SURVEY AND QUANTIFICATION OF NATURAL ENEMY FAUNA IN THE RICE ECOSYSTEMS IN THRISSUR DISTRICT

By
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THESIS

Submitted in partial fulfilment of the requirement for the degree of

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DECLARATION

I hereby declare that this thesis entitled "**Survey and quantification of natural enemy fauna in the rice ecosystems in Thrissur district**" 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 to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

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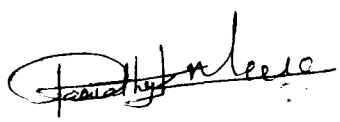

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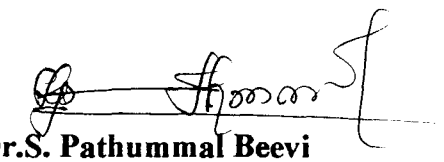
CERTIFICATE

Certified that this thesis, entitled "**Survey and quantification of natural enemy fauna in the rice ecosystems in Thrissur district**" is a record of research work done independently by **Miss. Parvathy Meera,** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.



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EXTERNAL EXAMINER

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Parvathy Meera

Affectionately dedicated to my parents

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INTRODUCTION

1. INTRODUCTION

Long histories of rice cultivation in many parts of the world have allowed stable relationships to evolve between rice pests and their natural enemies. Natural biological pest control managed insect pest before the advent of synthetic insecticides.

The destruction of predators and parasitoids that followed insecticide misuse resulted in resurgence of several rice pests including the brown planthopper (Bph), *Nilaparvata lugens* (Stal) (Chelliah *et al.*, 1989).

Classical and inundative biological control approaches so far tried have met with very inconsistent and quite often disconcerting results and there is very little potential for this strategy in rice. This emphasis maximising the impact of indigeneous natural enemies as an essential part of Integrated Pest Management (IPM) programme. Studies conducted in recent years have clearly shown the potential of natural enemies in the suppression of key pests of rice.

Increased attention is now being given for the implementation of Integrated Pest Management programme in rice with specific thrust on the conservation of natural enemies for promoting natural biological control with reduced insecticide use. Biological control of rice pests in tropical south and south east Asia lies in the identification and conservation of their natural enemies (Ooi and Shepard, 1992). Of the vast number of natural enemies present in the field only a few have been identified and studied. Systematic studies have not been conducted to understand the diversity of natural enemy fauna in different rice ecosystems.

The abundance and diversity of herbivorous and their natural enemies are related to the variation in habitats (Heong *et al.*, 1991; Beevi *et al.*, 2000). In a monoculture like rice, these communities vary with the environment, varieties,

cropping patterns and their management practices (Heong *et al.*, 1992). Understanding of temporal and spatial changes in the arthropod abundance, diversity and species complexity are important considerations in designing pest management strategies. Till recently pest surveillance programme was generally done for major pests alone.

It is equally important to estimate the population of parasitoids and predators in the surveillance programme as the pest defender ratio serves a great deal in deciding pest control strategies. A detailed survey, identification quantification and cataloguing of natural enemies present in different locations will serve a base for biocontrol studies.

No attempt has been made so far to study in detail on the pest and natural enemy abundance and diversity as affected by the two major rice ecosystems in Thrissur district, namely non-kole and kole areas. Hence the present study was undertaken with the following specific objectives:

- identification, quantification and comparison of pest and natural enemy complex present in two different ecosystems, non-kole and kole area in Thrissur district.
- to study the species complexity, abundance and relative occurrence of major pest, predators and parasitoids.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Rice field is characterised by the prevalence of large number of arthropod fauna. In a monoculture such as rice, arthropod communities may vary with the environment, varieties, cropping patterns and cultivation practices. Activity of natural enemies is one of the major factors in regulating key pests of rice. The work done so far in different rice growing areas on this aspects are reviewed hereunder.

2.1 Survey on arthropod fauna of rice ecosystems

Abundance of rice pests was studied at two sites in Orissa (Chakraborthy *et al.*, 1990). It was found that *N. lugens* and *C. lividipennis* were the most abundant pest and natural enemy respectively in the rice ecosystem.

Heong *et al.* (1991) analysed the arthropod community associated with irrigated rice grown in five sites in Luzon Islands, Philippines using guild categories. Phytophages and predators were predominant in all sites. The phytophages species were mainly Homoptera and dominated by *Nephotettix virescens* (Distant), *N. nigropictus* (Stal) (Cicadellidae) and *Nilaparvata lugens* (Stal) and *Sogatella furcifera* (Horvath) (Delphacidae). Predators were mainly Heteroptera with *Microvelia douglasi atrolineata* Bergoth (Veliidae), *Mesovelia vittigera* (Horvath) (Mesoveliidae) and *Cyrtorhinus lividipennis* Reuter (Miridae) as the most abundant species. Spiders were the next dominant group with *Pardosa pseudoannulata* (Boesenberg & Strand) and three species of *Tetragnatha* the most common. Differences in species diversity between the sites were easily differentiated using diversity indices. The relative differences in arthropod abundance, species richness and diversity may be attributed to the median temperatures, cropping pattern, and diversity in crop stages and germplasm in the sites. Predator-Homoptera correlations were significant in all cases. High positive correlations were obtained for veliids, spiders and *C. lividipennis*, in most sites.

Heong *et al.* (1992) compared the population dynamics of plant and leafhoppers and associated predators at five sites in the Philippines. The order of abundance of leaf and planthoppers was *N. virescens* > *S. furcifera* > *Nephotettix nigropictus* (Stal) > *N. lugens*. The dominant predators were mostly Heteroptera (*M.d. atrolineata, C. lividipennis*) followed by spiders *L. pseudoannulata* and *Callitrichia formosana*. They also reported that generalist predators associated with *N. lugens* namely *C. lividipennis, P. pseudoannulata* and *M.d. atrolineata* also attack the other homopteran species in rice ecosystem and thus their dynamics may well depend on the total phytophages homopteran species.

