5.00± 2.00
Chrysomelids				1.67± 1.53				1.67± 0.58				2.67± 2.08				3.67± 2.52				2.33± 1.53				1.67± 0.58
Solenopsis sp.				4.67± 3.79				4.33± 2.52				1.00± 1.00				1.67± 1.53				3.33± 2.52				4.00± 1.00
Tetrigids				1.33± 1.53				1.67± 1.53				1.67± 1.15				1.67± 0.58				2.00± 1.00				1.33± 1.53

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill) VC - Visual counting (per 20 m^2)

and Athiyannoor ranged from 0.33 to 1.33 per 10 sweeps and 0.40 per hill at Ulloor. The mean number of *A. formosana* observed was 1.00 per 10 sweeps and 0.30 per hill at Anad only.

Among the insect predators observed in the rice fields of Thiruvananthapuram, *M. discolor* and *Euscyrtus* sp. were seen in the non rice habitat also. Both the predators were seen in all the six locations surveyed. The mean population of *M. discolor* ranged from 1.00 to 3.33 per 10 sweeps and that of *Euscyrtus* sp. from 0.33 to 1.67 per 10 sweeps. Both *Tetragnatha* spp. (1.33 to 2.83 per 10 sweeps in five locations) and *A. formosana* (0.33 to 2.33 per 10 sweeps) were prevalent in the nonrice habitat too.

Parasitoids occurring at 70 DAT

The parasitoid *Apanteles* sp. alone was observed at 70 DAT and its mean population ranged from 1.00 to 2.67 per 10 sweeps in all the locations except Upaniyoor.

Neutrals occurring at 70 DAT

Culicids, *Atractomorpha* sp., *Camponotus* sp., chrysomelids, *Solenopsis* sp. and tetrigids were found in the nonrice habitat. Culicids were the dominant species, its population in the six locations ranging from 7.33 to 18.33 per 10 sweeps. The occurrence of *Atractomorpha* sp. ranged from 0.67 to 2.33 per 10 sweeps and that of *Camponotus* sp. from 1.67 to 5.00 per 10 sweeps. Population of chrysomelids ranged from 1.67 to 3.67 per 10 sweeps, followed by *Solenopsis* sp. (1.00 to 4.67 per 10 sweeps) and tetrigids (1.33 to 2.00 per 10 sweeps).

Pests occurring at 70 DAT

The various pests noted at 70 DAT were *C. medinalis*, *D. armigera*, *L. acuta*, *Nephotettix* spp., *M. histrio* and *O. chinensis* (Table 31). Among these, *Nephotettix* spp., *C. medinalis*, *L. acuta* and *M. histrio* were found in all the six locations surveyed. *Nephotettix* spp. was the dominant pest,

Table 31 Incidence of pests in the double cropped rice ecosystem of Thiruvananthapuram at 70 DAT (Season II)

Pests	Locations																	
	Ulloor			Anad			Punchakari			Karamana			Upaniyoor			Athiyannoor		
	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE	RE		NRE
	Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment			Method of assessment		
	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN	SN	DC	SN
C. medinalis	1.00± 1.73	0.70± 0.67		4.33± 2.52	0.80± 0.92		2.67± 0.58	0.30± 0.48		1.67± 1.53	0.40± 0.70		3.00± 1.00	0.30± 0.48		2.67± 1.15	0.20± 0.42	
D. armigera	0.33± 1.15			1.00± 1.00						0.67± 1.15								
L. acuta	7.67± 3.06	1.50± 1.51		7.33± 2.08	1.40± 1.17		3.67± 2.08	1.40± 1.17		5.00± 1.00	0.70± 0.82		4.00± 1.73	0.60± 0.84		5.00± 2.00	0.60± 0.84	
Nephotettix spp.	11.33± 2.51	6.40± 2.37		16.67± 3.51	3.90± 2.42		22.33± 14.50	3.60± 1.78		12.33± 5.51	3.10± 1.37		35.67± 18.72	4.50± 2.07		27.00± 25.98	1.70± 1.42	
M. histrio	3.00± 2.65		1.67± 0.58	2.67± 0.58	0.30± 0.48		1.67± 0.58	0.20± 0.42	2.00± 1.00	2.33± 0.58		1.33± 1.15	1.33± 0.58		1.33± 0.58	3.67± 2.08		2.00± 1.00
O. chinensis	7.67± 0.58		1.33± 0.58			1.67± 1.53	0.67± 1.15		1.67± 1.15			1.00± 1.00	2.00± 1.00		1.33± 0.58	1.33± 1.15		1.33± 0.58

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps) DC - Direct count (per hill)

the mean number recorded being 11.33, 16.67, 22.33, 12.33, 35.67 and 27.00 per 10 sweeps and 6.40, 3.90, 3.60, 3.10, 4.50 and 1.70 per hill from Ulloor, Anad, Punchakari, Karamana, Upaniyoor and Athiyannoor respectively. The mean number of *C. medinalis* recorded were 1.00, 4.33, 2.67, 1.67, 3.00 and 2.67 per 10 sweeps and 0.70, 0.80, 0.30, 0.40, 0.30 and 0.20 per hill in the above padasekharams respectively. Similarly, the mean population of *L. acuta* was 7.67, 7.33, 3.67, 5.00, 4.00 and 5.00 per 10 sweeps and 1.50, 1.40, 1.40, 0.70, 0.60 and 0.60 per hill in the six locations respectively. The mean population of *M. histrio* ranged from 1.33 to 3.67 per 10 sweeps. Through direct count, *M. histrio* was recorded from Anad (0.30 per hill) and Punchakari (0.20 per hill) only. Population of *D. armigera* was negligible and was recorded from three locations. The mean number of *D. armigera* collected were 0.33, 1.00 and 0.67 per 10 sweeps from Ulloor, Anad and Karamana respectively. *O. chinensis* was seen in all locations except Anad and Karamana. The pest recorded a mean population of 7.67, 0.67, 2.00 and 1.33 per 10 sweeps at Ulloor, Punchakari, Upaniyoor and Athiyannoor respectively.

Only two pests *viz.*, *M. histrio* and *O. chinensis* were observed in the nonrice habitat. The mean population of the former ranged from 1.33 to 2.00 per 10 sweeps in all the locations except in Anad and the mean population of the latter ranged from 1.00 to 1.67 per 10 sweeps in all the six locations surveyed.

4.1.2.3 Rice Ecosystem of Pokkali

Predators occurring at 30 DAT

The insect predators recorded at 30 DAT from different rice fields of Pokkali included, *Agriocnemis* spp., *M. discolor*, *O. nigrofasciata*, dragonflies, *L. fossarum* and *Microvelia* sp. (Table 32).

Among these, the mean number of *Agriocnemis* spp. noted were 1.00, 1.67, 3.67, 3.00 and 0.67 per 10 sweeps from Chellanam, Vyttila,

Table 32 Incidence of entomophages and neutrals in the rice ecosystem of Pokkali at 30 DAT (Season II)

Entomophages / Neutrals	Locations																							
	Chellanam				Vyttila				Cheranallur				Chalikkavattam				Kumbalangi				Kannamali			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN
Insect predators																								
Agriocnemis spp.	1.00± 1.00				1.67± 1.53				3.67± 2.08								3.00± 1.00				0.67± 1.15			
M. discolor	0.33± 0.58				3.00± 1.00				1.00± 1.73								1.67± 1.15				2.00± 1.00			
O. nigrofasciata	1.00± 1.00				1.67± 0.58								1.00± 1.00				0.67± 0.58				0.67± 0.58			
Euscyrtus sp.				1.00± 1.00				0.67± 1.15				0.67± 0.58				0.67± 1.15				1.33± 0.58				0.33± 0.58
Dragonflies	1.00± 1.00		1.33± 0.58		1.00± 1.00		2.33± 1.53		0.33± 0.58		2.00± 1.00		0.67± 0.52		1.67± 1.15		1.33± 0.58		1.33± 0.58		0.33± 0.58		1.67± 1.15	
Dragonfly naiads		3.00± 1.00				3.67± 1.15				2.33± 1.53				4.67± 1.53				3.67± 1.53				4.00± 1.73		
L. fossarum		4.00± 2.65				2.67± 1.53				4.33± 1.53				3.67± 1.53				4.00± 2.65				4.33± 1.53		
Microvelia sp.		3.67± 1.03				4.00± 1.00				4.67± 1.53				4.33± 2.52				5.33± 1.15				5.67± 2.08		
Spiders *Tetragnatha* spp.	2.67± 1.53			1.67± 0.58	2.33± 2.08			1.00± 1.00	1.67± 1.53			2.00± 2.00	2.00± 2.00			1.33± 0.58	1.67± 0.58			1.67 ± 0.58	2.00± 2.00			2.00± 1.00
Neutrals/ others Culicids				18.67± 5.51				10.67± 3.51				12.67± 4.04				14.33± 5.69				9.17 ± 5.63				14.67± 3.51
Camponotus sp.				1.00± 1.00								3.33± 2.52				3.33± 3.51				4.67 ± 3.06				2.00± 1.00

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) VC - Visual counting (per 20 m^2) SW – Sieving water (30 L)

Cheranallur, Kumbalangi and Kannamali respectively. Similarly 0.33, 3.00, 1.00, 1.67 and 2.00 per 10 sweeps were the mean number of *M. discolor* recorded from the same five locations. The mean number of *O. nigrofasciata* per 10 sweeps were 1.00, 1.67, 1.00, 0.67 and 0.67 from Chellanam, Vyttila, Chalikkavattam, Kumbalangi and Kannamali respectively. The mean number of dragonflies recorded from Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali were 1.00, 1.00, 0.33, 0.67, 1.33 and 0.33 per 10 sweeps respectively. The population of dragonflies ranged from 1.33 to 2.33 per 20 m^2, the maximum number (2.33 per 20 m^2) being observed in Vyttila through visual counting. The population of dragonfly naiads ranged from 2.33 to 4.67, the mean number recorded from the six locations concerned were 3.00, 3.67, 2.33, 4.67, 3.67 and 4.00. per 30 litres of water at 30 DAT.

The mean number of *L. fossarum* recorded were 4.00, 2.67, 4.33, 3.67, 4.00 and 4.33 per 30 litres of water from Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali respectively. The population of ripple bug *Microvelia* sp. from the six locations ranged from 3.67 to 5.67 per 30 litres of water at 30 DAT, the mean numbers recorded per location being 3.67, 4.00, 4.67, 4.33, 5.33 and 5.67 respectively.

Regarding spider predators, *Tetragnatha* spp. alone was recorded. The number of *Tetragnatha* spp. per 10 sweeps was 2.67, 2.33, 1.67, 2.00, 1.67 and 2.00 from Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali respectively.

Euscyrtus sp. alone was noted from the adjoining nonrice habitats. The number of crickets per 10 sweeps ranged from 0.33 to 1.33 in all the six locations surveyed. The spider, *Tetragnatha* spp. was also found in the nonrice habitat, its population ranging from 1.00 to 2.00 per 10 sweeps in all the six locations.

Parasitoids occurring at 30 DAT

Parasitoids were not observed in the Pokkali rice fields at 30 DAT.

Neutrals occurring at 30 DAT

Culicids and the black ant, *Camponotus* sp. were observed in the non rice habitats of Pokkali rice ecosystem. Culicids were the dominant neutrals, its occurrence in the six locations varied from 9.17 to 18.67 per 10 sweeps. Mean population of *Camponotus* sp. ranged from 1.00 to 4.67 per 10 sweeps in all the locations surveyed except Vyttila.

Pests occurring at 30 DAT

Pests inhabiting the rice fields of Pokkali at 30 DAT were *C. medinalis*, *D. armigera*, *Nephotettix* spp., *C. spectra* and *O. chinensis*. Only very low population of the pests was seen in Pokkali rice fields. The green leafhopper, *Nephotettix* spp. was the dominant pest and it occurred in all the six locations surveyed (Table 33). The mean population of the pest was 2.00, 1.33, 3.00, 1.33, 1.00 and 0.67 per 10 sweeps at Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali respectively. *C. medinalis* was recorded from only two locations *viz.*, Cheranallur (2.33 per 10 sweeps) and Chalikkavattam (0.33 per 10 sweeps). *D. armigera* occurred in all locations except Vyttila and the population ranged from 0.67 to 1.33 per 10 sweeps. The mean population of the white leafhopper *C. spectra* ranged from 0.33 to 0.67 per 10 sweeps in all locations except Kumbalangi. *O. chinensis* occurred in only two locations *viz.*, Vyttila and Kumbalangi (0.33 per 10 sweeps each).

Among the pests seen in the rice ecosystem, *Nephotettix* spp. and *O. chinensis* were seen from the adjoining non rice habitat. While the mean number of hoppers per 10 sweeps ranged from 0.67 to 2.67, the mean population of *O. chinensis* ranged from 1.00 to 2.00 per 10 sweeps.

Table 33 Incidence of pests in the rice ecosystem of Pokkali at 30 DAT (Season II)

Pests	Locations											
	Chellanam		Vyttila		Cheranallur		Chalikkavattam		Kumbalangi		Kannamali	
	RE	NRE	RE	NRE	RE	NRE	RE	NRE	RE	NRE	RE	NRE
	Method of assessment		Method of assessment		Method of assessment		Method of assessment		Method of assessment		Method of assessment	
	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN
C. medinalis					2.33± 2.31		0.33± 0.58					
D. armigera	1.33± 0.58				1.00± 1.00		0.67± 1.15		0.67± 0.58		0.67± 0.58	
Nephotettix spp.	2.00± 1.00	0.67± 0.58	1.33± 1.15	1.67± 1.53	3.00± 1.00	2.67± 2.06	1.33± 1.15	1.33± 1.58	1.00± 1.73	1.67± 2.89	0.67± 1.15	1.33± 2.31
C. spectra	0.33± 0.58		0.33± 0.58		0.67± 0.58		0.33± 0.58				0.33± 0.58	
O. chinensis		1.67± 1.53	0.33± 0.58	1.33± 0.58				1.00± 1.00	0.33± 0.58	2.00± 2.00		1.33± 1.15

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps)

Predators occurring at 50 DAT

Among the three insect predators seen at 50 DAT, *M. discolor* was recorded from all the six locations of Pokkali rice ecosystem (Table 34).

M. discolor was the dominant predator and its population being 3.33, 4.00, 4.33, 4.33, 7.33 and 9.00 per 10 sweeps at Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali respectively. This was followed by *Agriocnemis* spp., the population of which ranged from 0.33 to 1.33 per 10 sweeps in all the locations except Chalikkavattam. Incidence of *O. nigrofasciata* was recorded from Chellanam and Vyttila (0.33 per 10 sweeps each). The mean number of dragonflies noted from the six locations was 2.33, 3.00, 1.33, 2.00, 3.00 and 2.33 per 20 m^2 by visual count. The population of dragonfly naiads ranged from 1.67 to 5.00 per 30 litres of water, by sieving water. The mean number of *L. fossarum* recorded were 3.67, 4.67, 4.33, 3.67, 4.67 and 3.67 per 30 litres of water from the respective six locations. Similarly, the mean number of ripple bug, *Microvelia* sp. noted at 50 DAT were 4.33, 6.00, 2.33, 6.00, 3.00 and 3.33 per 30 litres of water in the respective six locations.

Tetragnatha spp. was the only spider observed in Pokkali rice ecosystem. The number of the spider obtained were 0.33, 0.67 and 0.67 per 10 sweeps from Chellanam, Vyttila and Chalikkavattam respectively.

Euscyrtus sp. was obtained at Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali the mean number per 10 sweeps being 2.00, 1.67, 2.67, 2.00, 3.00 and 1.67. *Tetragnatha* spp. was also recovered from nonrice habitat. The population ranged from 0.33 to 1.00 per 10 sweeps in the four locations *viz.*, Vyttila, Chalikkavattam, Kumbalangi and Kannamali.

Parasitoids occurring at 50 DAT

The parasitoid *Tetrastichus* sp. alone was observed at Chellanam (2.33 per 10 sweeps) and Vyttila (0.67 per 10 sweeps) respectively.

Table 34 Incidence of entomophages and neutrals in the rice ecosystem of Pokkali at 50 DAT (Season II)

Natural Enemies	Locations																							
	Chellanam				Vyttila				Cheranallur				Chalikkavattam				Kumbalangi				Kannamali			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN
Insect predators																								
Agriocnemis spp.	1.33± 1.53				0.33± 0.58				1.00± 1.00								0.67± 0.58				1.00± 1.00			
M. discolor	3.33± 2.30			0.67± 1.15	4.00± 4.00			0.67± 0.58	4.33± 2.31			1.33± 0.58	4.33± 2.52				7.33± 5.51			1.33± 1.53	9.00± 7.55			2.67± 2.89
O. nigrofasciata	0.33± 0.58				0.33± 0.58																			
Euscyrtus sp.				2.00± 1.00				1.67± 0.58				2.67± 1.53				2.00± 1.00				3.00± 1.00				1.67± 0.58
Dragonflies			2.33± 1.53				3.00± 1.00				1.33± 0.58				2.00± 1.00				3.00± 1.00				2.33± 0.58	
Dragonfly naiads		5.00± 1.00				2.33± 0.58				3.00± 1.00				1.67± 0.58				2.33± 0.58				3.67± 0.58		
L. fossarum		3.67± 1.53				4.67± 1.53				4.33± 2.52				3.67± 0.58				4.67± 1.53				3.67± 1.53		
Microvelia sp.		4.33± 2.52				6.00± 2.00				2.33± 0.58				6.00± 2.00				3.00± 1.00				3.33± 0.58		
Spiders *Tetragnatha* spp.	0.33± 0.58				0.67± 1.15			0.33± 0.58					0.67± 1.15			1.00± 1.00				0.67± 1.15				1.00± 1.00
Parasitoids *Tetrastichus* sp.	2.33± 4.04				0.67± 1.15																			
Neutrals/ others Culicids				12.00± 3.61				19.00± 8.19				15.80± 3.35				15.67± 2.08				17.00± 4.00				21.67± 3.79
Atractomorpha sp.				2.00± 2.00								0.67± 1.15				1.00± 1.00				1.00± 1.73				0.67± 0.58
Camponotus sp.				2.67± 3.05								2.00± 2.00				1.00± 1.73				3.00± 3.00				2.00± 2.00

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) VC - Visual counting (per 20 m^2) SW – Sieving water (30 L)

Neutrals occurring at 50 DAT

Culicids, *Atractomorpha* sp. and *Camponotus* sp. were found to colonise the nonrice vegetation near the rice fields. Culicids were the dominant species, its occurrence in the six locations ranging from 12.00 to 21.67 per 10 sweeps. The mean population of *Atractomorpha* sp. ranged from 0.67 to 2.00 per 10 sweeps and that of *Camponotus* sp. from 1.00 to 3.00 per 10 sweeps.