A field survey carried out by Bhalla (1997) on the diversity and abundance of arthropods in unsprayed paddy field recorded 11 orders of arthropods. Hymenoptera was the most abundant and diverse of the arthropods present. Homoptera with their various leaf and planthoppers was the next in abundance.

Field surveys carried out in three different locations in Fuzhou, fungian province, China during 1994, by Minsheng (1997) showed that the species richness of herbivorus insects, predatory insects, spiders and total species in the community varied with each field type because of the environmental variables and fluctuated with various growth stages of rice. It was concluded that the result of this study could be used to predict and forecast the population dynamics of rice pest and to develop a rational programme of integrated pest management for specific rice pests. The abundance and relative occurrence of natural enemies with that of phytophages in different rice ecosystems of Thrissur district of Kerala has been studied by Beevi *et al.* (2000a).

2.2 Abundance and diversity of natural enemies in rice ecosystem

The studies on the natural enemies prevalent under different situations and identification of the prominent ones are important pre-requisites in formulating biological control.

A field investigation by Cheng (1989) showed 76 species in 13 families of spiders in the paddy fields of South Zhenjiang. They were mainly in Araneidae, Lycosidae, Tetragnathidae, Theridiidae, Erigonidae, Clubionidae, Thomisidae, Oxyopidae and Linyphiidae. Of the arthropod predators 31.4 per cent was found to be spiders.

A survey conducted in parts of Thrissur and Ernakulam districts of Kerala to identify the natural enemies associated with brown planthopper (Bph) revealed that *C. lividipennis* and *Harmonia octomaculata* (Fab.) (=*Coccinella arcuata* F.) were widespread in the State as natural enemies of the pests (KAU, 1980). Yasumatsu *et al.* (1981) regarded damselflies as the important predators of stem borer moth. Rawat and Diwakar (1982) carried out a survey of parasitoids and predators of insect pests of rice on the kharif crop each year from 1975 to 1980 in Chhatisgarh region to assist in the planning of integrated control measures.

The combined action of the two predators *C. lividipennis* and *Lycosa pseudoannulata* (Boesenberg and Strand) is important in maintaining Bph population below damaging levels (IRRI, 1985). Bharadwaj and Pawar (1986) described *C. lividipennis, L. pseudoannulata, Paederus fuscipes,* Curtis *Brumus suturalis,* (Fabricus) *Coccinella septumpunctata* Linnaeus and *Scymnus* sp. as effective predators of rice planthoppers. Kaushik *et al.* (1986) observed the simultaneous occurrence of *P. fuscipes, B. suturalis* and *L. pseudoannulata* with *N. virescens, S. furcifera* and *N. lugens.*

Reghunath *et al.* (1990) conducted a study in the Vellayani lake ecosystem to assess the natural enemies associated with various rice insect pests. They listed 15 species of natural enemies of rice pests belonging to 13 families and five orders.

Gupta and Pawar (1992) described the spiders, coccinellids and carabids as the most important natural enemies of rice pests.

Ooi and Shepard (1992) reported that natural enemies control rice insect pests in tropical Asia. The occurrence and importance of natural enemy changes from season to season and between locations. Ying *et al.* (1996) listed a total of 85 species of natural enemies of rice pests belonging to 61 genera, 24 families and two orders from Hunan, China. Natural enemies particularly the complex of egg parasitoids, spiders and orthopteran predators regulate the population of rice yellow stem borer *S. incertulas* (Catling and Islam, 1993).

In rice fields of Karnataka *Polytoxus* sp. was recorded preying on adults of Bph (Gubbiah *et al.*, 1993). A survey was undertaken by Khaliq and Siddique (1995) in Azad Kashmir to identify the Odonata in rice fields. A total of 14 species were identified, six belonging to Libellulidae and eight to Coenagrionidae. Kobayashi *et al.* (1995) investigated the populations of *O. indica* larvae inhabiting the gall cavities of *O. oryzae.* Fortnightly surveys of natural enemies of pests in rice ecosystem of Kottankkara watershed in Kollam district of Kerala revealed the presence of 10 species of predators and five species of hymenopteran parasitoids (Nandakumar and Pramod, 1998).

The predatory complex of *N. lugens,* comprised of *C. lividipennis, L. pseudoannulata, Tetragnatha maxillosa* Thorel, *Atypena formosana* (Oi), *M.d. atrolineata, Pseudogonatopus* sp. *Micraspis* sp. and *Ophionea nigrofasciata* Schmidt-Goebel (Bhaskar, 1999). The hymenopteran diversity in single and double cropped paddy in Thrissur district has been studied (Beevi *et al.*, 2000b).

2.3 Common predators of rice ecosystem

Extensives studies have already been done on the population dynamics and impact of important predators on the management of key pests of rice. The relevant results have been compiled and presented below.

2.3.1 Predatory mirid, *C. lividipennis*

Pawar (1975) in a survey of planthoppers and leafhoppers in rice growing areas of Himachal Pradesh observed *C. lividipennis* attacking eggs and nymphs of plant and leafhoppers. This was the first record of mirid attacking the pest in India.

Kalode (1976) reported that in the kharif season in Hyderabad, *N. lugens* remained below the economic threshold level during the initial stages of growth of the crop as a result of ecological factors including predation by *C. lividipennis*.

Cyrtorhinus lividipinnis was found preying on the *N. lugens* at Bapatla, Andhra Pradesh during kharif in 1975 (Murthy *et al.*, 1976). Studies on the seasonal abundance of the two species showed that predator was capable of rapid multiplication and was able to control *N. lugens* under favourable conditions.

Pathak and Saha (1976) found the mirid preying on the nymphs of *N. lugens* in the Tarai region of India.

A survey conducted by Abraham (1980) revealed that *C. lividipennis* was widespread in Kerala. The number of planthopper adults or nymphs per m^2 ranged from 0-685 and population of the predator bug ranged from 8-51. Feeding trials revealed that *C. lividipennis* adults fed at the rate of 5-10 Bph eggs/day, while nymphs ate two eggs/day.

Knight *et al.* (1982) reviewed the quantitative information on the effect of natural enemies on *N. lugens* attacking rice in tropical agroecosystem. Studies in Philippines on the mirid egg-predator *C. lividipennis* suggested that it was ineffective except during outbreaks.

Cyrtorhinus lividipennis is an important egg predator of planthoppers and leafhoppers in tropical rice fields. It occurs in many rice growing areas and has

been found to be closely related to population of brown planthopper (Kuno and Dyck, 1984).

Cyrtorhinus spp. and *Tytthus* spp. are specialist predators on homopteran eggs inserted into plant tissue, although they prey to some extent on young nymphs (Greathead, 1982). He also found that *C. lividipennis* is the most abundant and frequently encountered species in rice fields.

The predatory mirid bug *C. lividipennis* is an effective natural enemy of rice hopper pests mainly brown planthopper *N. lugens*, white backed planthoppers *S. furcifera* and the green leafhopper *N. virescens* (Bentur and Kalode, 1985).

Nymphs and adults of the mirid *C. lividipennis* were reported to feed on the eggs and nymphs of rice leaf and planthopper (Geetha *et al.*, 1992).

2.3.2 Spiders

Many workers have recognized the importance of spiders in suppressing insect pest population of agricultural importance (Okuma, 1968, Kiritani, 1972, Chandra, 1978, Kamal, 1981).

Kiritani *et al.* (1972) reported that *Lycosa* fed on brown planthopper and green leafhopper in a ratio of 5:2.

The wolf spider *L. pseudoannulata* is one of the important predators of the brown planthopper, *N. lugens* (IRRI, 1973).

Samal and Misra (1975) reported about 20 species of spiders preying on *N. lugens* on rice fields in India. Salticids were the most voracious feeders followed by lycosids and oxyopids.

In the dry season rice crop at Baptla in Andhra Pradesh, three species of predatory spiders *Pardosa annandalei* (Gravely), *Argiope pulchella* and

Tetragnatha sp. operating at different vertical levels in the crop kept populations of *N. lugens* in check (Rao *et al.*, 1978).

Chatterjee and Dutta (1979) presented a list of nine species of spiders that were observed preying on *N. lugens*. Thomas *et al.* (1979) reported the occurrence of large numbers of spiders (average 2/hill) on rice crops in Kuttanadu, Kerala, where *N. lugens* is endemic. In field cage tests the seven spider species found to be efficient predators of *N. lugens* were *Lycosa* sp., *Pholcus* sp., *Marpissa mandali*, *Tetragnatha* sp., *Linyphia* sp., *Oxyopes sakuntalae* and *Argiope undata.*

Among the predators, spiders are highly abundant in rice fields preying on a wide array of insect pests (Barrion, 1980).

Spiders appeared to be the most important predators of WBPH nymphs and adults in the green house trials. *Lycosa pseudoannulata* killed 1.5 WBPH/day, while *O. javanus* killed 2.3 WBPH/day. *Argiope catenulata* Doleschall and *T. japonica* were 10 important spider species killing WBPH (IRRI, 1980).

Nath and Sarkar (1980) reported that six species (of the families Oxyopidae, Lycosidae, Thomisidae, Argiopidae, Salticidae and Linyphiidae, respectively) occurred on the summer crop at Khahankal and flood prone area of West Bengal. Spiders have higher host finding ability and capacity to consume greater number of prey than other paddy field inhabiting predators (Kamal, 1981).

Predation on Bph by the wolf spider *L. pseudoannulata* was observed in green house experiments (IRRI, 1985).

Gupta *et al.* (1986) recorded 15 species of spiders comprising 11 genera under six families.

Spiders constitute the major component of the predatory arthropod fauna of rice ecosystem and suppress the populations of the pests like brown

planthopper, green leafhopper, white-backed planthopper, leaf folder and whorl maggot significantly (Bhathal and Dhaliwal, 1990).

A survey conducted to study the abundance, diversity and food web of spiders in and around the Bangladesh Rice Research Institute Farm recorded 12 species belonging to 10 genera under eight families (Kamal *et al.*, 1990). *Oxyopes javanus* and *Tetragnatha javana* Thorell were found to be the common species in three rice environments i.e., seed bed, irrigated rice field and weedy fallow. Irrigated rice fields had richer and more diverse spider fauna. *L. Pseudoannulata, O. javanus* and *Plexippus* sp. were more abundant than the other species in all the three situations. They also found that the abundance and diversity of spider species are probably related to the growth stage of rice. The species richness value $\sqrt{ma}$) of spiders in rice fields was 3.6 as compared to 3.00 in seed bed and weedy fallow. The species diversity ($H^{'}$) and species evenness ($J^{'}$) of spiders in rice fields were 10 and 0.9 respectively. The overall result indicated that rice fields have richer and more diverse fauna among situations observed. But in terms of total number of individuals, the weedy fallow was the richest.

The detailed investigations on the structure and character of spider communities of single rice cropping field by Shi and Zhang (1991) recorded 45 species belonging to 25 genus. The main components of the communities were *Ummeliata insecticeps*, (Boesenberg and Strand) *Erigonidum graminicolumn* Sundevall, *Perata subpiraticus* and *P. pseudoannulata*. The diversity evenness and abundance index of mid-late stage of rice field were higher than that of early planting rice fields, while the dominance index was in reveres.

Spider fauna of rice ecosystem of Karnataka was studied by Ansari and Pawar (1992).