Pests occurring at 50 DAT

The pests seen at 50 DAT in the Pokkali rice fields were mainly the hemipterans. They included *L. acuta*, *Nephotettix* spp., *M. histrio* and *O. chinensis* (Table 35).

The mean number of *L. acuta* recorded from Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali were 1.00, 2.00, 6.33, 3.67, 2.67 and 2.33 per 10 sweeps respectively. Similarly, 10.00, 14.67, 4.33, 2.33, 4.00 and 4.67 per 10 sweeps were the mean number of *Nephotettix* spp. and 0.67, 0.33, 0.67, 0.67, 0.67 and 0.67 per 10 sweeps of *M. histrio* recorded in the above locations. The mean number of *O. chinensis* recorded were 3.00, 3.00, 2.33, 3.00, 0.33 and 1.33 per 10 sweeps from the six locations.

Majority of the pests recorded in the rice ecosystem were recovered from the adjoining vegetation of the rice fields. They included *L. acuta*, *Nephotettix* spp. and *O. chinensis*. The mean number of *L. acuta* per 10 sweeps ranged from 0.67 to 2.67; *Nephotettix* spp. from 1.00 to 3.67 per 10 sweeps and *O. chinensis* from 1.33 to 2.33 per 10 sweeps. All these pests were seen in the non rice habitats of the six locations surveyed.

Predators occurring at 70 DAT

The insect predators recorded from Pokkali rice ecosystem at 70 DAT were *Agriocnemis* spp., *M. discolor*, *P. fuscovittatus*, dragonflies, *L. fossarum* and *Microvelia* sp. (Table 36). These six predators were observed in all the six locations surveyed. *P. fuscovittatus* was the dominant predator observed, the

Table 35 Incidence of pests in the rice ecosystem of Pokkali at 50 DAT (Season II)

Pests	Locations											
	Chellanam		Vyttila		Cheranallur		Chalikkavattam		Kumbalangi		Kannamali	
	RE	NRE	RE	NRE	RE	NRE	RE	NRE	RE	NRE	RE	NRE
	Method of assessment		Method of assessment		Method of assessment		Method of assessment		Method of assessment		Method of assessment	
	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN
L. acuta	1.00± 1.75	0.67± 1.15	2.00± 1.00	1.00± 1.00	6.33± 1.53	2.67± 0.58	3.67± 0.58	1.33± 0.58	2.67± 3.06	1.33± 1.53	2.33± 1.53	1.67± 1.15
Nephotettix spp.	10.00± 9.64	3.33± 3.21	14.67± 11.59	3.67± 2.08	4.33± 1.53	1.33± 0.58	2.33± 2.52	1.67± 1.53	4.00± 2.65	2.67± 2.08	4.67± 2.08	1.00± 1.00
M histrio	0.67± 0.58		0.33± 0.58		0.67± 1.15		0.67± 0.58		0.67± 0.58		0.67± 0.58	
O. chinensis	3.00± 1.00	1.67± 0.58	3.00± 1.00	1.33± 0.58	2.33± 1.15	1.67± 0.58	3.00± 1.00	1.67± 1.53	0.33± 0.58	1.33± 0.58	1.33± 1.15	2.33± 0.58

RE - Rice ecosystem NRE - Non rice ecosystem SN - Sweep net (per 10 sweeps)

Table 36 Incidence of entomophages and neutrals in the rice ecosystem of Pokkali at 70 DAT (Season II)

Entomophages / Neutrals	Locations																							
	Chellanam				Vyttila				Cheranallur				Chalikkavattam				Kumbalangi				Kannamali			
	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE	RE			NRE
	Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment				Method of assessment			
	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN	SN	SW	VC	SN
Insect predators																								
Agriocnemis spp.	1.33± 1.53				3.00± 3.61				1.00± 1.00				0.33± 0.58				3.00± 1.00				0.33± 0.58			
M. discolor	4.33± 4.04			1.00± 1.00	2.33± 0.58			1.33± 0.58	4.33± 2.33			2.00± 1.00	5.67± 4.73			1.00± 1.00	2.67± 3.05			1.00± 1.00	3.33± 1.53			1.00± 1.73
P. fuscovittatus	6.33± 2.08				8.00± 2.00				6.33± 3.06				3.00± 1.00				5.00± 3.00				4.33± 2.52			
Euscyrtus sp.				6.33± 2.52				8.00± 5.57				1.33± 0.58				2.33± 2.52				3.00± 1.00				1.67± 0.58
Dragonflies	3.67± 2.08		1.33± 0.58		1.00± 1.00		1.33± 0.58		2.67± 2.52		2.33± 1.53		1.00± 1.00		1.33± 1.58		3.67± 1.53		1.67± 0.58		2.67± 1.15		3.00± 1.00	
Dragonfly naiads		4.00± 1.00				2.33± 0.58				3.67± 1.53				3.33± 1.15				2.00± 1.00				2.33± 0.58		
L. fossarum		4.00± 2.00				3.33± 1.15				3.33± 1.53				3.00± 1.00				3.00± 1.00				3.67± 0.58		
Microvelia sp.		4.33± 1.53				5.00± 1.00				6.33± 1.53				5.67± 1.53				6.00± 1.73				4.67± 2.08		
Parasitoids *Tetrastichus* sp.	1.67± 1.15								0.67± 1.15												1.00± 1.73			
Neutrals/ others Culicids				11.33± 4.16				13.00± 5.57				17.67± 3.06				22.00± 4.50				19.33± 4.51				15.67± 3.06
Camponotus sp.				4.00± 2.65								3.33± 3.06				4.00± 2.65				5.00± 4.58				4.67± 5.69
Solenopsis sp.				3.67± 1.53								5.33± 3.51				3.67± 2.52				5.67± 3.21				4.33± 1.53

RE – Rice ecosystem NRE – Non rice ecosystem SN - Sweep net (per 10 sweeps) VC - Visual counting (per 20 m^2) SW – Sieving water (30 L)

mean numbers per 10 sweeps was 6.33, 8.00, 6.33, 3.00, 5.00 and 4.33 in Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali respectively.

Regarding the mean number of *M. discolor* recorded it was 4.33, 2.33, 4.33, 5.67, 2.67 and 3.33 per 10 sweeps. *Agriocnemis* spp. recorded 1.33, 3.00, 1.00, 0.33, 3.00 and 0.33 per 10 sweeps. The mean population of 3.67, 1.00, 2.67, 1.00, 3.67 and 2.67 dragonflies per 10 sweeps were recorded from Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali respectively. The mean number of dragonflies recorded from Chellanam, Vyttila and Chalikkavattam through visual count was 1.33 each per 20 m^2 and the other locations *viz.*, Cheranallur, Kumbalangi and Kannamali recorded 2.33, 1.67 and 3.00 per 20 m^2 respectively. Through sieving water, the mean number of dragonfly naiads noted from the six locations were 4.00, 2.33, 3.67, 3.33, 2.00 and 2.33 per 30 litres of water respectively. The mean number of *L. fossarum* recorded were 4.00, 3.33, 3.33, 3.00, 3.00 and 3.67 from, Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali respectively. Through sieving water, the mean population of *Microvelia* sp. ranged from 4.33 to 6.33 per 30 litres of water, the mean population in each location being 4.33, 5.00, 6.33, 5.67, 6.00 and 4.67.

The insect predators noted from the non rice ecosystem of Pokkali rice fields were *M. discolor* and *Euscyrtus* sp. *M. discolor* population which varied from 1.00 to 2.00 per 10 sweeps and *Euscyrtus* sp. ranged from 1.33 to 8.00 per 10 sweeps in all the six locations surveyed.

Parasitoids occurring at 70 DAT

Incidence of *Tetrastichus* sp. was recorded from three locations *viz.*, Chellanam (1.67 per 10 sweeps), Cheranallur (0.67 per 10 sweeps) and Kannamali (1.00 per 10 sweeps).

Neutrals occurring at 70 DAT

Culicids, *Camponotus* sp. and *Solenopsis* sp. were the neutrals recorded from the nonrice habitat of Pokkali rice ecosystem. Culicids were dominant and its population in the six locations ranged from 11.33 to 22.00 per 10 sweeps. *Camponotus* sp. and *Solenopsis* sp. occurred in all locations except Vyttila, the population being 3.33 to 5.00 per 10 sweeps and 3.67 to 5.67 per 10 sweeps respectively.

Pests occurring at 70 DAT

The pests recorded at 70 DAT from the Pokkali rice ecosystem were *D. armigera*, *L. acuta*, *Nephotettix* spp., *C. spectra*, *M. histrio* and *O. chinensis*. Among these *L. acuta*, *Nephotettix* spp. and *O. chinensis* occurred in all the six locations surveyed (Table 37). *L. acuta* was the dominant pest, its population in the six locations being 7.00, 8.67, 11.00, 6.00, 5.33 and 5.00 per 10 sweeps respectively from Chellanam, Vyttila, Cheranallur, Chalikkavattam, Kumbalangi and Kannamali respectively. Presence of *Nephotettix* spp. (1.67 to 6.00 per 10 sweeps) and *O. chinensis* (0.33 to 7.33 per 10 sweeps) was seen in all the six locations. *D. armigera* occurred in two locations, *viz.*, Vyttila and Chalikkavattam (0.67 each per 10 sweeps). Very low population (0.33 to 1.00 per 10 sweeps) of *C. spectra* was recorded from all the locations except Chellanam. Similarly population of *M. histrio* was negligible (0.33 to 0.67 per 10 sweeps) in all the locations surveyed except Cheranallur.

Among the pests seen in the rice ecosystem, *L. acuta*, *Nephotettix* spp. and *O. chinensis* were recovered from the adjoining nonrice habitat. The mean number of rice bugs per 10 sweeps ranged from 0.67 to 2.67 in all the six locations surveyed. The occurrence of *Nephotettix* spp. in all the locations varied from 0.67 to 4.00 per 10 sweeps. The mean population of *O. chinensis* ranged from 0.33 to 1.67 per 10 sweeps.

Apart from the entomophages, neutrals and phytophages listed in tables 2 to 37, very low population of the following were also observed in the three rice ecosystems.

Table 37 Incidence of pests in the rice ecosystem of Pokkali at 70 DAT (Season II)

Pests	Locations											
	Chellanam		Vyttila		Cheranallur		Chalikkavattam		Kumbalangi		Kannamali	
	RE	NRE	RE	NRE	RE	NRE	RE	NRE	RE	NRE	RE	NRE
	Method of assessment		Method of assessment		Method of assessment		Method of assessment		Method of assessment		Method of assessment	
	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN	SN
D. armigera			0.67± 0.58				0.67± 0.58					
L. acuta	7.00± 5.00	2.33± 2.52	8.67± 4.93	2.33± 2.08	11.00± 6.24	2.67± 3.06	6.00± 6.00	1.67± 2.08	5.33± 2.52	1.33± 0.58	5.00± 2.00	0.67± 0.58
Nephotettix spp.	2.33± 2.08	1.00± 1.00	2.33± 2.52	0.67± 0.58	4.33± 1.53	1.67± 0.58	1.67± 1.53	3.00± 2.00	6.00± 3.60	4.00± 2.65	5.67± 3.06	2.33± 1.53
C. spectra			0.67± 1.15		0.67± 1.15		1.00± 1.00		0.33± 0.58		1.00± 1.00	
M. histrio	0.67± 0.58		0.33± 0.58				0.67± 0.58		0.33± 0.58		0.67± 0.58	
O. chinensis	1.33± 1.15	1.00± 1.00	3.00± 1.00	1.00± 1.00	2.33± 1.15	1.67± 1.53	0.33± 0.58	1.33± 2.31	7.33± 2.52	0.33± 0.58	2.00± 1.00	1.00± 1.73

RE - Rice ecosystem NRE - Non rice ecosystem SN- Sweep net (per 10 sweeps)

Common name	Scientific name	ES I	ES II	ES III
Entomophages				
Coccinellid beetle	*Menochilus sexmaculatus*	P	P	P
Staphylinid beetle	*Paederus fuscipes*	A	A	P
Spiders	*Araneus* sp.	P	A	A
	Oxyopes sp.	A	P	A
	Clubiona japonicola	A	P	A
	Argiope catenulata	A	P	A
	Argiope anasuja	P	P	A
	Plexippus sp.	P	A	A
	Phidippus sp.	P	A	A
	Oxyopes lineatipes	P	P	A
	Neoscona nautica	P	P	A
	Larinia sp.	A	A	P
	Peucitia sp.	A	A	P
	Brachymeria sp.	P	A	A
Parasitoids	*Amauromorpha* sp	P	A	A
	Xanthopimpla sp.	P	P	A
Neutrals/ Others				
May flies		A	P	A
Tabanids		A	P	A
Bees		A	A	P
Phytophages				
Yellow stem borer	*Scirpophaga incertulas*	P	P	P
White stem borer	*Scirpophaga innotata*	A	A	P
Zigzag leaf hopper	*Recilia dorsalis*	P	A	A
Green horned caterpillar	*Melanitis leda ismene*	P	P	A
Rice skipper	*Pelopidas mathias*	P	P	P
Yellow hairy caterpillar	*Psalis pennatula*	P	A	A
Climbing cut worm	*Mythimna separata*	P	A	P
Long horned grasshopper	*Conocephalus longipennis*	P	P	P
Rice leptispa	*Leptispa pygmaea*	A	P	A

ES I – Kuttanadu Ecosystem ES II – Double cropped Ecosystem
ES III – Pokkali Ecosystem P – Present A – Absent

4.1.3 Species Diversity

The diversity of arthropod species was reduced in the rice ecosystem of Kuttanadu where insecticides were frequently used (1.626). On the other hand, significantly higher diversity was noted in double cropped ecosystem of Thiruvananthapuram (1.970), where insecticides were applied need based and it was comparable to the diversity of species (2.089) seen in the ecosystem of Pokkali where the rice lands were free of insecticides (Table 38).

A significant difference was observed in the diversity of species during the two seasons in Kuttanadu. Greater diversity was observed during the second season compared to the first season, the diversity index being 1.828 and 1.424 respectively. No such seasonal variation was seen in the double cropped rice ecosystems of Thiruvananthapuram and Pokkali, the species diversity index being 2.038 and 2.153 during the first season and 1.903 and 2.026 in the second season respectively.

4.2 IDENTIFICATION OF SUITABLE PREY FOR REARING OF PREDATORS

Suitable prey for rearing of the dominant insect predators *viz.*, *C. lividipennis* and *M. discolor* and spider predators *viz.*, *T. maxillosa* and *L. pseudoannulata* observed in the survey were identified based on the developmental period, adult longevity and the number of prey consumed during the developmental period and adult life span of each predator.

4.2.1 Developmental Period of Insect Predators when Reared on Different Prey

C. lividipennis

Results presented in Table 39 indicated no significant difference in the incubation period of *C. lividipennis* when reared on first instar nymphs of *N. lugens*, *S. furcifera* and *Nephotettix* sp., the mean number of days ranging

Table 38 Species diversity in three heterogeneous rice ecosystems of Kerala

Ecosystems	Season I	Season II	Mean
Kuttanadu	1.424	1.828	1.626
Double cropped	2.038	1.903	1.970
Pokkali	2.153	2.026	2.089

CD (0.05)
Treatments 0.3586

Table 39 Developmental period and adult longevity of *Cyrtorhinus lividipennis* and *Micraspis discolor* when reared on different prey

Predator	**Prey**	Duration of different instars of predator (days)*							Adult longevity (days)
		EP	I	II	III	IV	V	Total	
C. lividipennis	1st instar *N. lugens*	7.40	2.20	2.60	2.40	3.40	5.00	23.00	21.80
	1st instar *S. furcifera*	8.00	3.00	3.60	3.40	4.20	4.60	26.80	19.40
	1st instar *Nephotettix* sp.	8.20	3.40	3.40	4.60	4.80	4.60	29.00	12.60
	CD (0.05)		0.796		0.755	1.037		2.945	4.727
	SE	0.316	0.258	0.355	0.245	0.337	0.374	0.956	1.534
		Duration of different instars of predator (days)*							Adult longevity (days)
		EP	I	II	III	IV	Pupa	Total	
M. discolor	Eggs of *M. discolor*	3.80	2.60	3.60	4.60	4.80	3.80	23.20	50.40
	2nd instar *N. lugens*	4.00	3.00	3.60	4.80	4.80	4.40	24.60	41.40
	2nd instar *S. furcifera*	4.40	2.80	3.60	4.20	4.60	4.20	23.80	38.20
	CD (0.05)								7.17
	SE	0.365	0.316	0.245	0.283	0.337	0.337	0.616	2.33

*Mean of five replications
EP – Egg period

from 7.40 to 8.20. Five nymphal stages were observed for the predator when reared on all the three prey. The duration of the first nymphal instar of *C. lividipennis* was significantly short (2.20 days) when reared on first instar *N. lugens* compared to the time taken for completion of the instar when reared on first instar *S. furcifera* (3.00 days) and *Nephotettix* sp. (3.40 days) which were on par. Second instar nymphs of *C. lividipennis* fed with the three different prey did not show any significant difference in the mean number of days taken for completion of the instar (2.60 to 3.40 days). The third instar of *C. lividipennis* was significantly shorter when reared on first instar *N. lugens* (2.40 days), closely followed by the duration of the instar when reared on *S. furcifera* (3.40 days) and *Nephotettix* sp. (4.60 days). The period taken for the completion of the fourth instar of *C. lividipennis* was significantly lower when fed with first instar *N. lugens* (3.40 days) and it was on par with the time taken when reared on first instar *S. furcifera* (4.20 days) but differed significantly from the period taken when reared on first instar *Nephotettix* sp. (4.80 days). Duration of the fifth instar did not vary significantly when reared on the three hopper species.