Kamal *et al.* (1992) reported that *L. pseudoannulata* was the most efficient predator of GLH when compared with *T. javana* and *O. javanus*.

Although spiders feed on a wide array of rice pests, their numerical dominance, stability and diverse behaviour suggested that they were the most significant group of borer predators (Catling and Islam, 1993). Spider populations built up rapidly in the pre-flooded field with highest numbers in the sweeps in fully, the numbers were lower in August and September but increased in October when tetragnathids became more numerous. The density of spider egg sacs also increased steadily greatest number occurring in August.

Murata (1995) conducted a survey to study the density of spiders and their prey in the paddy fields by sweeping method. Ten to 14 families were caught in the study area. Tetragnathid spiders were the most abundant followed by thomisids and clubionids. The spider density flucluated quite synchronously with the densities of planthoppers and leafhoppers. Spiders are the predators of green leafhopper brown planthopper and yellow stem borer (Venkateshalu *et al.*, 1998).

A detailed survey of spider species distributed in four rice tracts of Tamil Nadu by Anbalagan and Narayanasamy (1999) revealed the presence of 21 species belonging to 16 genera of ten families. Spiders like *L. pseudoannulata, O. javanus, Pardosa sumatrana* Thorell, *T. mandibulata, T. maxillosa* and *T. javana* were more populated than other species detected. Population abundance and species diversity of the spiders are found directly related to the growth stage of rice plant. But there existed a clear cut difference in the occurrence of spider species in different regions of rice ecosystem.

2.3.3 Predatory Coccinellids

Coccinella (= *Harmonia*) *arcuata* F. a predator of rice planthoppers *S. furcifera* and *N. lugens* was recorded in 1966 and 1967 at Cuttack (Israel and Rao, 1968).

Abraham *et al.* (1973) recorded *C. arcuata* a predator of Bph for the first time in Kerala State.

Abraham and Mathew (1975) reported that average number of *N. lugens* eaten per day by larvae in the four instars and by the adults of *C. arcuata* was 15, 18, 25, 27 and 29 respectively. The predator population was largest during February-March.

Mammen and Nair (1977) reported that the adults of *C. arcuata* as an efficient predator of nymphs and adults of *Baliothrips biformis* (Bagnall) on rice in Kuttanad tract, Kerala. This is the first record of the Coccinellidae preying on the thrips.

Coccinella rependa Thunberg, *Menochilus sexmaculatus* (Fab.) were predacious on *N. lugens* in Mandya (Manjunath, 1979).

Samal and Misra (1982) observed the larvae of *C. rependa* feeding on nymphs of *N. lugens* on rice at Cuttack. Prey consumption averaged 98 third instar nymphs per day in the laboratory.

Adults of *Brumoides suturalis* (F.) were found preying on nymphs and adults of *S. furcifera* and nymphs of *N. virescens* in New Delhi (Garg and Sethi, 1983).

Larvae of *Micraspis discolor* (Fab.) were found preying on nymphs and adults of *N. lugens* in Cuttack. *M. discolor* preferred third instar nymphs of the delphacid as prey and consumed an average of 47 of them during the entire larval stage under laboratory condition (Samal and Misra, 1985).

Brumoides suturalis, Coccinella septumpunctata L. *M. sexmaculata* and *Scymnus* sp. were found associated with leaf and planthoppers (Kaushik *et al.*, 1986).

Thakur *et al.* (1991) observed *M. sexmaculatus, Coccinella* sp. and *Brumus* spp. preying on *N. lugens* in North Eastern Madya Pradesh.

2.3.4 The veliid bug *M. d. atrolineata*

Kobayashi (1961) observed seasonal fluctuations of *M. d. atrolineata* in paddy fields in Iota, Southern Japan and found that the density reached 400 individuals m^{-2} in insecticide free fields.

The veliid *M. d. atrolineata* has been noted as a predator of the green rice leafhopper *N. cincticeps* (Otake, 1977). Density in July to September was often as high as 100 and sometime reached 1000 m^{-2}.

Ban and Kiritani (1980) conducted a comparative study of aquatic insects densities in paddy fields in Southern Japan. They found that *M. douglasi* predominated in the rice fields.

Kenmore (1980) studied Bph population dynamics in paddy fields in the Philippines. He surveyed veliid density in flooded paddy fields in various seasons and localities and found that peak density was fairly constant at about 500 individuals m^{-2}. The veliid did not appear to show a density related response to Bph population levels.

Microvelia sp. was recorded as a predator of the Bph nymphs, on rice in Japan (Samal and Misra, 1981). Several species of *Microvelia* are distributed throughout tropical South East Asia, *M. d. atrolineata* predominates in Luzon Philippines (Yano *et al.*, 1981).

Chen and Chiu (1982) reported that both the nymphs and adults of *M. douglasi* which walked rapidly over any water surface in rice field, preyed on nymphs and adults of the planthopper as well as other insects falling in to water.

The veliid is a predator of Bph (especially small nymphs) GLH and WBPH in the Philippines (IRRI, 1982).

In India the veliid *M. d. atrolineata* was reported preying on *N. lugens* for the first time in Karnataka (Gubbiah, 1983). Adults and nymphs of the bug were found on the surface of water near rice plant infested with the planthoppers.

Nakasuji and Dyck (1984) considered *M. d. atrolineata* as one of the most important natural enemies of the brown planthopper in tropical Asia. Predator density in paddy fields is generally high and high density often induces plural hunting, which promotes efficiency in capturing prey.

2.4 Parasitoids of key pests of rice

2.4.1 Stem borer parasitoids

Rao *et al.* (1969) recorded several parasitoids of paddy stem borers in India. They were *Goniozus indicus, Parasierola* sp., *Elasmus* sp., *Tetrastichus* spp., *Trichogramma* spp., *Chelonus* spp., *Amauromorpha* spp., *Isotimia* sp., *Telenomus* spp., *Cotesia (= Apanteles)* spp., *Tropobracon schoenobii* and *Temelucha* sp.