Regarding the total nymphal period, lowest duration (23.00 days) was observed when nymphs of *C. lividipennis* were reared on first instar *N. lugens* and was significantly superior to other treatments. The developmental period was prolonged to 26.80 days and 29.00 days when reared on first instar of *S. furcifera* and *Nephotettix* sp. respectively and both the treatments were on par.

Lifespan of adult *C. lividipennis* was significantly longer when it consumed first instar nymphs of *N. lugens*, the mean number of days being 21.80 days. On *S. furcifera* and *Nephotettix* sp., the longevity of the adult predator was 19.40 and 12.60 days respectively.

M. discolor

Significant difference was not observed in the egg period of *M. discolor* when reared on eggs of *M. discolor*, second instar *N. lugens* and second instar *S. furcifera* (Table 39). The mean number of days taken for completion of the stage ranged from 3.80 to 4.40. Following the egg period, four larval instars and a pupal stage were noted in the development of *M. discolor*. As in the case of egg period, no significant difference was seen in the duration of the different instars, pupal period and total duration taken for development. While the mean number of days taken for the first, second, third and fourth instars ranged from 2.60 to 3.00, 3.60, 4.20 to 4.80 and 4.60 to 4.80 respectively, it ranged from 3.80 to 4.20 for completion of the pupal period. The total duration from egg to adult ranged from 23.20 to 24.60 days.

However, longevity of the adult beetles reared on different prey showed significant variation. It was significantly higher (50.40 days) when reared on the eggs of *M. discolor*. The treatment was superior to the other prey tested *viz.*, second instar nymphs of *N. lugens* (41.40 days) and *S. furcifera* (38.20 days).

4.2.2 Developmental Period of Spiders when Reared on Different Prey

T. maxillosa

The spider *T. maxillosa* underwent nine nymphal instars when reared on *N. lugens, S. furcifera* and *Nephotettix* sp. (Table 40). The period taken for the completion of the first instar did not differ significantly, the mean number of days being 9.40, 10.20 and 9.80 respectively. A similar trend was seen in the completion of the second and third instars, the period ranging from 8.00 to 9.20 and 7.40 to 9.00 days respectively. Duration of the fourth instar was significantly short when *T. maxillosa* was reared on *Nephotettix* sp. (7.20 days) compared to the days taken when reared on *S. furcifera* (9.00 days) and *N. lugens* (9.60 days) which were on par.

However, significant difference was not observed in the developmental period of the fifth and sixth instars (8.20 to 8.40 days and 8.00 to 9.40 days respectively) when reared on adults of the prey. Duration of the seventh instar of *T. maxillosa* was significantly short when reared on *Nephotettix* sp. (7.40 days) compared to its duration when fed with *S. furcifera* (8.60 days) and *N. lugens*

Table 40 Developmental period and adult longevity of *Tetragnatha maxillosa* and *Lycosa pseudoannulata* when reared on different prey

Predator	**Prey**	Duration of different instars of predator (days)*											Adult longevity (days)
		I	II	III	IV	V	VI	VII	VIII	IX	X	Total	
T. maxillosa	*N. lugens*	9.40	8.60	9.00	9.60	8.40	9.40	8.80	7.80	8.60	–	79.60	16.40
	S. furcifera	10.20	9.20	8.40	9.00	8.20	8.20	8.60	7.40	8.80	–	78.40	15.90
	Nephotettix sp.	9.80	8.00	7.40	7.20	8.20	8.00	7.40	8.20	7.00	–	71.20	22.50
	CD(0.05)				1.779			1.067			–	4.379	2.528
	SE	0.497	0.447	0.638	0.577	0.497	0.548	0.346	0.462	0.577	–	1.421	0.8206
L. pseudoannulata	*N. lugens*	8.60	8.40	10.00	10.80	9.60	9.60	9.80	11.40	7.20	8.40	93.80	38.10
	S. furcifera	9.00	9.20	10.20	12.00	10.80	11.00	9.40	11.60	7.80	9.00	100.00	32.20
	Nephotettix sp.	9.20	9.20	12.60	12.60	11.40	12.40	12.80	12.00	8.00	9.40	109.60	24.50
	CD(0.05)			2.250	1.378		1.509	1.530				7.400	3.1950
	SE	0.497	0.447	0.730	0.447	0.594	0.489	0.497	0.638	0.599	0.374	2.401	1.0368

*Mean of five replications

I to IV instar - Nymphs of pests given as prey   V instar to Adult - Adults of pests given as prey

(8.80 days) which were on par. Statistically, no significant difference was seen in the duration of eighth and ninth instars of *T. maxillosa*. The duration of these instars ranged from 7.40 to 8.20 days and 7.00 to 8.80 days respectively.

The total duration of the nymphal instars of *T. maxillosa* was significantly reduced when reared on *Nephotettix* sp. (71.20 days). This was followed by the mean duration taken for its development when reared on *S. furcifera* (78.40 days) which was on par with *N. lugens* (79.60 days).

Maximum longevity was observed when adult *T. maxillosa* consumed *Nephotettix* sp. (22.50 days). Significantly shorter life span of *T. maxillosa* was seen when fed with *N. lugens* (16.40 days) and *S. furcifera* (15.90 days).

L. pseudoannulata

Duration of the first and second instars of *L. pseudoannulata* did not vary significantly when reared on nymphs of *N. lugens*, *S. furcifera* and *Nephotettix* sp. (Table 40). The mean number of days taken for completion of the instars ranged from 8.60 to 9.20 and 8.40 to 9.20 respectively. The third instar was completed in a mean number of ten days when it consumed *N. lugens*. This was closely followed by the mean number of days taken when reared on *S. furcifera* (10.20 days). A longer time was taken for the completion of the third instar when *Nephotettix* sp. was the prey, the mean number of days taken being 12.60 days. Duration of the fourth instar of the spider on the three prey differed significantly. A mean number of 10.80 days was required for completion of the instar when *N. lugens* was the prey followed by 12.00 days on *S. furcifera* and 12.60 days on *Nephotettix* sp.

The duration of the fifth instar did not differ significantly on different prey, the mean number of days taken ranging from 9.60 to 11.40. The period taken for the completion of sixth and seventh instars of the spiderlings on the different prey differed significantly. Only 9.60 days were taken to complete the development of the sixth instar when *L. pseudoannulata* was reared on *N. lugens*. The spiderlings reared on *S. furcifera* and *Nephotettix* sp. required a mean number of 11.00 and 12.40 days respectively for completion of the instar. The mean number of days required for the seventh instar was on par when reared on *S. furcifera* (9.40 days) and *N. lugens* (9.80 days) whereas on *Nephotettix* sp., it had a significantly longer duration (12.80 days). No significant difference was seen in the period taken for the completion of eighth, ninth and tenth instars and the mean number of days ranged from 11.40 to 12.00, 7.20 to 8.00 and 8.40 to 9.40 days respectively. Considering the total duration of the instars, shortest period was noted when reared on *N. lugens* followed by *S. furcifera*, the mean number of days being 93.80 and 100.00 respectively. Longer period was taken for completion of the instars on *Nephotettix* sp., the mean number of days required being 109.60.

Adult longevity was maximum when *L. pseudoannulata* consumed *N. lugens* (38.10 days) followed by *S. furcifera* (32.20 days). Longevity of the adults was significantly reduced, when reared on *Nephotettix* sp., the mean number of days being 24.50.

4.2.3 Number of Prey Consumed by Insect Predators

C. lividipennis

The first instar nymphs of *C. lividipennis* did not feed on any of the prey supplied (Table 41). During the second instar, the predator consumed a mean number of 8.60 first instar *N. lugens* which was significantly higher than the number of first instar *S. furcifera* (5.40) and *Nephotettix* sp. (4.20) preyed. Similarly, more number of first instar *N. lugens* (5.20) were consumed by the third instar nymphs of *C. lividipennis* and it was significantly superior to the first instar *S. furcifera* (3.20) and *Nephotettix* sp. (2.80) consumed. The mean consumption of the latter two prey was on par. The same trend was observed in the number of prey consumed during the fourth instar. Significantly higher number of first instar *N. lugens* (4.40) followed by *S. furcifera* (2.80) and *Nephotettix* sp. (2.40) were preyed on by the fourth instar. The latter two were on par. The fifth instar of *C. lividipennis* consumed a mean number of 7.40 first instar *N. lugens*. This was

Table 41 Number of prey consumed by *Cyrtorhinus lividipennis* and *Micraspis discolor* during their developmental period

Predators	**Prey**	Number of prey consumed						
		Nymphal instars of the predator*						
		I	II	III	IV	V	Total (II-V)	Adult
C. lividipennis	1st instar *N. lugens*		8.60	5.20	4.40	7.40	25.60	63.40
	1st instar *S. furcifera*		5.40	3.20	2.80	2.40	13.80	36.40
	1st instar *Nephotettix* sp.		4.20	2.80	2.40	1.60	11.00	17.60
	CD (0.05)		1.067	1.283	1.207	1.233	1.949	6.652
	SE		0.346	0.416	0.392	0.400	0.632	2.159
		Nymphal instars of the predator*					Total (I – IV)	Adult
		I	II	III	IV	Pupa		
M. discolor	Eggs of *M. discolor*	1.20	3.80	5.60	10.60	–	21.20	76.20
	2nd instar *N. lugens*	0.00	2.80	4.20	5.80	–	12.80	65.80
	2nd instar *S. furcifera*	0.00	1.40	3.00	6.20	–	10.60	48.60
	CD (0.05)		1.037	1.488	2.278	–	3.153	11.753
	SE	0.1155	0.337	0.483	0.739	–	1.023	3.814

*Mean of five replications

followed by the consumption of first instar *S. furcifera* (2.40) and *Nephotettix* sp. (1.60) which were on par.

Significant difference was observed in the total number of prey consumed during the nymphal period of *C. lividipennis* when different prey were supplied. While a mean number of 25.60 first instar nymphs of *N. lugens* was consumed during the period, only 13.80 *S. furcifera* and 11.00 *Nephotettix* sp. were consumed.

Significant difference was also noted in the mean number of different prey consumed by the adult *C. lividipennis* during its life span. Compared with other prey, the total number of first instar *N. lugens* (63.40) consumed was significantly superior. This was followed by the consumption of first instar *S. furcifera* (36.40). *Nephotettix* sp. (17.60) was the least consumed prey. All the treatments were significantly different.

M. discolor

The first instar grubs of *M. discolor* preyed only on its eggs (1.20). It did not feed on the second instar nymphs of *N. lugens* and *S. furcifera* (Table 41). During the second instar, the consumption of the different prey by *M. discolor* differed significantly. The grubs fed on significantly higher number of eggs of *M. discolor* (3.80). The mean number of second instar nymphs of *N. lugens* and *S. furcifera* consumed by the grubs were 2.80 and 1.40 respectively. The third instar grubs too consumed more number of eggs of *M. discolor*, the mean number of eggs consumed being 5.60 and it was significantly superior to the second instar nymphs of *N. lugens* (4.20) and *S. furcifera* (3.00) consumed. The fourth instar grubs of *M. discolor* consumed a mean number of 10.60 eggs which again was significantly superior to the other prey eaten. The mean number of second instar *S. furcifera* and *N. lugens* consumed were 6.20 and 5.80 respectively and they were on par.

Significant difference was observed in the total number of different prey consumed during the development period of *M. discolor.* The nymphal instars of *M. discolor* devoured significantly more number of its eggs (21.20) than the other two prey tested *viz.*, second instar nymphs of *N. lugens* (12.80) and *S. furcifera* (10.60). The latter two were on par.

The adults of *M. discolor* too consumed significantly more number of its eggs (76.20). This was closely followed by 65.80 second instar *N. lugens* and consumption of these two prey was on par. An average of 48.60 second instar nymphs of *S. furcifera* were eaten by adult *M. discolor* during its life span.

4.2.4 Number of Prey Consumed by Spider Predators

T. maxillosa

The mean number of prey consumed by the different nymphal instars of *T. maxillosa* during their developmental period and in the adult stage are presented in Table 42.

The second instar of *T. maxillosa* consumed significantly higher number of *Nephotettix* sp. (8.00). The mean number of *S. furcifera* and *N. lugens* consumed were 4.40 and 4.00 respectively and they were on par. During the third instar too, a significant difference was observed in the number of different prey consumed. More number of *Nephotettix* sp. (14.40) were consumed by the spiderlings followed by *S. furcifera* (7.80) and *N. lugens* (5.20). A similar difference was noted in the mean number of prey eaten by the fourth instar spiderlings. Significantly more number of *Nephotettix* sp. (18.20) were consumed compared to the number of *S. furcifera* (13.20) and *N. lugens* (7.00) eaten.

In the fifth instar, maximum consumption of prey was recorded in *Nephotettix* sp. treatment, the number eaten being 21.00 adults per spiderling. The mean number of *S. furcifera* fed was 15.40 per spiderling followed by *N. lugens* (12.20). Significantly higher number of *Nephotettix* sp. (22.40) was

Table 42. Number of prey consumed by *Tetragnatha maxillosa* and *Lycosa pseudoannulata* during their developmental period

Predator	Prey	Number of prey consumed per spider*										
		II	III	IV	V	VI	VII	VIII	IX	X	Total	
											II to IX	Adults
T. maxillosa	*N. lugens*	4.00	5.20	7.00	12.20	17.00	22.20	19.40	17.00	–	104.00	27.60
	S. furcifera	4.40	7.80	13.20	15.40	18.60	20.80	22.20	15.40	–	117.80	26.50
	Nephotettix sp.	8.00	14.40	18.20	21.00	22.40	24.40	28.00	21.40	–	157.80	31.00
	CD (0.05)	1.331	1.814	2.236	2.869	2.591		4.248	3.523	–	14.142	
	SE	0.4320	0.5887	0.7257	0.9309	0.8406	1.5958	1.3784	1.1430	–	4.5891	1.7371
											II to X	Adults
L. pseudoannulata	*N. lugens*	7.00	10.60	12.80	11.00	15.20	20.00	52.80	65.60	47.60	242.60	54.00
	S. furcifera	3.20	4.40	7.80	13.40	20.60	31.40	43.20	45.00	34.80	203.80	47.60
	Nephotettix sp.	2.80	3.60	6.00	7.80	10.80	14.00	19.40	18.80	15.80	99.00	31.20
	CD (0.05)	1.933	1.467	2.374	2.578	2.603	4.307	5.776	5.367	7.451	11.461	5.534
	SE	0.6271	0.4761	0.7702	0.8367	0.8446	1.3976	1.8743	1.7416	2.4179	3.7193	1.7962

*Mean of five replications

II to IV instar - Nymphs of pests given as prey   V instar to Adult - Adults of pests given as prey consumed by sixth instar of *T. maxillosa* also, followed by *S. furcifera* (18.60) and *N. lugens* (17.00) which were on par. Significant variation was not seen in the consumption of the different prey by the seventh instar. The mean number of different prey consumed during the instar varied from 20.80 to 24.40 per spider. The consumption of *Nephotettix* sp. was significantly higher during the eighth instar of *T. maxillosa* (28.00) followed by *S. furcifera* (22.20) and *N. lugens* (19.40). During the last nymphal instar also, consumption of *Nephotettix* sp. was significantly higher (21.40). The least consumed prey was *S. furcifera* (15.40). The mean number of *N. lugens* consumed was 17.00 and they were on par.

The total prey consumed during the different instars of spiderlings of *T. maxillosa* showed significant difference among the three prey tested. The spiderlings consumed more number of *Nephotettix* sp. (157.80), followed by *S. furcifera* (117.80) and *N. lugens* (104.00) which were on par.

No significant difference was seen in the mean number of the different prey consumed by the adult spider, the mean number of *Nephotettix* sp., *N. lugens* and *S. furcifera* consumed being 31.00, 27.60 and 26.50 respectively during its adult life span.

L. pseudoannulata

The second instar spiderlings of *L. pseudoannulata* consumed significantly higher number of *N. lugens* (7.00) followed by *S. furcifera* (3.20) and *Nephotettix* sp. (2.80) which were on par (Table 42). A similar trend was seen during the third instar also. The mean number of *N. lugens* consumed was significantly higher (10.60) compared to the other prey. The mean number of *S. furcifera* and *Nephotettix* sp. consumed were 4.40 and 3.60 respectively and they were on par. A similar trend was seen in the mean consumption of prey during the fourth instar. The consumption of *N. lugens* (12.80) was significantly higher followed by *S. furcifera* (7.80) and *Nephotettix* sp. (6.00) which were on par.

In the fifth instar, the mean number of *S. furcifera* and *N. lugens* eaten by the spiderlings were on par, the mean number consumed being 13.40 and 11.00 respectively. *Nephotettix* sp. was also consumed by the spiderlings, the number fed on, being significantly less (7.80). The mean number of prey consumed during the sixth instar differed significantly for the different prey. Significantly higher numbers of *S. furcifera* (20.60) was consumed. This was followed by *N. lugens* (15.20) and *Nephotettix* sp. (10.80) which differed significantly. The same trend was seen in the seventh instar also. Significantly higher number of *S. furcifera* (31.40) was fed on by the spiderlings followed by *N. lugens* (20.00) and *Nephotettix* sp. (14.00) for completion of the instar. During the eighth instar of *L. pseudoannulata,* the spiderlings consumed significantly higher number of *N. lugens,* the mean number being, 52.80 per spider compared to *S. furcifera* (43.20) and *Nephotettix* sp. (19.40). The ninth instar spiderlings consumed significantly maximum number of *N. lugens* (65.60) and it differed significantly from the mean number of *S. furcifera* (45.00) and *Nephotettix* sp. (18.80) consumed. During the final instar, the prey consumption was reduced when compared to the ninth instar; 47.60 *N. lugens*, 34.80 *S. furcifera* and 15.80 *Nephotettix* sp. were eaten in the tenth instar. All the treatments differed significantly.

The total prey consumed during the nymphal instars of *L. pseudoannulata* differed significantly with the various prey. The spiderlings of *L. pseudoannulata* devoured more number of *N. lugens* (242.60) followed by *S. furcifera* (203.80). *Nephotettix* sp. (99.00) was the least consumed prey during the entire period of development.

The mean number of prey consumed by the adult *L. pseudoannulata* during its life span was maximum for *N. lugens* (54.00) followed by *S. furcifera* (47.60) and *Nephotettix* sp. (31.20) which were significantly different.

4.3 EFFICIENCY OF PREDATORS IN SUPPRESSING PLANT AND LEAFHOPPERS OF RICE

4.3.1 Searching Capacity

Among the predators tested, *C. lividipennis* exhibited better ability to search for plant and leafhoppers as indicated by the area of discovery (0.406) (Table 43). This was followed by *M. discolor* (0.319) and *L. pseudoannulata* (0.277) which were on par. Comparatively the searching capacity of *T. maxillosa* for the hoppers was low (0.173).

Regarding the prey searched, *N. lugens* was the most sought after prey by the predators as indicated by the mean 'area of discovery' of the different predators (0.443) followed by *S. furcifera* (0.315). *Nephotettix* sp. (0.194) and *R. dorsalis* (0.223) were on par in the rate at which they were attacked.

Considering the efficiency of individual predators, the searching capacity of *C. lividipennis* was significantly high for *N. lugens* (0.784). The searching capacity of the predator for the other pests was statistically on par, the area of discovery ranging from 0.211 to 0.368.. A similar trend was seen in the searching capacity of *M. discolor*. While the area of discovery was 0.629 for *N. lugens*, it was only 0.264 for *S. furcifera*, 0.145 for *Nephotettix* sp. and 0.240 for *R. dorsalis*.

The searching capacity of *T. maxillosa* was the same for each of the prey, the 'area of discovery' ranging from 0.123 to 0.211. However, *L. pseudoannulata* had a greater preference for *S. furcifera* and its searching capacity for the pest was significantly superior (0.429) to that of the other pests. The searching capacity for the other pests *viz.*, *N. lugens, Nephotettix* sp. and *R. dorsalis* was on par, their area of discovery being 0.235, 0.209 and 0.235 respectively.

Regarding the prey searched, *N. lugens* was significantly better searched by *C. lividipennis* and *M. discolor* as indicated by the area of discovery being 0.784

Table 43. Searching capacity of major insect and spider predators of plant and leafhoppers of rice

Predators	Area of discovery				Mean
	Prey				
	N. lugens	*S. furcifera*	*Nephotettix* sp.	*R. dorsalis*	
*C. lividipennis**	0.784	0.368	0.211	0.260	0.406
*M. discolor***	0.629	0.264	0.145	0.240	0.319
T. maxillosa	0.123	0.119	0.211	0.157	0.173
L. pseudoannulata	0.235	0.429	0.209	0.235	0.277
Mean	0.443	0.315	0.194	0.223	

CD (0.05) : Predator : 0.0803 Prey : 0.0803 Interaction : 0.1606

* 1^{st} instar nymphs of prey tested

** 2^{nd} instar nymphs of prey tested and 0.629 respectively. Comparatively they were less searched by the two spiders as indicated by the significantly lower area of discovery (0.235 and 0.123) and they were on par. Considering *S. furcifera, L. pseudoannulata* (0.429) and *C. lividipennis* (0.368) searched better for the prey and were significantly superior to *M. discolor* (0.264) and *T. maxillosa* (0.119). Both the predators, *M. discolor* and *T. maxillosa* were on par.

Nephotettix sp. was equally preferred by both the spiders and insect predators, their 'area of discovery' ranging from 0.145 to 0.211. Similarly, *R. dorsalis* was also equally searched by the insect and spider predators with the area of discovery of the predators being 0.260, 0.240, 0.235 and 0.157 for *C. lividipennis*, *M. discolor, L. pseudoannulata* and *T. maxillosa* respectively.

4.3.2 Feeding Potential

Results of the studies conducted on the feeding potential of the two insect predators and two spiders found predominantly in rice ecosystems of Kerala are presented in Tables 44 and 45.

4.3.2.1 Insect Predators

Among the prey *viz.*, first instar nymphs of *N. lugens, S. furcifera* and *Nephotettix* sp. provided, *C. lividipennis* preyed on significantly higher number of the first instar nymphs of *N. lugens* the mean number of nymphs eaten being 40.40 over a period of seven days (Table 44). A significantly lower number of first instar nymphs of *S. furcifera* (25.00) and *Nephotettix* sp. (13.40) were consumed by *C. lividipennis*.

M. discolor preferred its eggs to second instar *N. lugens* and *S. furcifera* when tested for its feeding potential. The mean number of eggs consumed was significantly higher, being 20.40. The mean number of second instar nymphs of *N. lugens* and *S. furcifera* preyed upon was significantly lower being 13.60 and 12.00 respectively and statistically these were on par.

Table 44 Feeding potential of *Cyrtorhinus lividipennis* and *Micraspis discolor*

(Mean number consumed in 7 days)*

Predator	**Prey**			CD (0.05)	SE
	1st instar *N. lugens*	1st instar *S. furcifera*	1st instar *Nephotettix* sp.		
C. lividipennis	40.40	25.00	13.40	3.986	1.293
	Eggs of *M. discolor*	2nd instar *N. lugens*	2nd instar *S. furcifera*		
M. discolor	20.40	13.60	12.00	3.567	1.157

Table 45 Feeding potential of *Tetragnatha maxillosa* and *Lycosa pseudoannulata*

(Mean number consumed in 7 days)*

Spiders	**Prey**			Mean
T. maxillosa	*N. lugens*	*S. furcifera*	*Nephotettix* sp.	
Male	11.20	13.60	15.20	13.33
Female	13.60	16.80	18.00	16.13
Mean	12.40	15.20	16.60	14.73
L. pseudoannulata				
Male	25.20	19.40	15.60	20.07
Female	28.00	25.00	18.40	23.80
Mean	26.60	22.20	17.00	21.93
Mean	19.50	18.60	16.80	

CD (0.05)

(Pd) Predator	:	1.27	Pd Pr	:	2.21
(S) Sex	:	1.27	S Pr	:	2.21
Pd S	:	1.80	Pd S Pr	:	3.12
(Pr) Prey	:	1.56			

*Mean of five replications

4.3.2.2 Spider Predators

Between the two spiders, *L. pseudoannulata* was observed to be a significantly better predator of hoppers in rice ecosystem (Table 45), preying on a mean number of 21.93 hoppers over a period of seven days compared to 14.73 hoppers consumed by *T. maxillosa*. Between the sexes, the females of the spiders (19.97) consumed significantly more number of hoppers than the males (16.70).

Among the hoppers, both *N. lugens* and *S. furcifera* were equally preyed on by the araenophages, the mean number of hoppers preyed being 19.50 and 18.60 per spider per seven days respectively and they were significantly superior to *Nephotettix* sp. (16.80 per spider per seven days).

Considering the predatory potential of the individual spiders, *T. maxillosa* consumed maximum number of *Nephotettix* sp. (16.60 per spider per seven days) closely followed by *S. furcifera* (15.20 per spider per seven days). Statistically they were on par. *N. lugens* was least consumed, being 12.40 per spider over a period of seven days. Though the feeding potential of the females of *T. maxillosa* was higher (13.60 *N. lugens*, 16.80 *S. furcifera* and 18.00 *Nephotettix* sp. per spider per seven days) than the males (11.20 *N. lugens*, 13.60 *S. furcifera* and 15.20 *Nephotettix* sp. per spider per seven days), significant difference was observed only in the consumption of *Nephotettix* sp. However, generally females of *T. maxillosa* showed significant preference for hoppers (16.13) than males (13.33).

On the other hand, the feeding potential of *L. pseudoannulata* was significantly high for *N. lugens*, the number consumed being 26.60 per spider per seven days. This was followed by *S. furcifera* (22.20) which was statistically superior to the third prey *viz.*, *Nephotettix* sp. (17.00 per spider per seven days). As in the case of *T. maxillosa,* though the females of *L. pseudoannulata* consumed more number of the hoppers (28.00 *N. lugens*, 25.00 *S. furcifera* and 18.40 *Nephotettix* sp.) than the males (25.20 *N. lugens,* 19.40. *S. furcifera* and 15.60

Nephotettix sp.), significant difference was observed only in the consumption of *N. lugens*. Generally, females of *L. pseudoannulata* preyed on a significantly higher number of hoppers (23.80) than males (20.07).

4.3.3 Prey Preference

4.3.3.1 Insect predators

The mirid bug, *C. lividipennis* preferred first instar nymphs of *N. lugens* (23.40 nymphs per mirid per seven days) to *S. furcifera* (9.80 nymphs per mirid per seven days) and *Nephotettix* sp. (3.80 nymphs per mirid per seven days) when a mixed diet of the hoppers was given (Table 46). The preference for *N. lugens* in the mixed population was significantly superior to preference for *S. furcifera* and *Nephotettix* sp. Similarly, compared to *Nephotettix* sp., *C. lividipennis* preferred significantly more *S. furcifera* for consumption.

M. discolor showed significantly distinct preference for its eggs (20.20 eggs per adult per seven days) when exposed to a mixed diet consisting of its eggs and second instar nymphs of *N. lugens* and *S. furcifera* over a period of seven days. Between *N. lugens* and *S. furcifera,* adults of the coccinellid predator showed significantly greater preference for the second instar nymphs of *N. lugens* (13.20 adults per seven days) than second instar nymphs of *S. furcifera* (8.40 adults per seven days).

4.3.3.2 Spider Predators

When a mixed diet of three prey *viz.*, *N. lugens, S. furcifera* and *Nephotettix* sp. was given, *L. pseudoannulata* consumed significantly more number of prey, the average number of total prey consumed being 39.00 per adult spider per seven days (Table 47). *T. maxillosa* ate only a mean number of 18.40 hoppers per adult per seven days. Between the sexes, female of the spiders consumed significantly more number of hoppers (29.70 per female per seven days) (mean of 18.80 + 40.60) than the males, (27.70 per male per seven days) (mean of 18.00 + 37.40). When the spiders were considered individually, there was no significant difference in the total number of hoppers consumed by the

Table 46 Relative preference of *Cyrtorhinus lividipennis* and *Micraspis discolor* for different prey in a mixed diet

(Mean number consumed in 7 days)*

Predator	Prey			CD (0.05)	SE
	1st instar *N. lugens*	1st instar *S. furcifera*	1st instar *Nephotettix* sp.		
C. lividipennis	23.40	9.80	3.80	2.541	0.824
	Eggs of *M. discolor*	2nd instar *N. lugens*	2nd instar *S. furcifera*		
M. discolor	20.20	13.20	8.40	4.515	1.465

Table 47 Relative preference of *Tetragnatha maxillosa* and *Lycosa pseudoannulata* for different prey in a mixed diet

(Mean number consumed in 7 days)*

Spiders	Prey			Total No. of hoppers
T. maxillosa	*N. lugens*	*S. furcifera*	*Nephotettix* sp.	
Male	4.20	5.40	8.40	18.00
Female	4.60	4.20	10.00	18.80
Mean	4.40	4.80	9.20	18.40
L. pseudoannulata				
Male	20.20	11.80	5.40	37.40
Female	22.80	13.20	4.60	40.60
Mean	21.50	12.50	5.00	39.00
Mean	12.95	8.65	7.10	

CD (0.05) (Pd) Predator : 1.03 (Pr) Prey : 1.26 (S) Sex : 1.03

Pd S : 1.46 Pd Pr : 1.78 S Pr : 1.78

Pd S Pr : 2.52 *Mean of five replications different sexes of *T. maxillosa* (18.80 per female and 18.00 per male). On the contrary, a significant difference was observed in the number of hoppers eaten by the females (40.60 per female per seven days) and males (37.40 per male per seven days) of *L. pseudoannulata*.

Among the prey, the spiders preferred *N. lugens* followed by *S. furcifera* and *Nephotettix* sp. as indicated by the mean number of the hoppers consumed (12.95, 8.65 and 7.10 per spider per seven days, respectively). Considering the prey preference of the individual spiders, while a similar trend was noticed in the case of *L. pseudoannulata,* the number of hoppers fed on being 21.50, 12.50 and 5.00 per seven days respectively, *T. maxillosa* showed a significant preference for the green leafhoppers, the number consumed in seven days being 9.20 per spider. No significant difference was seen in the number of *N. lugens* (4.40 hoppers) and *S. furcifera* (4.80 hoppers) consumed.

When supplied with a mixed diet of different hoppers, both sexes of *T. maxillosa* showed significantly higher preference for green leafhoppers, *Nephotettix* sp., the mean number consumed being 8.40 per male and 10.00 per female per seven days. The preference for *S. furcifera* (5.40 per male and 4.20 per female per seven days) and *N. lugens* (4.20 per male and 4.60 per female) was on par. *L. pseudoannulata* showed a definite preference for *N. lugens* (20.20 per male and 22.80 per female per seven days) and a significantly lesser preference for *S. furcifera* (11.80 per male and 13.20 per female per seven days). The least preferred prey in the mixed diet was *Nephotettix* sp. (5.40 per male and 4.60 per female per seven days).

4.3.4 Hyperpredatory Activity of Insect and Spider Predators

Results of the study on hyperpredatory activity of the dominant insect and spider predators seen in rice ecosystem are presented in Table 48. The three insect predators, *viz.*, *O. nigrofasciata, C. lividipennis* and *M. discolor* exhibited neither cannibalism nor hyperpredatory activity towards other insect or spider predators. Studies on cross predation

Table 48 Hyperpredatory activity of dominant predators in rice ecosystem, %

Predators	'Predator prey'									
	Insect predators						Spider predators			
Insect	*Cyrtorhinus lividipennis*	*Micraspis discolor*	*Ophionea nigrofasciata*	*Crocothemis* sp.	*Agriocnemis* sp.	*Polytoxus fuscovitattus*	*Tetragnatha maxillosa*	*Lycosa psuedoann-ulata*	*Oxyopes* sp.	*Atypena formosana*
Cyrtorhinus lividipennis	*	*	*	*	*	*	*	*	*	*
Micraspis discolor	*	*	*	*	*	*	*	*	*	*
Ophionea nigrofasciata	*	*	*	*	*	*	*	*	*	*
Crocothemis sp.	50	*	*	*	*	*	20	*	10	*
Agriocnemis sp.	30	*	*	*	*	*	*	*	*	*
Polytoxus fuscovitattus	*	30	*	*	*	*	*	*	*	*
Spider										
Tetragnatha maxillosa	70	*	*	*	30	*	*	*	*	*
Lycosa pseudoannulata	90	*	*	*	*	*	*	*	*	*
Oxyopes sp.	60	*	*	*	*	*	*	*	*	30
Atypena formosana	*	*	*	*	*	*	*	*	*	*

* No hyper predatory activity

between dragonflies and other predators revealed that maximum predation of adult dragonfly (*Crocothemis* sp.) was on *C. lividipennis* (50 per cent), followed by *T. maxillosa* (20 per cent) and *Oxyopes* sp. (10 per cent). No hyperpredatory activity was exhibited towards other predators tested, *viz.*, *Agriocnemis* sp., *P. fuscovittatus, M. discolor, O. nigrofasciata, L. pseudoannulata* and *A. formosana. Crocothemis* sp. did not consume its own species indicating the absence of cannibalism.

Agriocnemis sp. when tested with other predators, consumed only the adults of *C. lividipennis*, the percentage of hyperpredation being 30. Similarly, the reduviid, *P. fuscovittatus* also showed feeding preference for *M. discolor* only (30 per cent).

Considering the hyperpredatory activity of the spider predators, *T. maxillosa* consumed both *C. lividipennis* (70 per cent) and *Agriocnemis* sp. (30 per cent) the maximum consumption being for *C. lividipennis*. On the other hand *L. pseudoannulata* showed high cross predation for *C. lividipennis* (90 per cent). *Oxyopes* sp. also consumed two predators *viz., C. lividipennis* and *A. formosana*, the percentage of predation being 60 and 30 respectively.

Neither the other insect predators nor the spider predators were cross predated upon by *L. pseudoannulata. A. formosana* did not show any hyper predation. None of the spiders showed cannibalism.

Among the various predators tested as prey, the mirid bug, *C. lividipennis* was the only species which was preferred for cross predation by a number of other predators, the percentage of predation ranging from 30 to 90 per cent. The other 'predator prey' *viz., M. discolor* and *Agriocnemis* sp. and 'spider predator prey' *viz., T. maxillosa, Oxyopes* sp. and *A. formosana* were preferred for hyperpredation by only one predator each.

4.4 TOXICITY OF INSECTICIDES TO PREDATORS

The toxicity of carbaryl, phosphamidon, monocrotophos, quinalphos and methyl parathion to various predators are presented in Tables 49 to 53.

C. lividipennis

Among the insecticides tested, carbaryl with a LC_{50} value of 0.0075 per cent was observed to be least toxic to *C. lividipennis* at 24 HAT followed by phosphamidon (LC_{50} 0.0064 per cent)(Table 49). Monocrotophos (LC_{50} 0.0047 per cent) and methyl parathion (LC_{50} 0.0033 per cent) were more toxic. Quinalphos (LC_{50} 0.0025 per cent) was the most toxic insecticide to the predator. The same trend of toxicity was noticed at 48 HAT also. Carbaryl (0.0061 per cent) was the least toxic insecticide followed by phosphamidon (0.0049 per cent), monocrotophos (0.0039 per cent), methyl parathion (0.0030 per cent) and quinalphos (0.0019 per cent).

The toxicity of carbaryl, phosphamidon, monocrotophos and methyl parathion to *C. lividipennis* when assessed in comparison to quinalphos showed that the insecticides were 0.3333 to 0.7576 and 0.3115 to 0.6333 times less toxic than quinalphos at 24 HAT and 48 HAT respectively.

M. discolor

The results presented in Table 50 indicated that carbaryl (LC_{50} 0.0149 per cent) and phosphamidon (LC_{50} 0.0144 per cent) were less toxic to *M. discolor* at 24 HAT. Methyl parathion (LC_{50} 0.0089 per cent), quinalphos (LC_{50} 0.0058 per cent) and monocrotophos (LC_{50} 0.0046 per cent) showed greater toxicity to the predator. At 48 HAT, phosphamidon (LC_{50} 0.0121 per cent) proved least toxic followed by carbaryl (LC_{50} 0.0094 per cent). As at 24 HAT, greater toxicity was observed with methyl parathion (LC_{50} 0.0062 per cent), quinalphos (LC_{50} 0.0042 per cent) and monocrotophos (LC_{50} 0.0041 per cent).