Parasitoids attacking egg mass of *S. incertulas* in West Bengal were *Tetrastichus schoenobii, Telenomus dignus* (Gahan), *Telenomus dignoides* Nixon, *Telenomus rowani* (Gahan) and *Trichogramma japonicum* (Ashmead) (Hikim, 1979).

Nath and Hikim (1979) studied the ichneumonid parasitoids of rice yellow stem borer in West Bengal. They reported *Tropobracon schoenobii, Chelonus munakatae* Munakata and *Amauromorpha flavipes* from larvae, *Stenobracon nicevillei* (Binghan) and *Chelonus* sp. from larvae and pupae and *Rhaconotus schoenobivorus* (Rohver) and *Apanteles schoenobii* from pupae.

Panda *et al.* (1980) observed that the eggs of the yellow stem borer were parasitised by *T. dignoides, T. japonicum* and *Tetrastichus schoenobii* to the extent of 21.5, 0.3 and 5.3 per cent respectively. Rai and Gawda (1980) reported

Tetrastichus schoenobii, T. japonicum and *T. rowani* from Karnataka. Total parasitism ranged from 42-92 per cent. *T. rowani* was the most abundant of the three parasitoids.

A field survey carried out by Rajapaske and Kulasekara (1980) recorded an average parasitization of 88 per cent on stem borer egg mass. Among the five species they listed, *T. dignus* was the most prevalent species occurring on more than 65 per cent of the total egg mass counted.

Trichogramma japonicum has been reported as the most abundant parasitoid in Andhra Pradesh (Anonymous, 1983). Rao *et al.* (1983) reported 77 per cent egg parasitism by *Tetrastichus* sp., *Telenomus* sp., *Trichogramma* sp. in Warangal region of India.

Trichogramma japonicum is a potential egg parasitoid of rice yellow stem borer (Arasumallaiah *et al.*, 1984). The parasitoids reared from *S. incertulas* collected on rice in Coimbatore included *Tetrastichus schoenobii, T. rowani, Telenomus* sp. *Scelio* sp., *A. schoenobii, Rhaconotus* sp. and *Amauromorpha accepta metathoracicea* Ashmead (Chandramohan and Chelliah, 1984).

Hikim (1988) observed parasitism of egg masses by two or more species of parasitoids during the peak period of parasite activity. He also reported that *Telenomus* spp. were most abundant followed by *Tetrastichus schoenobii* and *T. japonicum*.

Telenomus dignus and *T. japonicum* were recorded from eggs of *S. incertulas* in rice fields of Ludhiana, Panjab (Brar *et al.*, 1994). The mean percentage of egg parasitism by *T. dignus* ranged from 35-43 per cent. *T. dignus* and *T. schoenobii* has been reported as the most abundant parasitoids of *S. incertulas* in Gujarat (Pandya *et al.*, 1995).

2.4.2 Gall fly parasitoids

Platygaster oryzae Cameron and *Neanastatus grallirius* were found parasitising the larvae and pupae of gall midge *O. oryzae* in Uttar Pradesh (Ramaiah, 1970). Chand (1981) recorded 40 per cent parasitism by *Platygaster* spp. on *O. oryzae* from Ranchi. Patnaik (1981) reported that the rice gall midge *O. oryzae* is parasitised by *P. oryzae* and *N. grallarius*. Parasitism by *Platygaster* spp. is recorded 100 per cent during November in Andhra Pradesh (Rao *et al.*, 1981). *N. grallarius* and *P. oryzae* together parasitised 20.6-93 per cent of larvae and pupae of *O. oryzae* (Kalidas and Agarwal, 1984).

Patnaik and Satpathy (1984) reported that *P. oryzae* and *N. grallarius* acting alone or together were significant in controlling *O. oryzae* in Orissa. *O. oryzae* was heavily parasitised (21-94%) by *N. grallarius* and *P. oryzae* (Potineni and Agarwal, 1984). The gall fly parasitoid species observed in Orissa were *P. oryzae, Neanastatus* spp., *Propicroscytus mirificus* (Girault), *Eurytoma* sp. and *Teliamesa* sp. *Platygaster oryzae* was recorded as the most dominant parasitoid.

Jena *et al.* (1985) studied the abundance activity and parasitism by *P. oryzae* on *O. oryzae* at Bhubaneshwar. Mathur *et al.* (1991) revealed that *P. oryzae* was most active against *O. oryzae*. Kobayashi and Kudugamage (1994) investigated the hymenopteran parasitoids and parasitism rates of gall midge in paddy fields of 11 districts of Srilanka.

2.4.3 Leaf folder parasitoids

Many species of parasitoids of leaf folder *C. medinalis* have been identified from different parts of Asia.

Rao *et al.* (1969) reported 32 species of larval and pupal parasitoids of *C. medinalis* in India.

In a survey conducted by Abraham *et al.* (1974) found that *Apanteles sylepta, Goniozus* sp., *Coelinius* sp. and *Elasmus* parasitising the larvae of *C. medinalis* whereas *Tetrastichus israeli* and *Brachymeria excarinata* Gahan were found attacking the pupae of *C. medinalis.* This is the first record of *A. sylepta, Coelinius* sp. and *T. israeli* attacking *C. medinalis.*

Das *et al.* (1974) observed ants of the genus *Pheidole* preying on larvae of *C. medinalis. Trichogramma* sp. was found parasitising the eggs of *C. medinalis* on potted rice plants in rice fields in Cuttack (Yadava, 1980).

Cnaphalocrocis medinalis larvae found to be parasitised by the braconid *Apanteles* sp., *Apanteles agustibasis* Wilkinson and *Bracon* sp., while pupae were parasitised by the ichneumonid *Xanthopimpla flavolineata* Cameron and *Ctenopelma* sp. (Pati and Mathur, 1982).