Table 49 Dose response relationship and toxicity of different insecticides to *Cyrtorhinus lividipennis*

Insecticides	24 HAT				48 HAT			
	Heterogenity χ^2	Regression equation	$LC_{50} \pm$ SE %	Relative toxicity	Heterogenity χ^2	Regression equation	$LC_{50} \pm$ SE %	Relative toxicity
Carbaryl	2.48	Y=1.3881 X+7.9515	0.0075±0.00147	0.3333	2.90	Y=1.4734 X+8.2658	0.0061±0.00126	0.3115
Phosphamidon	4.76	Y=1.6929 X+8.7132	0.0064±0.00144	0.3906	4.59	Y=1.7363 X+9.0121	0.0049±0.00094	0.3878
Monocrotophos	3.04	Y=1.3365 X+8.1116	0.0047±0.00095	0.5319	3.96	Y=1.5098 X+8.6445	0.0039±0.00079	0.4872
Quinalphos	4.19	Y=1.2966 X+8.3824	0.0025±0.00053	1.0000	2.58	Y=1.3110 X+8.5621	0.0019±0.00042	1.0000
Methyl parathion	1.72	Y=1.3965 X+8.4681	0.0033±0.00066	0.7576	1.80	Y=1.6059 X+9.0298	0.0030±0.00062	0.6333

Y = Probit X = Log dose

Table 50 Dose response relationship and toxicity of different insecticides to *Micraspis discolor*

Insecticides	24 HAT				48 HAT			
	Heterogenity χ^2	Regression equation	$LC_{50} \pm$ SE %	Relative toxicity	Heterogenity χ^2	Regression equation	$LC_{50} \pm$ SE %	Relative toxicity
Carbaryl	6.34	Y=1.1324 X+7.0691	0.0149±0.00309	0.3893	4.07	Y=1.1978 X+7.461	0.0094±0.00199	0.4468
Phosphamidon	8.10	Y=1.7668 X+8.2515	0.0144±0.00238	0.4028	8.55	Y=1.7537 X+8.3638	0.0121±0.00210	0.3471
Monocrotophos	8.56	Y=1.9259 X+9.5062	0.0046±0.00072	1.2609	5.15	Y=1.5865 X+8.7891	0.0041±0.00075	1.0240
Quinalphos	3.33	Y=1.2814 X+7.8637	0.0058±0.00115	1.0000	4.46	Y=1.4042 X+8.3351	0.0042±0.00083	1.0000
Methyl parathion	4.11	Y=1.1622 X+7.3821	0.0089±0.00185	0.6517	5.97	Y=1.1997 X+7.6453	0.0062±0.00134	0.6770

Y = Probit   X = Log dose

Regarding the relative toxicity of the insecticides to *M. discolor* when compared to quinalphos, monocrotophos was observed to be 1.2609 and 1.0240 times more toxic at 24 and 48 HAT respectively. Carbaryl, phosphamidon and methyl parathion were 0.3893 to 0.6517 and 0.3471 to 0.6770 times less toxic than quinalphos at 24 and 48 HAT respectively.

T. maxillosa

Among the insecticides tested, methyl parathion (LC_{50} 0.0089 per cent) appeared least toxic to *T. maxillosa* 24 HAT (Table 51). The other insecticides in the increasing order of toxicity were carbaryl (0.0072 per cent), monocrotophos (0.0070 per cent), quinalphos (0.0054 per cent) and phosphamidon (0.0038 per cent). Carbaryl (0.0057 per cent) and methyl parathion (0.0052 per cent) were less toxic to the spider at 48 HAT followed by monocrotophos (0.0038 per cent), quinalphos (0.0037 per cent) and phosphamidon (0.0035 per cent).

Considering the relative toxicity of these insecticides in relation to quinalphos, phosphamidon was found to be 1.4211 and 1.0571 times more toxic at 24 and 48 HAT respectively. The other insecticides, monocrotophos (0.7714 and 0.9737), carbaryl (0.7500 and 0.6491) and methyl parathion (0.6067 and 0.7115) were less toxic than quinalphos.

***Agriocnemis* sp.**

Carbaryl (LC_{50}, 0.0079 per cent, 0.0060 per cent) and quinalphos (LC_{50} 0.0071 per cent, 0.0051 per cent) were comparatively less toxic to *Agriocnemis* sp. when observed at 24 and 48 HAT (Table 52). Monocrotophos (LC_{50} 0.0043 per cent and 0.0040 per cent), methyl parathion (LC_{50} 0.0034 per cent and 0.0027 per cent) and phosphamidon (LC_{50} 0.0033 per cent and 0.0031 per cent) were more toxic to the predator.

Compared to quinalphos, the check insecticide, phosphamidon, methyl parathion and monocrotophos were respectively 2.1515, 2.0882 and 1.6512

Table 51 Dose response relationship and toxicity of different insecticides to *Tetragnatha maxillosa*

Insecticides	24 HAT				48 HAT			
	Heterogenity χ^2	Regression equation	$LC_{50} \pm$ SE %	Relative toxicity	Heterogenity χ^2	Regression equation	$LC_{50} \pm$ SE %	Relative toxicity
Carbaryl	3.94	Y=1.4287 X+8.0572	0.0072±0.00134	0.7500	4.23	Y=1.6035 X+8.6009	0.0057±0.00103	0.6491
Phosphamidon	2.09	Y=1.9668 X+9.7591	0.0038±0.00059	1.4211	3.03	Y=2.1314 X+10.2356	0.0035±0.00055	1.0571
Monocrotophos	2.08	Y=1.3806 X+7.9733	0.0070±0.00132	0.7714	2.67	Y=1.6317 X+8.9513	0.0038±0.00069	0.9737
Quinalphos	4.40	Y=1.4818 X+8.3583	0.0054±0.00098	1.0000	4.27	Y=1.4463 X+8.5219	0.0037±0.00071	1.0000
Methyl parathion	3.13	Y=1.4801 X+8.0335	0.0089±0.00162	0.6067	4.31	Y=1.5749 X+8.6025	0.0052±0.00095	0.7115

Y = Probit X = Log dose

Table 52 Dose response relationship and toxicity of different insecticides to *Agriocnemis* sp.

Insecticides	24 HAT				48 HAT			
	Heterogenity χ^2	Regression equation	$LC_{50} \pm$ SE %	Relative toxicity	Heterogenity χ^2	Regression equation	$LC_{50} \pm$ SE %	Relative toxicity
Carbaryl	4.51	Y=1.3844 X+7.9089	0.0079±0.00155	0.8987	3.60	Y=1.4499 X+8.2237	0.0060±0.00126	0.8500
Phosphamidon	3.18	Y=1.4947 X+8.7183	0.0033±0.00062	2.1515	1.31	Y=1.6991 X+9.2551	0.0031±0.00061	1.6450
Monocrotophos	2.80	Y=1.7222 X+9.0682	0.0043±0.00076	1.6512	1.63	Y=1.9054 X+9.5646	0.0040±0.00073	1.2750
Quinalphos	1.52	Y=1.5067 X+8.2371	0.0071±0.00134	1.0000	4.06	Y=1.5412 X+8.5319	0.0051±0.00104	1.0000
Methyl parathion	2.17	Y=1.3629 X+8.3689	0.0034±0.00068	2.0882	1.85	Y=1.5066 X+8.8614	0.0027±0.00057	1.8890

Y = Probit X = Log dose

(24 HAT) and 1.6450, 1.8890 and 1.2750 (48 HAT) times more toxic to the predator. Carbaryl was 0.8987 and 0.8500 times less toxic than quinalphos at 24 and 48 HAT.

O. nigrofasciata

The results (Table 53) indicated that monocrotophos (LC_{50} 0.0096 per cent), methyl parathion (LC_{50} 0.0087 per cent) and carbaryl (LC_{50} 0.0077 per cent) were less toxic to the predator at 24 HAT. Comparatively, quinalphos (LC_{50} 0.0047 per cent) and phosphamidon (LC_{50} 0.0047 per cent) were more toxic at 24 HAT. Similarly at 48 HAT methyl parathion (LC_{50} 0.0115 per cent) and carbaryl (LC_{50} 0.0063 per cent) were less toxic while monocrotophos, (LC_{50} 0.0048 per cent), phosphamidon (LC_{50} 0.0038 per cent) and quinalphos (LC_{50} 0.0027 per cent) were more toxic.

The relative toxicity studies indicated that only phosphamidon was as toxic as quinalphos at 24 HAT while at 48 HAT, it was 0.7105 times less toxic. Carbaryl, monocrotophos and methyl parathion were 0.6104, 0.4896 and 0.5402 (24 HAT) and 0.4286, 0.5625 and 0.2348 (48 HAT) times less toxic than quinalphos.

Table 53 Dose response relationship and toxicity of different insecticides to *Ophionea nigrofasciata*

Insecticides	24 HAT				48 HAT			
	Heterogenity χ^2	Regression equation	$LC_{50} \pm$ SE %	Relative toxicity	Heterogenity χ^2	Regression equation	$LC_{50} \pm$ SE %	Relative toxicity
Carbaryl	6.44	Y=1.0364 X+7.1882	0.0077±0.00139	0.6104	5.15	Y=1.2193 X+1.6826	0.0063±0.00116	0.4286
Phosphamidon	0.89	Y=0.9679 X+7.2517	0.0047±0.00094	1.0000	2.38	Y=1.1470 X+7.7781	0.0038±0.00075	0.7105
Monocrotophos	1.45	Y=1.0594 X+7.1386	0.0096±0.00192	0.4896	3.56	Y=1.0810 X+7.5093	0.0048±0.00096	0.5625
Quinalphos	3.16	Y=0.8247 X+6.9206	0.0047±0.00107	1.0000	2.45	Y=0.9489 X+7.4420	0.0027±0.00064	1.0000
Methyl parathion	3.27	Y=1.1211 X+7.4940	0.0087±0.00143	0.5402	3.49	Y=1.4571 X+7.8275	0.0115±0.00189	0.2348

Y = Probit X = Log dose

DISCUSSION

5. DISCUSSION

Rice cultivation in tropical Asia is presumed to have originated in Northeast Thailand nearly nine thousand years ago (Bray, 1986). Raising of this staple food in India dates back to five thousand years (Pasalu, 2003). The antiquity in the cultivation of the crop implies an intricate association of the arthropods in the paddy ecosystem with the crop. Under natural conditions, the tri-level interaction involving the plant, pest and natural enemy stabilizes the system. Any disturbance to this delicate balance, whether natural or induced, leads to spatial and temporal changes in the arthropod communities. Over the years, enormous changes occurred in the species composition and status of phytophages and entomophages. Two fundamental forces were mainly instrumental in effecting the change *viz*., environmental factors and human interference. With the onset of green revolution change in the faunal composition was magnified. Widespread adoption of high yielding varieties together with its associated agronomic practices and inevitable use of chemical pesticides not only aggravated pest problems but also led to significant changes in the status of different pests. Sucking pests emerged as a serious problem in most of the rice fields especially in the last two decades (Heinrichs and Mochida, 1984; Kenmore *et al*., 1984; Dahal and Neupane, 1990; Heong and Aquino, 1990; Roshansingh *et al*., 2000).

A major change was also observed in the occurrence and abundance of natural enemies in rice ecosystems. Population of parasitoids dwindled and was replaced by increasing population of predators. Predominance of predators paved the way for their exploitation and utilisation as potential biological control agents. In this context, araenophagy also emerged as an important regulatory mechanism of insect pests in rice ecosystems (Holt *et al*., 1987; Tanaka, 1989; Lee *et al*., 1993). Added to this, studies on temperature tolerance of insect predators like *C. lividipennis* and spiders indicated that while the spiders were more tolerant to high temperature, *C. lividipennis* was extremely susceptible. Apparently, global warming which will increase global temperature by 3 $\pm$ 1.5 ^{0}C within the next 40 years, might give a new dimension to the concept of an efficient predator (Heong and Domingo, 1992). High temperature tolerance will be a crucial factor in the exploitation of a bio-control agent in pest management.

Besides pests and natural enemies, other insects are also seen in rice ecosystems, which hitherto have been virtually ignored. Recently, the role these "non-pest and non-beneficial" play in rice ecosystem has been studied and documented. The neutral species of insects serve as abundant source of food for generalist predators early in the crop season, thus enabling the build up of population of predators to high levels even before pests appear. Such a pattern of early and independent build up of generalist natural enemies in rice ecosystems indicate that rice agro-ecosystems are intrinsically buffered and consistently protected from the damages of herbivores (Settle *et al.*, 1996).

In the global scenario of rice entomology, only limited information is available on predators in rice ecosystems of Kerala, their relative abundance and potential in pest management, neutrals and their role and the current status of pests. Even today management strategies are directed only against conventional major pests like yellow stem borer, brown plant hopper, gall fly, leaf roller, rice bug and case worm without proper assessment of their present status (KAU, 2002). Obviously, in the light of the recent concept of rice ecosystems (Settle *et al.*, 1996), more information on pests, their relative abundance, associated natural enemies and 'other insects' in the rice fields of Kerala is required for effective implementation of economically viable IPM strategies. With this view the present investigation was taken up to address the insufficiency in the understanding of the arthropod communities in rice ecosystems of the State, identify potential indigenous predators, explore possibilities of utilizing them for pest management and to review and update the present status of the pest species.

5.1 RELATIVE STATUS OF ENTOMOPHAGE - PHYTOPHAGE – NEUTRAL COMMUNITY IN RICE ECOSYSTEMS

Analysis of the entomophage-phytophage-neutral community in three heterogeneous ecosystems of Kerala during two consecutive seasons at 30, 50 and 70 DAT revealed the dominance of pests in Kuttanadu (70.94 per cent) and double cropped rice ecosystem of Thiruvananthapuram (61.39 per cent), where insecticides were applied indiscriminately and on need basis respectively (Fig. 1). On the other hand, population of pests (28.12 per cent) was low in Pokkali ecosystem where no insecticides were applied. The population of natural enemies was 26.24 per cent in Kuttanadu and 37.17 per cent in double cropped rice ecosystem of Thiruvananthapuram. High population of bio-agents (70.39 per cent) was observed in Pokkali ecosystem. The result is a clear indication of the disruptive influence of unwarranted usage of chemical pesticides. Contrary to the desired regulation of pests, use of insecticides led to the increase in population of pests thereby upsetting the natural biological balance and creating instability of the ecosystems in Kuttanadu and double cropped rice fields of Thiruvananthapuram. Similar deleterious effect of insecticides on arthropod community in rice ecosystems is well documented (Chelliah and Rajendran, 1984; Fabellar and Heinrichs, 1984; Kandasamy and Ravikumar, 1986; Heong, 1990).

Close observation of the natural enemies indicated that between predators and parasitoids, the two potential group of bioagents in rice ecosystem, the population of predators was significantly higher in all the three ecosystems, constituting 90.71, 93.10 and 99.40 per cent of the total

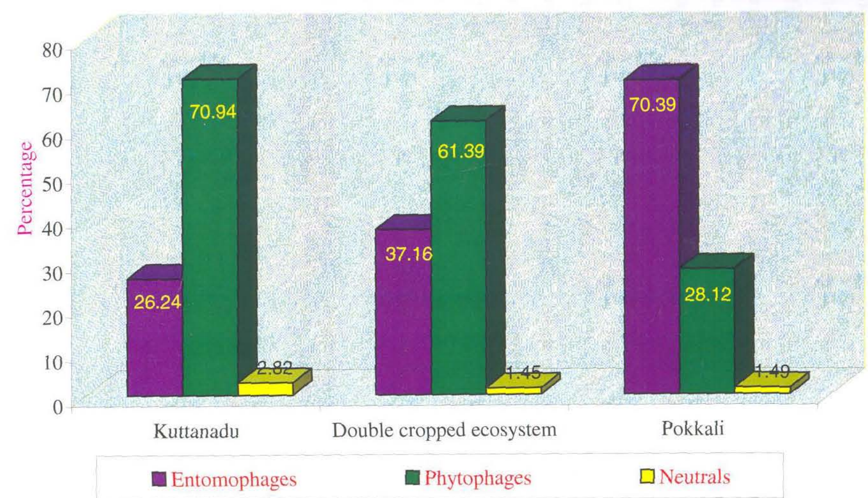


Fig.1 Abundance of entomophages, phytophages and neutrals in three rice ecosystems

population in Kuttanadu ecosystem, double cropped rice fields of Thiruvananthapuram and Pokkali ecosystem respectively (Fig.2a). In the rice fields of Pokkali, population of predators was even higher than that of pests. Population of the host specific parasitoids was remarkably low comprising only 9.29, 6.90 and 0.60 per cent of the natural enemy population in the three ecosystems respectively. The observation conforms to the findings of Pasalu (2003), who reported that in the last two decades, comparatively fewer parasitoids were seen in the rice ecosystems. Franqui *et al.* (1988) and Suzuki and Raga (1992) also made similar observations.

Among the predators, the insect predators (Fig 2b) dominated in all the three ecosystems (70.62 per cent in Kuttanadu ecosystem, 59.52 per cent in double cropped ecosystem and 90.91 per cent in Pokkali ecosystem). The commonly seen predators included the dragonflies, damselflies, *C. lividipennis, M. discolor, O. nigrofasciata, P. fuscovittatus*, crickets, *L. fossarum*, *Microvelia* sp. and *Conocephalus* sp. Among these, *C. lividipennis* and *M. discolor* were dominant. The results agree with the findings of Peter (1988), Shepard and Rapusas (1989) and Rajendram and Devarajah (1990). Next to the insect predators, spiders were the other dominant group of natural enemies seen conforming to the observations of Heong *et al.*, (1992). They constituted 29.38 per cent, 40.48 per cent and 9.09 per cent of the predator population in Kuttanadu ecosystem, double cropped ecosystem and Pokkali ecosystem respectively. The spiders seen commonly included *T. maxillosa, L. pseudoannulata, A. formosana* and *O. javanus* of which *T. maxillosa* and *L. pseudoannulata* were predominant. Other spiders noted in the rice fields were *Clubiona japonicola, Argiope catenulata* (Doleschall), *Argiope anasuja* Thorell, *Plexippus* sp., *Phidippus* sp., *Oxyopes lineatipes* (C.L. Koch), *Larinia* sp., *Peucitia* sp. and *Neoscona nautica* (Plate 3 a and 3 b).

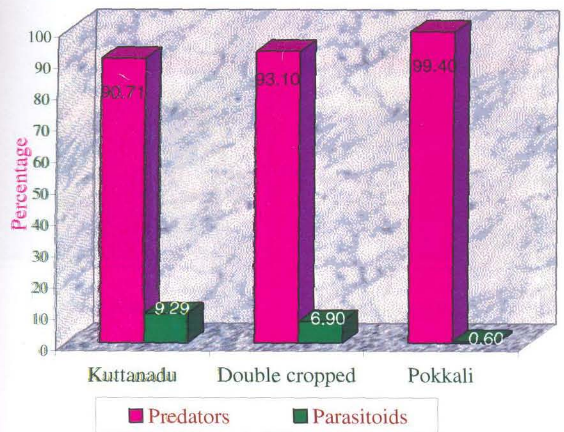


Fig 2 a Occurrence of predators and parasitoids in three rice ecosystems

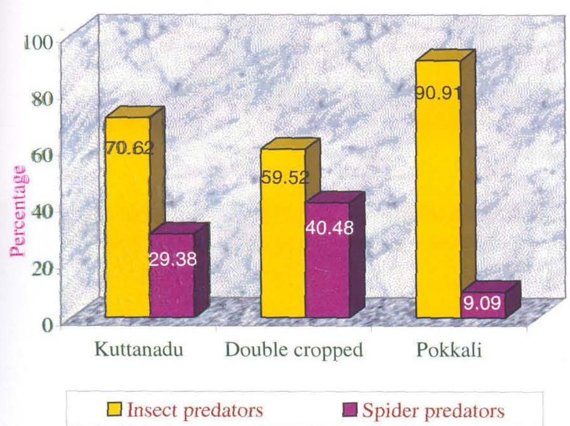
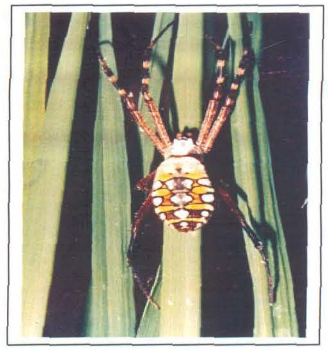


Fig.2 b Occurrence of predators in three rice ecosystems

Clubiona japonicola



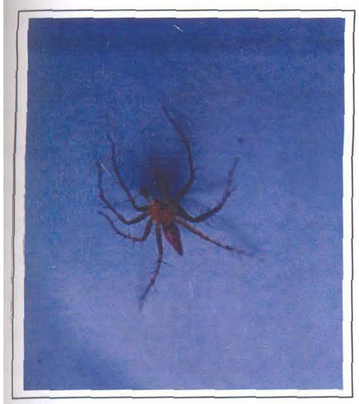
Argiope catenulata (dorsal view)

Argiope anasuja

Plexippus sp.

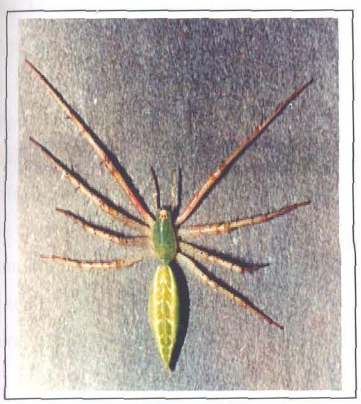
Phidippus sp.

Plate 3 a New spider species recorded



Oxyopes lineatipes

Larinia sp



Peucitia sp.

Neoscona nautica

Plate 3 b New spider species recorded

The diverse complex of natural enemies and their relative abundance in rice ecosystems mirrored the effect of changing agro ecological conditions on pest survival and status.

Distinct dominance of sucking pests was seen in all the three ecosystems (Fig. 3) inspite of the wide heterogenity in physical and chemical characteristics of soil, climatic conditions and agronomic practices. They constituted 93.09, 77.38 and 66.55 per cent of the pest population in Kuttanadu ecosystem, double cropped rice fields of Thiruvananthapuram and Pokkali rice fields. This was followed by the defoliators which formed 6.54, 19.70 and 15.98 per cent of the pest population respectively. The important sucking pests observed in the three ecosystems were *S. furcifera*, *Nephotettix* sp., *N. lugens, C. spectra, R. dorsalis, L. acuta, H. ganglbaueri* and *M. histrio* in Kuttanadu ecosystem, *Nephotettix* sp., *S. furcifera*, *C. spectra, L. acuta* and *M. histrio* in double cropped rice fields of Thiruvananthapuram and *Nephotettix* sp., *N. lugens*, *S. furcifera, C. spectra, L. acuta* and *M. histrio* in Pokkali ecosystem. Even during the three stages of the crop *viz.*, vegetative (30 DAT), tillering (50 DAT) and reproductive (70 DAT), sucking pests dominated in the three ecosystems followed by the defoliators. Among the sucking pests, the hoppers constituted the bulk of the population (Fig. 4a). Among the three hoppers, *Nephotettix* sp. was dominant, the percentage of occurrence ranging from 47.67 to 93.26 (Fig. 4b). Sizeable population of *S. furcifera* was also seen, percentage of which ranged from 6.38 to 35.86. Population of *N. lugens* was low, percentage of which ranged from 0.00 to 16.47. Domination of hoppers like *N. lugens*, *Nephotettix* sp. and *S. furcifera* considered to be minor pests three decades back has been observed in several parts of the world (Kalode, 1983; Reddy *et al.*, 1987; Holdom *et al.*, 1989; Heong and Aquino, 1990). Among several factors, indiscriminate use of insecticides has been one of the major reasons for resurgence of these hoppers.

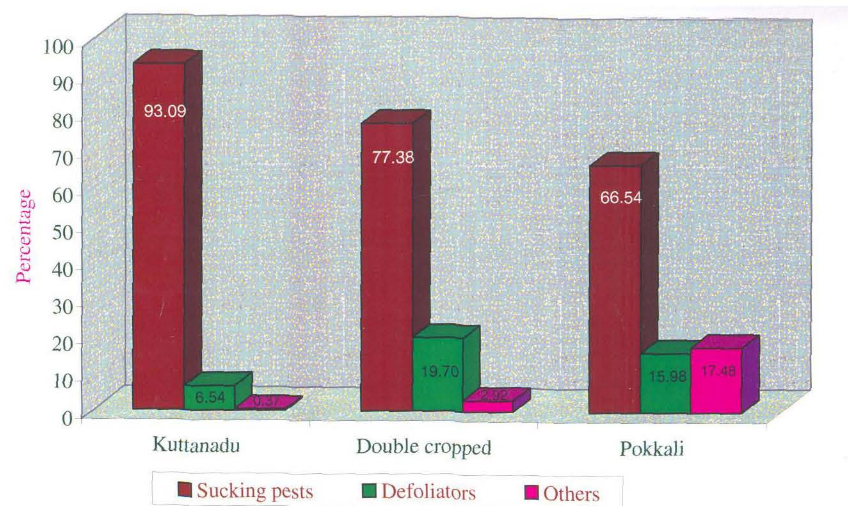


Fig.3 Occurrence of different types of pests in three rice ecosystems

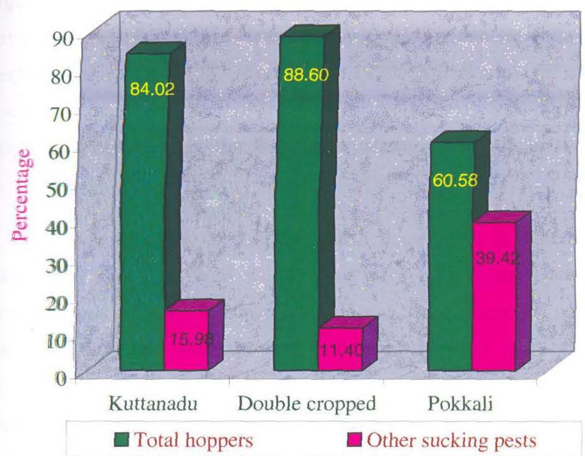


Fig 4 a Occurrence of hoppers and other sucking pests in three rice ecosystems

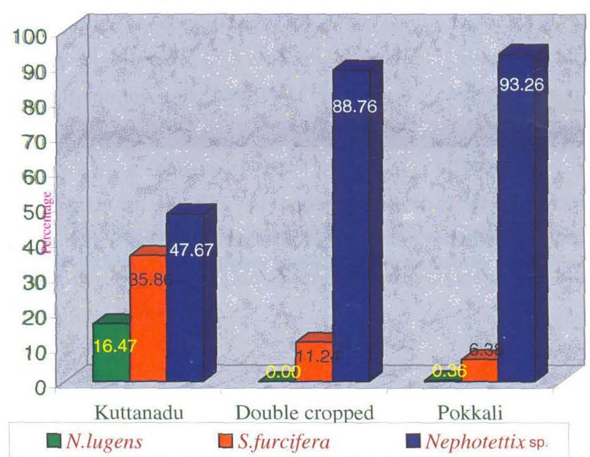


Fig.4 b Occurrence of different hopper pests in three rice ecosystems

Resurgence of *N. lugens* (Heinrichs and Mochida, 1984), *Nephotettix* sp. (Kobayashi, 1961; Dahal and Neupane, 1990; Heong and Aquino, 1990) and *S. furcifera* (Saini *et al.*, 1982; Luo *et al.*, 1990; Ambikadevi *et al.*, 1998) were reported from several rice tracts. Contrarily, only low population of *N. lugens* was observed in the three ecosystems of Kerala in the present study.

Two decades back, *N. lugens* was a major pest in Kerala (KAU, 1983-84). *Nephotettix* sp. and *S. furcifera* were only minor pests. With the introduction of several varieties tolerant to *N. lugens*, widespread cultivation of the same was practised to protect the crop from the ravages of the pest. This led to a slow decline in the population of the pest. Subsequently, a gradual increase in the population of *Nephotettix* sp. was noted in several important rice tracts of the State (KAU, 1995-96 and Ambikadevi *et al.*, 1998). The results of the present study clearly defined the changed status of pests in the rice ecosystems of Kerala consequent to changed agroecological conditions. This could be due to the cultivation of the tolerant variety 'Jyothi' in Kuttanadu and double cropped ecosystems of Thiruvananthapuram and 'Vyttila 4' in Pokkali. *Nephotettix* sp. and *S. furcifera* had established as pests to be reckoned within rice ecosystems. When a particular pest species is affected by specific interventions such as growing of resistant varieties or application of insecticides, other species living in the same niche may become dominant with the removal of competition. Similar observations were made by Heong and Aquino (1990)

Another interesting phenomenon noted in the rice fields was the negligible population of certain pests like yellow stem borer, case worm and gall fly, still considered as major ones in Kerala (KAU, 2002). A few reports had earlier indicated the perceptible change occurring in the status of the major pests (Ambikadevi, *et al.*, 1998 and Ajayakumar, 2000). The present study confirmed the change. Cultivation of pest tolerant varieties and action of natural enemies probably accounted for the negligible population of most of the pests considered as major ones in Kerala.

On the other hand, sucking pests like the rice bug and the rice ear head thrips considered as important pests of rice for a long time were seen damaging the crop during the respective stages. Obviously the changed cultivation practices did not influence the incidence of these pests.

Thus the results of the study on the status of natural enemies and pests in three rice ecosystems of Kerala lend credence to the hypothesis that the natural enemies in an ecosystem is one determinant of the composition of its pest community and abundance of individual species. Predators dominated in the ecosystem and among the predators, population of *C. lividipennis, M. discolor, T. maxillosa* and *L. pseudoannulata* was higher reflecting the dominance of hoppers in the ecosystem. However, inspite of the changed status of pests and natural enemies, even today research is focused on the identification and study of parasitoids of rice pests rather than that of predators. Such emphasis was justifiable when pests like rice stem borers, gall fly etc. dominated in the ecosystems. However, in the light of the changed pest status, exploitation of general predators like spiders, which also check the population of other pests (Pantua and Litsinger, 1984; Shepard and Arida, 1986; Rubia *et al.*, 1990) is more desirable.

The population of neutrals was low in all the three rice ecosystems being 2.82 per cent, 1.45 and 1.49 per cent in Kuttanadu ecosystem, double cropped rice fields of Thiruvananthapuram and Pokkali ecosystem respectively. The neutrals in the rice fields are a highly neglected group. Though considered as omnivorous earlier, studies conducted on the community ecology of irrigated tropical rice fields of Java in Indonesia established a trophic linkage among organic matter, the neutrals (detritivores and filter feeders) and generalist predators. These served as a consistent and abundant source of food for the general predators early in the crop season thus increasing their population significantly. The high population of the predators in turn prevented the pest population from rising to damaging levels in natural ecosystems. Studies on the patterns of emergence showed that population of neutrals peaked at about 30 DAT and then declined over the rest of the season whereas herbivore population only began to emerge later in the growing season (50 to 70 DAT) (Settle *et al.*, 1996). A similar observation on high population of general predators supported by alternate prey keeping herbivores under check up to the vegetative phase was seen in the double cropped rice fields of Thiruvananthapuram earlier (Nalinakumari and Hebsybai, 2002). Contrarily, only low population of neutrals was seen in the three rice ecosystems in the present study. However, a high population of the neutrals was seen in the adjoining vegetation (Fig. 5).

Chironomids are known for their resistance to pollutants and insecticides (Pinder, 1986) and high population of the plankton feeders was noted in insecticide treated plots by Settle *et al.* (1996) in Indonesia. Similarly, resurgence of chironomids due to insecticide application in rice fields has also been noted elsewhere (Takamura, 1993). Obviously, insecticide application was not the reason for the low population of neutrals observed in Kuttanadu ecosystem and double cropped rice fields of Thiruvananthapuram. Some other unfavourable conditions prevailing in the ecosystems may have been responsible for the low number of neutrals observed which need further exploration.

Regarding the diversity of arthropod species in the three ecosystems, comparatively more number of arthropod species were seen in Pokkali ecosystem and double cropped rice fields of Thiruvananthapuram than in Kuttanadu ecosystem as indicated by the species diversity index. Probably this may be due to the indiscriminate use of insecticides in Kuttanadu leading to instability of the ecosystem. On the other hand Pokkali ecosystem, where no insecticide was used, had a greater diversity

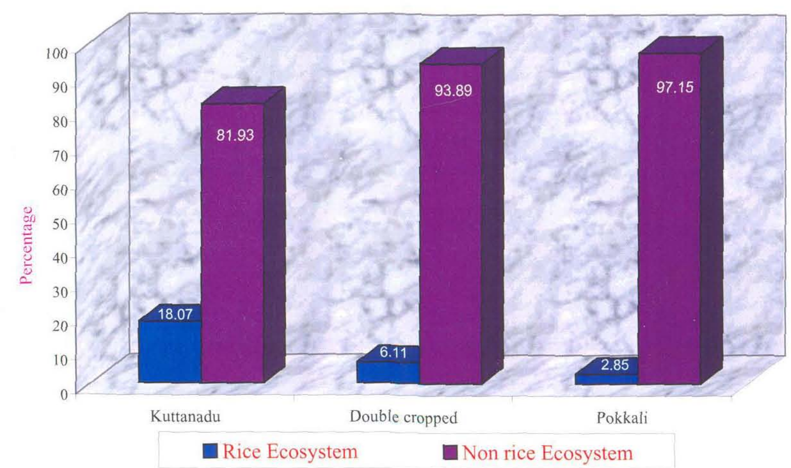


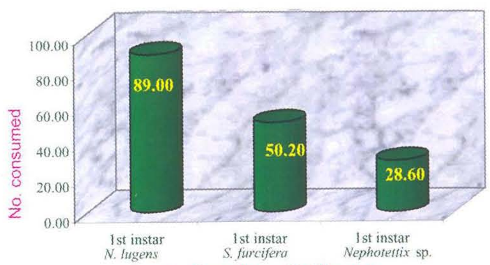
Fig.5 Occurrence of neutrals in rice and non rice ecosystems

of species creating a more stable system. A comparable diversity of species was also seen in double cropped rice fields of Thiruvananthapuram where insecticide was applied only on need basis.

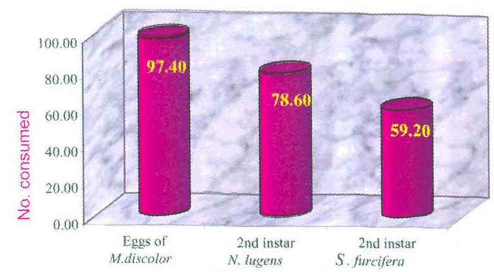
5.2 SUITABLE PREY FOR REARING PREDATORS

Augmentation bio-control is the ideal method for exploiting predators for pest management. The strategy involves mass multiplication of bio-agents for which suitable diets, whether natural or artificial are mandatory. An easy and feasible method for culturing predators is by rearing them on suitable natural prey. Though the potential predators identified in the rice ecosystem of Kerala *viz*., *C. lividipennis, M. discolor, T. maxillosa* and *L. pseudoannulata* preferably consume large number of hoppers especially *N. lugens, S. furcifera* and *Nephotettix* sp. little information is available on the comparative suitability of these hoppers as diet for the predators.

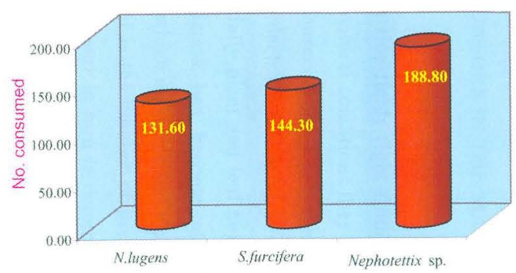
Investigations conducted indicated that the first instar nymphs of *N. lugens* was the best prey for rearing *C. lividipennis* compared to *S. furcifera* and *Nephotettix* sp., as evidenced by the shortest time taken by the nymphs for development (23.00 days) on the prey, longest lifespan of adults (21.80 days) and intake of the prey (89.00) in its life cycle (Fig. 6a). *S. furcifera* was the next suitable prey and *Nephotettix* sp. was the least preferred prey. Suitability of eggs and first instar nymphs of *N. lugens* for rearing *C. lividipennis,* is well documented (Rajendram and Devarajah, 1986 and Manti and Shepard, 1990 a). The preferred food of *M. discolor* was its own eggs (Fig. 6 b). Nymphal duration was significantly short and adult longevity significantly longer when the predator consumed its own eggs (50.40days). Few reports are available on suitable diet of *M. discolor*.