Fourteen species of parasitoids were collected from the larvae of the leaf folder *C. medinalis* and *Marasmia patnalis* and over 75 per cent were in the genera *Cardiochilus, Cotesia, Copidosomopsis, Goniozus* and *Macrocentrus* (IRRI, 1985).

Ahmed *et al.* (1989) carried out a survey in rice fields in Pakistan to identify the natural enemies of *C. medinalis.* The main parasitoids collected were *Trichogramma* sp. (in 8.35 per cent of eggs), *A. angustibasis* (in 6.14 per cent of larvae), *Brachymeria* sp., *Solenopsis geminata* (Fab.) and *Ischnura forcipala.*

Arida and Shepard (1990) studied the difference in rates of parasitism on leaf folder *C. medinalis* in transplanted and direct seeded rice. Highest level of parasitism occurred when predation was lowest. *Trichogramma* sp. was the most abundant egg parasitoid. At least 12 species of parasitoids emerged from leaf folder larvae. *Goniozus triangulifer* Kieffer was one of most common parasitoids. Other abundant parasitoid groups included *Cardiochilus philippinensis* Ashmead, *Macrocentrus* nr *trimaculus, Trichoma* sp. and *Temelucha* sp.

2.4.4 Plant and leafhopper parasitoids

The parasitoid complex on nymphs and adults of Bph include Drynidae, Strepsiptera and Pipunculidae (Miura *et al.*, 1977, Otake *et al.*, 1976). It has been reported that *Anagrus* sp., *Anagrus optabilis* (Perkins) and *Oligosita* sp. parasitised planthoppers but mymarids failed to parasitise leafhoppers (Anon, 1978).

Manjunath (1979) has reported *Oligosita* sp., *Haplogonatopus* sp., *Echthrodelphax fairchildii* (Perkins) and *Elenchus* sp. as promising in checking the population of hoppers.

Three mymarid genera viz. *Anagrus* Haliday, *Gonatocerus* Nees and *Mymar* Cuelis and one trichogrammatid *Oligosita* Walker were found parasitising rice hoppers in Philippines (Chandra, 1980). *Anagrus* was the most common one parasitising the brown planthopper, white-backed planthopper and green leafhoppers, while *Gonatocerus* was specific to the Glh species. *Mymar* was a rare parasitoid. The trichogrammatid *Oligosita* parasitise all the four hopper species studied. Parasitoid complex of *N. lugens* in the rice fields of different countries has been listed by Greathead (1982).

Intensive surveys in Andrapradesh by Bentur and Kalode (1985) resulted in the discovery of 100 egg parasitoids, seven nymphal parasitoids and a hyperparasite. This was the first record of *Oligosita tachikawai, Anagrus armatus* (Ashmead) and *Gonatopus* sp. Among the egg parasitoids *Anagrus* spp. and *Oligosita* spp. were predominant on planthoppers while *Gonatocerus* sp. and *Paracentrobia* on leafhoppers.

Parasitoids of *N. lugens* in rice included the egg parasitoids *Anagrus* sp. and *Oligosita* sp. and nymphal-adult parasitoids belonging to Drynidae, Pipunculidae and Strepsiptera (Gupta and Pawar, 1989).

Watanabe *et al.* (1990) studied the natural enemies of *N. lugens* and *S. furcifera* in two direct sown rice fields of Muda area in Sri Lanka. Parasitism by Hymenoptera was the major mortality factor in the egg stage. The parasitoids *Anagrus* sp. and *Oligosita* sp. emerged from eggs of both speices of delphacid.

2.5 Correlation studies

Kenmore (1980) analysed population changes of Bph in six unsprayed rice crops during 1977-79 at IRRI. Analysis of samples showed that there was a strong correlation between spider density (chiefly *Lycosa* spp.) and peak prey density (r = 0.929) and that spiders exhibited a density dependent numerical response (r = 0.812-0.969).

Bharadwaj and Pawar (1986) reported that *L. pseudoannulata* had a positive correlation (4 = 0.436) with *N. virescens, S. furcifera* and *N. lugens*, whereas *C. lividipennes, P. fuscipes, B. suturalis* and *C. septumpuctata* had a negative collection (r = -0.318).

Lycosa pseudoannulata showed a positive correlation with the total leaf and planthopper population. While the population of *P. fuscipes* and *B. suturalis* exhibited a negative correlation (Kaushik *et al.*, 1986).

Predator-Homoptera correlations were significant in irrigated rice fields of Philippines. Highly positive correlations were obtained for veliids, spiders and *C. lividipennis* (Heong *et al.*, 1991).

Reddy (1991) studied the co-variation between insects in rice field and the important spider species. Most common spiders were *P. pseudoannulata, A. formosana* and *T. maxillosa*. *T. maxillosa* population appeared to be directly related to the number of dipterans. Similar relationships were found between *A. formosana* and Bph, WBPH, dipterans and all hoppers. *Pardosa pseudoannulata* populations however were not related to Bph and WBPH.

The populations of *C. lividipennis*, *L. pseudoannulata*, *T. maxillosa* and *Pseudogonatopus* sp. showed a significant positive correlation and those of *A. formosana*, *M. douglasi*, *Micraspis* sp. and *O. nigrofasciata* had significant negative correlation with the population of *N. lugens* (Bhaskar, 1999).

Beevi *et al.* (2000a) noticed a highly positive correlation ($P = <0.005$) between the population of homopterans and their major predator *C. lividipennis*. Positive correlations were also observed between the pest and predators and pest and parasitoids.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation was undertaken with the objective of quantifying the pests and natural enemies present in different paddy ecosystems of Thrissur district. The species composition, abundance and relative occurrence of predators, parasitoids and insect pests present in different rice fields of Thrissur district was assessed. The survey work was conducted at farmer's field during rabi season of 1998-99 (October-November, 1998 to March-April, 1999).