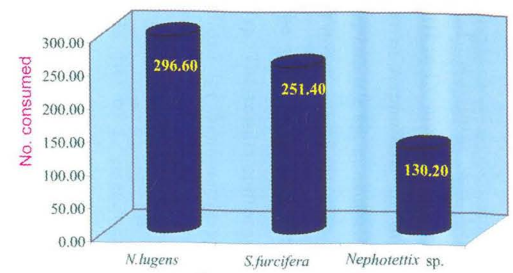
a. *Cyrtorhinus lividipennis*



b. *Micraspis discolor*



c. *Tetragnatha maxillosa*



d. *Lycosa pseudoannulata*

Fig.6 Prey consumed by different predators throughout their lifespan

The suitable prey for rearing *T. maxillosa* was *Nephotettix* sp. Throughout the developmental period (II to IX instars) and in its adult life too, the spider consumed more number of *Nephotettix* sp. than *N. lugens* and *S. furcifera,* the total number of *Nephotettix* sp. consumed being 188.8 in its life time (Fig. 6 c). The nymphal duration was also completed in the shortest period (71.20 days) and the adult had significantly longer longevity (22.50 days) on *Nephotettix* sp. The results conformed to earlier reports on the preference of *T. maxillosa* for *Nephotettix* sp. (Nirmala, 1990 and Vungsilabutr, 1988).

Unlike *T. maxillosa,* the suitable diet of *L. pseudoannulata* was observed to be *N. lugens.* The total duration of the nymphal stages of the spider was significantly short when reared on *N. lugens* (93.80 days) and adult life span was longer (38.10 days). Total consumption of the prey during the life cycle was 296.60 (Fig.6d). The results agreed with the findings of Rajendran (1987) and Ganeshkumar (1994).

5.3 POTENTIAL OF MAJOR PREDATORS IN THE MANAGEMENT OF HOPPERS

Predators are always present in rice fields right from the time of sowing till harvest of the crop. Under natural conditions they tend to keep the pest in check. Identification and conservation of potential indigenous ones offer a feasible and practical approach for managing pests. With the predominance of sucking pests, especially plant and leaf hoppers in rice growing tracts, exploitation of predators has become all the more important. The most important feature which makes an individual predator potentially useful for biological control is the number of prey consumed by the predator. The voracity of a predator in turn is determined by its searching capacity for the prey, which again is influenced by its feeding potential, prey preference and hyperpredation.

Considering the searching capacity of *C. lividipennis, M. discolor, T. maxillosa* and *L. pseudoannulata,* the insect predators searched better for hoppers than the spiders as indicated by their 'area of discovery' described in para 4.3.1. It is a well established fact that *C. lividipennis* and *M. discolor* prey only on selected insect pests while the spiders feed on any insect. This may be due to the more 'specialist' nature of the insect predators than the highly 'generalist' nature of the spider predators. Generalist feeding is one of the several traits spiders possess that ensure individuals' survival over times of food shortage as they have evolved under conditions of food limitation (Riechert and Lockley, 1984). Moreover, polyphagy in spiders is necessary for dietary reasons. They maintain mixed diet to ensure that essential amino acid needs are met (Greenstone, 1990). Probably, this accounted for the lesser searching capacity of the spider predators for hoppers, highlighting its opportunistic nature of prey capture (Rajendran, 1987).

Between the two insect predators, the rate of attack of *C. lividipennis* was significantly higher and among the four hoppers tested *viz., N. lugens, S. furcifera, Nephotettix* sp. and *R. dorsalis, N. lugens* was the most attacked prey. *C. lividipennis* feeds preferably on hoppers (Liquido and Nishida,1985) while *M. discolor* feeds on a variety of soft bodied insects like aphids, leaf hoppers, coccids and mites (Aziz *et al.*, 1969). This specificity of *C. lividipennis* might have contributed to its greater searching capacity especially for *N. lugens*.

Between the two spiders, the searching capacity of *L. pseudoannulata* was higher with the spider showing greater rate of attack on *S. furcifera* followed by *N. lugens*. *T. maxillosa* did not show any remarkable difference in its search for the different hoppers. This may be attributed to the dwelling habit of the spiders. *L. pseudoannulata* is usually seen at the lower part of the rice plant (Chiu, 1979). This might have accounted for the greater consumption of *S. furcifera* and *N. lugens* by

L. pseudoannulata as both these pests are seen congregating at the base of the rice plant and the spider has easy access to these prey. *T. maxillosa* is usually seen above the canopy of plants and as such can prey easily on *Nephotettix* sp. Moreover, as it moves about the plant quiet frequently, *N. lugens* and *S. furcifera* are also readily available to the predator. This might have probably accounted for the relative non preference for the different prey unlike *L. pseudoannulata* (Samiayyan and Chandrasekharan, 1998).

Different opinions prevail on the relevance of the 'area of discovery' obtained from laboratory tests in evaluating the potential of predators in the field. According to Nicholson and Bailey (1935), the parameter may bear little resemblance to the actual performance of a natural enemy in the field as several factors are correlated with the searching capacity of natural enemies. Still, being an important attribute of a predator, the results obtained from the laboratory test could act as a base for evaluating the impact of the predator on the population of its prey in the field, as a predator must search for its prey from one meal to the next unlike parasitoids for which food is assured.

Even though predators feed on a range of insects they do show preference for certain prey. In the context of pest management, this trait of a predator is significant as it plays an important role in the regulation of pests. Quantification of such inherent characters of individual species in the field is difficult warranting laboratory investigations.

Studies conducted on prey preference of *C. lividipennis* showed that when first instar *N. lugens, S. furcifera* and *Nephotettix* sp. were offered simultaneously, *C. lividipennis* definitely preferred *N. lugens* (Fig. 7a). Of the total hoppers consumed, 63.00 per cent was *N. lugens*. The least consumed prey was *Nephotettix* sp. (10.00 per cent). Preference of

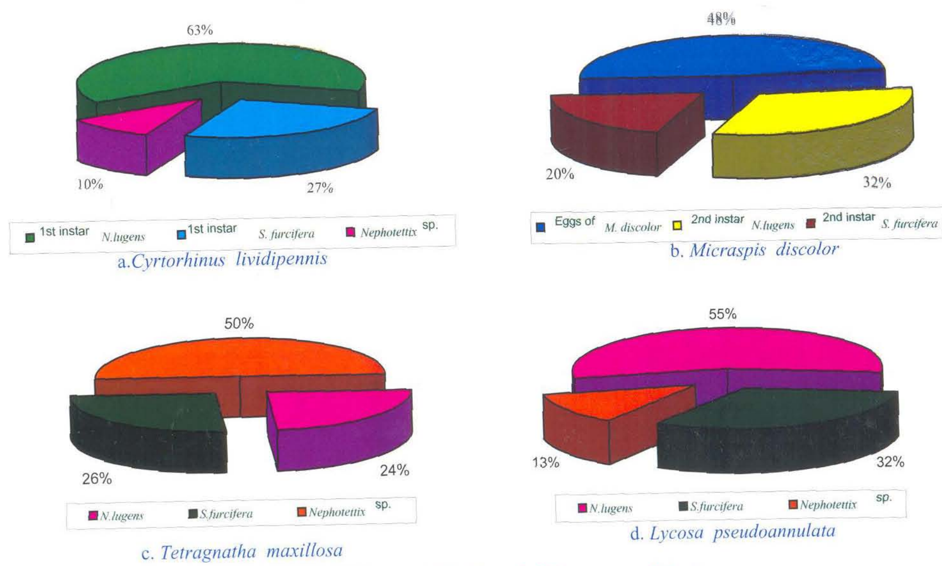


Fig. 7 Prey preference of different predators

C. lividipennis for *N. lugens* was reported earlier (Pophaly *et al*., 1978; Ganeshkumar and Velusamy, 1996 a; IRRI, 1998).

Similarly *M. discolor* consumed more of its eggs which constituted 48.00 per cent of the total diet (Fig.7b). This predator is usually seen abundantly during rice flowering and hence are forced to feed on pollen which is readily available (Shepard and Rapusas, 1989). However, if coccinellid beetles are forced to feed largely on non insect food like pollen, honey dew, nectar etc. its reproduction will be adversely affected as the food are nutritionally unsatisfactory for ovigenesis. Hence they tend to feed on their own eggs in low prey densities for such feeding nearly double the life of the young larva and increases its searching capacity (Hagen, 1962). This may have influenced the preference of *M. discolor* for its eggs.

When mixed diet was offered to the spiders, *T. maxillosa* preyed more on *Nephotettix* sp. which constituted 50 per cent of its diet. Its preference for *S. furcifera* (26 per cent) and *N. lugens* (24 per cent) was more or less similar (Fig.7c). On the other hand, *L. pseudoannulata* preferred *N. lugens* which formed 55 per cent of its diet (Fig. 7d). The next preference of the spider was for *S. furcifera* which constituted 32 per cent of its diet. Preference for *Nephotettix* sp. (13 per cent) was low. Similar observations have been made by Samiayyan and Chandrasekharan (1998). When *Nephotettix* sp. and *N. lugens* were caged together with *L. pseudoannulata* for twelve days, the spider killed three times *N. lugens* than *Nephotettix* sp.(Chiu,1979).

Contradictory reports on the prey preference are also available, Kiritani *et al*., (1972) indicated that the ratio of prey taken by a spider was five *Nephotettix* sp. to two *N. lugens* in Japan. In another experiment conducted at IRRI, it was found that *L. pseudoannulata* when caged with nymphs of *N. lugens, S. furcifera,* and *Nephotettix* sp. preferred *S. furcifera* to *N. lugens,* and *Nephotettix* sp. (IRRI, 1979).

Once the prey preference of the predator is known, the knowledge of the feeding potential is essential in order to monitor the feeding pattern of the predator. Such information together with the population trend in the field will decide the potential of the predator in pest management.

Determination of the consumption rate of *C. lividipennis* indicated that an adult consumed 5.80 *N. lugens* per day while it consumed only 3.60 and 1.90 *S. furcifera* and *Nephotettix* sp. respectively (Fig. 8a). The results agree with the findings of Rajendran *et al.* (1987). They observed that the adults of the predator consumed on an average 5.89 first and 2.79 fourth instar nymphs of *N. lugens* per day respectively. A higher consumption rate (8.98 per female and 2.36 per male) was also observed by Manti and Shepard (1990 b). Adults of *M. discolor* preyed on 2.90 eggs per day. The consumption of *N. lugens* and *S. furcifera* was only 1.90 and 1.70 respectively (Fig. 8b). No studies have been conducted earlier on the comparative consumption rate of the predator, *M. discolor*.

Regarding the feeding potential of *T. maxillosa*, the per day consumption of *N. lugens* (1.80 per spider), *S. furcifera* (2.20 per spider) and *Nephotettix* sp.(2.40 per spider) did not vary greatly (Fig. 8c). The result is in agreement with earlier findings (Chiu, 1979 and Nirmala, 1990).

However, the number of *N. lugens* consumed per day by *L. pseudoannulata* was higher being 3.80 per spider closely followed by *S. furcifera* (3.20) (Fig.8d). Contrarily, highest feeding activity of *L. pseudoannulata* on *S. furcifera* was recorded (5.90 per day) by Salim and Heinrichs (1986).

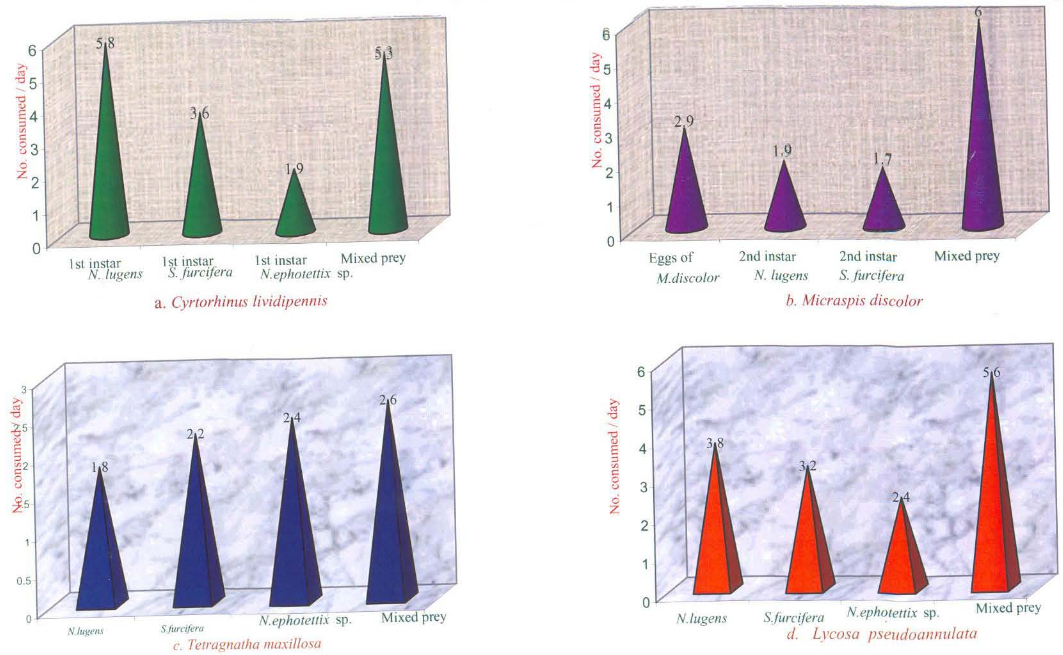


Fig. 8 Consumption rate of different predators

It is a well known fact that nutritional profile of host insects is a dominating factor in prey-predator interaction ensuring feeding and egg production of the predacious insects. Considering the prey preference and predatory potential of the predators, *N. lugens* sufficed to satiate *C. lividipennis* as indicated by the number consumed per day when given individually (5.80) and in a mixed diet (5.30) thus highlighting the narrow specificity of the predator. On the other hand, a marked difference was seen in the dietary requirement of *M. discolor,* as indicated by its consumption of the prey when given individually and together. The intake of food was doubled when a mixed diet of eggs of *M. discolor*, second instar nymphs of *N. lugens* and second instar nymphs of *S. furcifera* was given, strongly suggesting that its eggs alone could not meet the nutritional requirement adequately.

Between the two spider predators, not much difference was noted in the dietary intake of *T. maxillosa* when given its preferred prey alone and also a mixed diet. On the other hand, the total diet consumed by *L. pseudoannulata* was remarkably increased when a mixed diet was supplied probably indicating its wider choice and a 'true spider preference' for any prey.

Studies on hyperpredation revealed that *L. pseudoannulata, T. maxillosa, Oxyopes* sp., *Agriocnemis* sp., *Crocothemis* sp. and *P. fuscovittatus* exhibited distinct hyperpredatory activity. Interestingly, maximum cross predation was seen for the mirid bug, *C. lividipennis*, the activity ranging from 30 to 90 per cent. The spiders generally showed greater preference for the mirid bug (60 to 90 per cent), with *L. pseudoannulata* showing maximum preference for *C. lividipennis* (Plate 4). Observation on hyperpredation of spiders on insect predators in rice ecosystem has been made by Ganeshkumar (1994). He observed that adults of *O. javanus* fed readily on nymphs and adults of *C. lividipennis*.

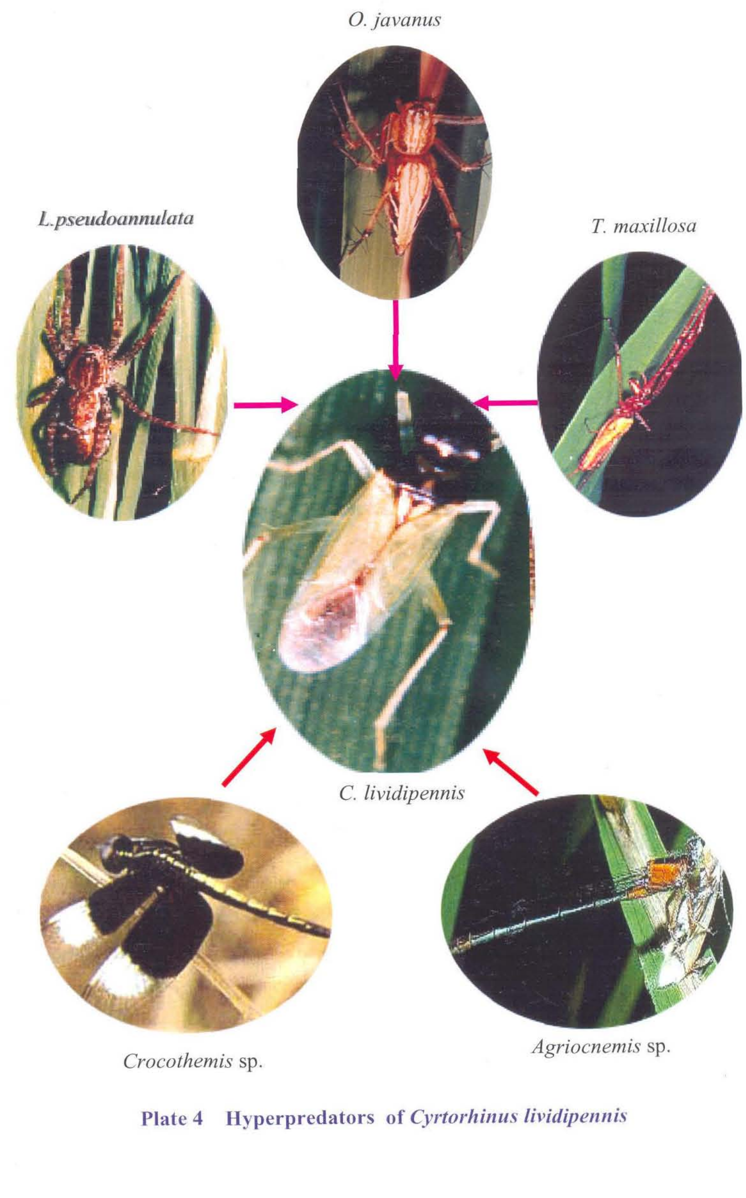


Plate 4 Hyperpredators of *Cyrtorhinus lividipennis*

Mortality due to cannibalism was not observed among the insect predators and the spiders in the present investigation. Contrarily cannibalism among spiders have been reported when food supply was inadequate or the population of the spider was more than two per hill (Chiu and Wang, 1973; Chiu *et al.*, 1974; Barrion *et al.*, 1981; Rajendran, 1987). When ten *L. pseudoannulata* were caged together, 24 per cent mortality was observed due to cannibalism and similarly one *L. pseudoannulata* was observed to kill 60 per cent of *C. lividipennis* (Salim and Heinrichs, 1986).