3.1 Selection of sites

The available rice fields in Thrissur district were stratified into two agro-ecological situations namely kole and non-kole area. Twelve rice growing areas were selected as experimental sites. The design adopted for the sample was one of the stratified multistage random sampling with agro-ecological situations (kole and non kole area) as strata, National extension service (NES) blocks as primary sampling unit, Panchayat as secondary sampling unit, Padashekharams as third stage sampling unit and sample plots as ultimate sampling unit.

One NES block from kole region and one NES block from non-kole region was selected randomly from the list of NES blocks of Thrissur district. From each NES block a random sample of two Panchayats were selected. From each selected Panchayat three Padashekharams were selected randomly. One farmer from each Padashekharam was selected at random from the list of farmers who were not using any pesticides. A plot of twenty cents (816 sq. m.) was selected from each padasekharam for the survey. The descriptions of sites selected for the survey are given in Table 1.

3.2 Sampling

The sampling of pests and natural enemies was done by using a standard sweep net (32 cm. diameter) starting from 15 days after transplanting up to the

Table 1. Description of sites

Block	Panchayat	Village	Locations	Agroecological situations	Cropping pattern	Variety	Date of sampling
Non kole lands							
	Vilvattom	Vilvattom	Mannuthy		Double	Jyothi	2-11-98 to 26-12-98
			Vilvattom		crop	Chiteni	5-10-98 to 16-11-98
Ollukkara			Nettissery	Medium elevation (>7.5 m), rainfed, low land, laterite soil, double crop paddy area	paddy	Jyothi	4-3-99 to 6-4-99
	Pananchery	Thekkump-adam	Tekkumpadam			Jyothi	1-3-99 to 9-4-99
			Pattikkad			Jyothi	,,
			Pananchery			Jyothi	,,
Kole lands							
	Koorkenchery	Nedupuzha	Nedupuzha	Low elevation (MSL -7.5 m) hydromorphic soil, rich in organic matter, flooding during monsoon (Jun-Sept) extensive and contiguous area, paddy is raised after drainage of water.	Single	Mattathriveni	7-12-98 to 23-1-99
			Avinissery		crop	Jyothi	,,
Cherpu			Kanimangalam		paddy	Jyothi	5-1-99 to 12-2-99
	Parallam						
		Parallam	Jubilipadam			Jyothi	8-1-99 to 16-2-99
			Parallam			Jyothi	,,
			Mullakkara			Jyothi	,,

panicle emergence stage. From each 20 cents plot five samples were taken from five locations as five double stroke sweeps. The collections in each sample were killed separately in ethyl acetate and collected in separate polyethene bags and brought to laboratory. A total of six samples were taken at weekly intervals. The specimens on each sampling date from different locations were transferred into petridishes labelled properly and then dried by keeping in hot air oven at 50°C and maintained for further sorting, counting and identification. The specimens were observed and studied in the laboratory using a stereomicroscope. The samples from each location on each sampling date were examined separately. All the arthropods obtained in the samples were separated and grouped based on the taxonomic orders, genera and identified up to species level wherever possible. The number of specimens obtained under each category on each date was counted and recorded. The count of five sweep net collections on each sampling date was pooled and the total number of pests and natural enemies were recorded. They were then grouped into different guild categories as phytophages, entomophages (Predators and Parasitoids) Diptera and others (Heong *et al.*, 1991).

The available published records were referred for the confirmation of identification at species level of insect pests and predators. The hymenopterans were identified up to the species level with the help of taxonomic keys. Final identification and confirmation of the species was done by Dr.T.C.Narendran, Professor of Zoology, Calicut University, Calicut.

3.3 *In situ* count of plant and leafhopper and their predators

The *in situ* population count of Brown Planthopper (Bph) *Nilaparvata lugens* (Stal), leafhoppers (*Nephotettix* spp.) and their predators were also taken from the selected plots at weekly intervals starting from 15 days after transplanting till the harvest of the crop. Population counts were taken from twenty hills, which were selected randomly by moving diagonally in the plot. Population of leaf and planthoppers and its important predators viz. *Cyrtorhinus lividipennis* Reuter,

Lycosa sp., *Tetragnatha* sp., *Ophionea* sp., *Micraspis* sp., *Microvelia* sp. and Staphylinid were recorded separately for each hill. The area between four adjacent rows was taken equivalent to one hill to count the predator floating on water.

3.4 *In situ* collection of parasitoids of *Scirpophaga incertulas* (Walker)

Stem borer egg masses available in the selected plots at the time of sampling were collected at weekly intervals. Each egg mass was kept in separate tubes in the laboratory and observed daily. Moist cotton swab was placed inside the tube to maintain humidity. The total number of egg masses collected and the parasitised egg masses were also recorded. The parasitoids emerged were oven dried and preserved for further identification. They were then identified with the help of taxonomic keys and by sending to the taxonomists.

3.5 Larval and pupal parasitoids of rice leaf folder (RLF) *Cnaphalocrocis medinalis* Guen.

Leaf folder larvae and pupae were collected from all locations on each sampling date. They were maintained in the laboratory in glass jars and fed with fresh paddy leaves every day. In order to ensure the freshness of leaves, rice plants with their root system dipped in water in glass tubes with cotton plug was used. The parasitoids emerged were observed, recorded the numbers and identified up to species level wherever possible.

3.6 Parasitoids of larvae and pupae of gall fly *Orseolia oryzae* (Wood and Mason)

Galls containing larvae and pupae of rice gall midge *O. oryzae* were collected from the plots. The presence of last stage larvae and pupae in the field collected galls was ascertained by visual observation. The portion of gall containing larvae and pupae were cut into small pieces and kept in specimen tubes and observed for the emergence of parasitoids. The number of parasitoids emerged

and gall fly emerged was recorded. The parasitoids were preserved and later identified the species.