Overall assessment of the predatory efficiency of the insect and spider predators revealed that *C. lividipennis* and *L. pseudoannulata* are potential predators of hoppers in rice ecosystem. The most abundant predator of hoppers is the mirid bug, *C. lividipennis*. Although primarily an egg predator, *C. lividipennis* also feeds on the hoppers. The spiders are also a major regulator of the hoppers feeding both on nymphs and adults. Several researchers have considered spiders as an important constant mortality factor in rice ecosystems as they are present throughout the year (Ooi, 1988; Bhathal *et al.*, 1990). Ooi (1988) speculated that the presence of spiders in rice field might determine the establishment and subsequent increase of pest populations especially hoppers as they are one of the most ubiquitous groups of predaceous organisms in the animal kingdom feeding exclusively on insects. They rarely show specificity towards prey, their generalist feeding nature ensuring survival at times of food shortage. In the rice ecosystem, these are the early colonisers of the field and their existence is assured by the presence of neutrals especially the detritivores and filter feeders which serve as dietary sources. Moreover, as spiders kill 50 times the number of prey it actually consumes, they assume greater importance as potential predator (Riechert and Lockley, 1984).

5.4 IMPACT OF INSECTICIDES ON PREDATORS

An understanding of the response of natural enemies to insecticides is imperative as it would lead to better utilization of natural enemies in pest management. It has been observed that insecticides differ in their effect on pests and natural enemies. Certain insecticides have a narrow spectrum of activity and are selective on individual pest species and natural enemies (Dyck *et al.*, 1979). Insecticides which are effective in controlling pests without having any adverse effect on natural enemies provide an attractive means of pest control.

Studies on the effect of the broad spectrum insecticides (carbaryl, phosphamidon, monocrotophos, quinalphos and methyl parathion) commonly used for controlling rice pests in Kerala, showed that all of them were highly toxic at the recommended dose to the insect and spider predators. Toxicity of several of these insecticides to predators has been observed earlier. Population of spiders was heavily affected by application of methyl parathion at 0.75 kg a.i. per ha when observed at 14 and 30 DAT. On the other hand, the insecticide did not cause significant reduction in population of *C. lividipennis* (Arida *et al.*, 1997). While acephate, chlorpyriphos and monocrotophos (0.50 kg a.i. per ha) were safe to *L. pseudoannulata* and *T. javana,* phorate (1.00 kg a.i. per ha) and carbofuran (0.75 kg a.i. per ha) were more toxic to the predator (Ganeshkumar and Velusamy, 2000). Monocrotophos (0.04 per cent) resulted in 100 per cent mortality of *C. lividipennis* (Jhansilakshmi *et al.*, 1998).

It is evident from an overview of the study that with evolution of modern agriculture, a definite shift has occurred in the pest status in the rice tracts of Kerala with the hoppers especially *S. furcifera* and *Nephotettix* sp. together with stage specific sucking pests dominating the scene. Cultivation of varieties tolerant to a handful pests like yellow stem borer, gall midge and brown planthopper over the years has resulted in an appreciable decrease in the population of these major pests. A predominance of predators especially hopper predators like *C. lividipennis, M. discolor, T. maxillosa* and *L. pseudoannulata* was also noted in the fields. The study emphasized the necessity of characterising the arthropod community in rice fields periodically, to determine the identity and relative abundance of pests and the nature and extent of natural control operating in the system. IPM strategies to be effective and economical should be implemented based on a comprehensive understanding of the ecosystem. The study also stressed the efficiency of predators in managing pests. As a diverse complex of predators are present in the rice ecosystem, identification of the potential ones and optimal use of these agents will lead to effective natural control.

Among the dominant predators, the spiders were observed to be potential. The possibility of exploiting spiders in rice ecosystem could be thought of, as a wide range of spider species inhabits rice fields. Not only do their presence limit the habitats open to insect pests, but they also threaten insect pests with various foraging strategies. Besides consuming a large number of insect pests, they also have the trait of killing insects living in their territory (Riechert and Lockley, 1984). Moreover, on account of their generalist nature of feeding, a number of pests can be kept at bay, simultaneously. These reasons favour the exploitation of spiders as potential biological control agents in rice ecosystems. In the context of global warming too, the ability of spiders to withstand high temperature unlike, *C. lividipennis* enhances its predatory potential in rice fields. Emphasis should be given to guard these potential predators in pest management strategies for exploiting them in biological control.

In conclusion, periodical assessment of the arthropod community in rice ecosystems, growing of varieties tolerant to major pests and regulation of incident pests by conserving naturally occurring predators through optimal habitat modification and use of predator friendly insecticides when absolutely needed will go a long way in sustainable production of rice in Kerala.

The future line of work should be oriented towards systematic study of rice dwelling indigenous predators, in each and every rice growing tract to identify the potential ones. Priority should be given for systematic study of spiders in various rice environments to document and characterize the fauna as a basis for biocontrol studies. Based on the information gathered, location specific simple and cost effective strategies should be formulated to conserve the bioagents for stimulating the naturally functioning pest regulatory mechanism in the system.

Studies on the neutrals should also be intensified, as these support the predators in the early stages. Research may be streamlined to identify methods like increasing organic matter in rice fields for increasing population of neutrals which in turn will boost the abundance of general predators.

As insecticides are a necessary evil at times, the new generation molecules and botanical pesticides should be evaluated for their relative toxicity to pests and safety to the predators and neutrals for identifying suitable ones for rice ecosystems.

SUMMARY

6. SUMMARY

Biotic and abiotic stresses in agro-ecosystems often lead to the replacement of existing pest communities and emergence of new pest species. Extensive cultivation of resistant varieties and greater use of chemical pesticides over the past three decades have resulted in a tremendous shift in the composition and status of pests in rice ecosystems. Research findings indicated the dominance of certain minor sucking pests like planthoppers and leafhoppers in the rice ecosystems of the tropics and sub tropics accompanied by successional changes in the natural enemy complex. Abundant population of generalist predators capable of effecting natural biological control were also seen in the ecosystems. The present study was taken up with a view to record the changes, if any, in the arthropod community in rice ecosystems of Kerala, to identify the potential indigenous predators, to find out suitable natural prey for mass culturing of the potential predators in the laboratory, to investigate the efficiency of these predators in suppressing the hopper pests of rice and to determine the relative toxicity/safety of insecticides used commonly for the control of rice pests to the predators.

Survey was conducted in three heterogeneous rice ecosystems of the State *viz*., Kuttanadu ecosystem where insecticides were used rampantly, double cropped ecosystem in Thiruvananthapuram district where insecticides were applied on need basis and Pokkali ecosystem where insecticides were not applied to identify the potential indigenous predators and to assess the current status of the pest species. The suitability of different prey for rearing the dominant predators identified in the survey was determined through assessment of duration of different instars, adult longevity when reared on the prey and the number of prey consumed. The predatory efficiency was studied in terms of searching capacity, feeding potential, prey preference and hyperpredatory activity. The relative toxicity/ safety of carbaryl, phosphamidon, monocrotophos , quinalphos and methylparathion in terms of LC_{50} was assessed. The major findings of the study are summarised below:

Significant changes were observed in the species composition and status of the arthropods in the three different rice ecosystems of Kerala. While pests dominated in Kuttanadu (70.94 per cent), and double cropped rice fields of Thiruvananthapuram (61.39 per cent) where insecticides were applied rampantly and on need basis respectively, natural enemies dominated in Pokkali ecosystem (70.39 per cent) where no insecticides were applied. Pests constituted only 28.12 per cent of the total arthropod population in the ecosystem. Population of the neutrals was very low in all the three rice ecosystems. Significant variation could not be observed in the population of pests and natural enemies during the different seasons and stages of growth of the crop.

Between predators and parasitoids, population of predators was higher in all the three ecosystems, being 90.71, 93.10 and 99.40 per cent in the Kuttanadu ecosystem, double cropped rice fields of Thiruvananthapuram and Pokkali ecosystem respectively. Only very low population of parasitoids could be recorded in the three ecosystems.

Insect predators dominated the predator fauna in the three ecosystems (70.62 per cent in Kuttanadu, 59.52 per cent in double cropped rice fields of Thiruvananthapuram and 90.91

per cent in Pokkali rice fields). Spiders constituted 29.38 per cent, 40.48 per cent and 9.09 per cent of the predator population. *C. lividipennis* and *M. discolor* were the important insect predators observed in the rice ecosystems. *T. maxillosa* and *L. pseudoannulata* were the major spider predators. The four bio-agents are important predators of hoppers.

Among the pests seen in the three ecosystems, the sucking pests were dominant, constituting 93.09, 77.38 and 66.55 per cent of the pest population in Kuttanadu ecosystem, double cropped rice fields of Thiruvananthapuram and Pokkali ecosystem respectively, followed by the defoliators. Population of other pests was negligible.

Among the sucking pests, the hoppers dominated in all the ecosystems. The percentage of total hopper pests recorded from Kuttanadu, double cropped ecosystem of Thiruvananthapuram and Pokkali rice fields was 84.02, 88.60 and 60.58 respectively. Among the hoppers, *Nephotettix* sp. was predominant constituting 47.67 per cent (Kuttanadu), 88.76 per cent (double cropped ecosystem of Thiruvananthapuram) and 93.26 per cent (Pokkali), followed by *S. furcifera*. Population of *N. lugens* was very low.

Stage specific sucking pests like rice bug and earhead thrips were also seen damaging the crop during the respective stages of the crop. Incidence of major pests like stem borer and gall fly was negligible.

Population of neutrals was low in all the three rice ecosystems. However, a high population of neutrals (67.98

per cent to 78.48 per cent) was observed in the adjoining non rice fields.

Species diversity index indicated greater diversity and consequently better stability of Pokkali ecosystem where no insecticides was applied. This was followed by double cropped rice fields of Thiruvananthapuram where need based application of insecticide was followed. Less diversity was observed in Kuttanadu rice ecosystem, where high levels of insecticides were applied.

Based on the duration of the nymphal period, longevity of adults and the number of prey consumed during the entire life span, the suitable prey for rearing the insect predator *C. lividipennis* was observed to be the first instar nymphs of *N. lugens*. Eggs of *M. discolor* was its best diet. *Nephotettix* sp. was the suitable prey for *T. maxillosa* followed by *S. furcifera, N. lugens* was a poor prey. *N. lugens* was the best prey for rearing *L. pseudoannulata* followed by *S. furcifera* and *Nephotettix* sp. was a poor prey for the spider.

The insect predators *C. lividipennis* and *M. discolor* showed better ability to search for planthoppers than the spiders. Between the two insect predators, the rate of attack of *C. lividipennis* was significantly higher and among the four hoppers tested *viz., N. lugens, S. furcifera, Nephotettix* sp. and *R. dorsalis, N. lugens* was the most attacked prey. Between the two spiders, the searching capacity of *L. pseudoannulata* was higher as the spider showed greater rate of attack on *S. furcifera. T. maxillosa* did not show any remarkable difference in its search for the different hoppers.

C. lividipennis preferred *N. lugens* for consumption when first instar nymphs of *N. lugens, S. furcifera* and *Nephotettix* sp. were provided together. *M. discolor* showed distinct preference for its own eggs. When a mixed diet of *N. lugens, S. furcifera* and *Nephotettix* sp. was offered, *T. maxillosa* and *L. pseudoannulata* showed significant preference for *Nephotettix* sp. and *N. lugens* respectively. No significant difference was seen in the prey preference of males and females of the spiders.

Considering the feeding potential of the insect predators, *C. lividipennis* consumed more number of first instar *N. lugens* (40.40) and *M. discolor* consumed more of its eggs (20.40) over a period of seven days. The spider *L. pseudoannulata* preyed on a mean of 21.93 hoppers in seven days compared to *T. maxillosa* (14.73 hoppers in seven days). The feeding potential of female spiders was significantly superior to that of the males. Individually, prey preference of *T. maxillosa* was higher for *Nephotettix* sp. and *L. pseudoannulata* for *N. lugens.*

None of the predators tested showed cannibalism. Hyperpredatory activity was observed in *Crocothemis* sp., *Agriocnemis* sp., *P. fuscovittatus, T. maxillosa, Oxyopes* sp. and *L. pseudoannulata*. The mirid bug *C. lividipennis* was a highly preferred prey for hyper predation.

The commonly used insecticides for rice pest control *viz.*, carbaryl, phosphamidon, monocrotophos, quinalphos and methyl parathion caused 80 to 100 per cent mortality of predators when tested at the dose normally recommended for controlling pests.

The results of the study emphasized the need for periodical assessment of the arthropod community in rice ecosystems, as agro-ecological conditions tend to shift the status of phytophages and entomophages from time to time. Based on the results, growing of varieties tolerant to major pests and regulation of incident pests by conserving naturally occurring predators through optimal habitat modification and use of predator friendly insecticides when absolutely needed will go a long way in sustainable production of rice in Kerala.

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MAJOR PREDATORS IN RICE ECOSYSTEMS AND THEIR POTENTIAL IN RICE PEST MANAGEMENT

BY

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ABSTRACT

Survey conducted in three heterogeneous rice ecosystems of Kerala *viz.*, Kuttanadu rice fields of Alappuzha district with high load of pesticide, double cropped rice fields of Thiruvananthapuram district with moderate level of pesticide and Pokkali rice fields of Ernakulam district with no pesticide during two consecutive seasons at the vegetative, tillering and reproductive stages of the crop revealed a distinct change in the composition and status of natural enemies and pests in rice ecosystem.

While pests dominated in Kuttanadu and double cropped rice fields of Thiruvananthapuram, natural enemies dominated in Pokkali ecosystem. Among the natural enemies, population of predators was significantly higher in all the three ecosystems. Population of parasitoids was very low. Among the predators, insect predators dominated the predator fauna followed by the spiders in the three ecosystems. The important insect predators observed were the mirid bug *Cyrtorhinus lividipennis* Reuter and the coccinellid beetle *Micraspis discolor* (Fabricius) and the major spider predators recorded were *Tetragnatha maxillosa* Thorell and *Lycosa pseudoannulata* (Boesenberg et Strand).

Among the pests seen in the three ecosystems, the sucking pests were dominant followed by the defoliators. Stage specific sucking pests like the ricebug *Leptocorisa acuta* (Thunb) and earhead thrips *Haplothrips ganglbaueri* Schmutz too were seen infesting the crop during the respective crop stages. Hoppers were the predominant sucking pests in all the three rice ecosystems. Population of other sucking pests was very low. Among the hoppers *Nephotettix* sp. and *Sogatella furcifera* (Horvath) were predominant. Comparatively, population of the brown planthopper, *Nilaparvata lugens* (Stal) was

low. Population of other pests considered as major ones in the State like yellow stem borer *Scirpophaga incertulas* (Walker), gall fly *Orseolia oryzae* (Wood-Mason), case worm *Parapoynx stagnalis* Zeller etc. was negligible.

The population of neutrals was low in all the three rice ecosystems. On the other hand, high population of these 'other insects' was seen in the adjoining vegetation.

Greater diversity of arthropod species was observed in the insecticide-free Pokkali rice ecosystem and insecticide-rationally-used double cropped rice ecosystem of Thiruvananthapuram. Less diversity of species was seen in Kuttanadu rice ecosystem where insecticides were applied indiscriminately.

Studies on the suitability of different prey for mass culturing *C. lividipennis, M. discolor, T. maxillosa* and *L. pseudoannulata* under controlled conditions indicated that the best prey for *C. lividipennis* was the first instar nymphs of *N. lugens* , for *M. discolor* its eggs, for *T. maxillosa*, *Nephotettix* sp. and for *L. pseudoannulata*, *N. lugens.*

Efficiency of the predators in suppressing hopper pests when assessed in terms of searching capacity, feeding potential, prey preference and hyperpredation revealed that the insect predators *C. lividipennis* and *M. discolor* showed better ability to search for plant hoppers, especially *N. lugens* and *S. furcifera*. Comparatively, the searching capacity of the spiders for hoppers was low. The feeding potential and prey preference of *C. lividipennis* was significantly high for first instar nymphs of *N. lugens*. Similarly, *M. discolor* preferred more of its own eggs than the other prey tested. The spider, *L. pseudoannulata* was observed to be a significantly better predator of hoppers than *T. maxillosa.* None of the predators tested showed cannibalism. Hyperpredatory activity was observed in *Crocothemis* sp., *Agriocnemis* sp., *Polytoxus fuscovittatus* (Stal), *T. maxillosa, Oxyopes* sp. and *L. pseudoannulata.* The mirid bug *C. lividipennis* was a highly preferred prey for hyperpredation.

The commonly used insecticides for rice pest control *viz.*, carbaryl, phosphamidon, monocrotophos, quinalphos and methyl parathion caused 80 to 100 per cent mortality of predators at the dose normally recommended for pest control.

The results of the study emphasized the need for periodical assessment of the arthropod community in rice ecosystems as agro-ecological conditions tend to shift the status of phytophages and entomophages from time to time. Based on the results, growing of varieties tolerant to major pests and regulation of incident pests by conserving naturally occurring predators through optimal habitat modification and use of predator-friendly insecticides when absolutely needed will go a long way in sustainable production of rice in Kerala.