3.7 *In situ* assessment of spider population

Spiders present on rice plant canopy and base of the plants were counted and collected in specimen tubes. They were brought to the laboratory for identification of species.

Spiders were preserved in Oudeman's fluid (85 parts of 70 per cent alcohol + 5 parts of glycerine + 8 parts of glacial acetic acid). Preservative was changed after 2-3 days as it become diluted by body fluids of specimens. Spiders were got identified by Dr.P.A.Sebastian, Lecturer, Sacred Heart College, Thevara.

3.8 Statistical tools employed in the study

3.8.1 Quantitative estimates of pests and natural enemies

The data on six sampling periods were pooled and the mean numbers were used for analysis. The population of natural enemies (predators and parasitoids) and phytophages in different locations were compared by analysis of variance test. Comparisons of population of natural enemies and phytophages between two agroecological situation (non-kole and kole area) were made by analysis of variance.

Quantitative estimation of different species and number of individuals in different rice ecosystems was made by estimating species diversity, species evenness and species richness as follows,

i) Species diversity (H') was computed based on Shannon-Weiver formula

$$H' = -\Sigma \, Pi \log Pi$$

where

$$Pi = \frac{Ni}{N}$$

Ni - total number of individuals in a species

N - total number of individuals in all the species encountered

ii) Evenness (J') was also calculated to estimate equitability component of diversity by the formula Pielou (1975)

$$J' = \frac{H'}{\log_{10} S}$$

Where S = species richness

iii) Richness ($\sqrt{ma}$) was calculated using the formulae (Pielou, 1975)

$$\sqrt{ma} = \frac{S - 1}{\log_{10} N}$$

Where S = total number of species collected

3.8.2 Correlation studies

Data from all the locations were pooled and correlation coefficients were worked out to study the relationship between the population of entomophages and phytophages.

RESULTS

4. RESULTS

4.1 Species composition of pests and natural enemies

4.1.1 Phytophages

The total arthropods collected and identified from 12 different rice fields were categorised into two major guilds as phytophages and entomophages. The dipteran insects and other minor arthropods were grouped separately as miscellaneous since majority of them could not be identified to ascertain their exact role. All the important species of phytophages and entomophages observed in the present study are presented in Table 2.

Under the phytophages, altogether there were nine species of sap sucking insects representing five families, in the orders Hemiptera and Thysanoptera. The suborder Homoptera were represented by two families Cicadellidae and Delphacidae. In the family Cicadellidae the important sucking pests observed were *Nephotettix* spp., *Cicadella spectra* Distant and *Recilia dorsalis* (Motsch). The brown planthopper *Nilaparvata lugens* (Stal.) and white-backed planthopper *Sogatella furcifira* (Horvath) were the species found under Delphacidae. The phytophagous Heteroptera were represented by two families viz. Pentatomidae and Alydidae. In Pentatomidae two species recorded were *Menida histrio* (Fb.) and *Tetroda histeroides* (Fb.). *Leptocorisa acuta* (Tumb.) was the single species recorded under Alydidae. The other group of sucking pest observed was *Baliothrips biformis* Bagnall in the order Thysanoptera.

The defoliators and stem borers of the order Lepidoptera consisted of eight species under five families. The important species recorded were *Cnaphalocrocis medinalis* Guen., *Scirpophaga incertulas* (Walker), *Nymphula depunctalis* Guen., *Spodoptera mauritia* Boisd., *Pelopidas mathias* (Fab.), *Parnara colaca* Moore, *Melanitis leda ismene* Crumer and *Psalis pennatula* Hb. The

Table 2. List of pests and natural enemies identified

Guilds / Taxa	Family	Species
A) Phytophages		
i) Sap feeders Hemiptera		
Homoptera	Cicadellidae	*Nephotettix* spp., *Cicadella spectra* Distant, *Recilia dorsalis* (Motsch)
	Delphacidae	*Sogatella furcifera* (Horvath), *Nilaparvata lugens* (Stal)
Heteroptera	Pentatomidae	*Menida hisrio* F., *Tetroda histeroides* Fab.
	Alydidae	*Leptocorisa acuta* (Tumb)
Thysanoptera	Thripidae	*Baliothrips biformis* (Bagnall)
ii) Defoliators root feeders, stem borers		
Coleoptera	Chrysomelidae	*Haltica cyanea* Web. *Oides affinis* J. *Leptispa pygmea* Baby
	Curculionidae	*Echinocnemus oryzae* Marshall
	Hispidae	*Dicladispa armigera* Oliv.
Lepidoptera	Pyralidae	*Cnaphalocrocis medinalis* Guen. *Scripophaga incertalas* (Walker) *Nymphula depunctalis* Guen
	Noctuidae	*Spodoptera mauritia* Boisd.
	Hesperidae	*Pelopidas mathias* (Fab.) *Parnara colaca* Moore
	Satyridae	*Melanitis leda ismene* Cramer
	Lymantriidae	*Psalis pennatula* Hb.
Orthoptera	Acridiidae	*Hieroglyphus banian* (Fab.) *Oxya chinensis* Thunberg

Contd.

Table 2. Continued

Guilds / Taxa	Family	Species
	Tettigoniidae	*Conocephalus pallidus* Redt.
	Gryllidae	*Euscyrtus concinnus* Hanu
	Gryllotalpidae	*Gryllotalpa africana* (P. de Beauv)
Diptera	Cecidomyiidae	*Orseolia oryzae* (Wood-Mason)
	Ephydridae	*Hydrellia philippina* Ferino
B) Entomophages		
1) Predators		
Coleoptera	Coccinellidae	*Micraspis* spp. *Brumoides* sp. *Coccinella transversalis*
	Carabidae	*Ophionea* spp. *Paederus fuscipes* Curtis
Heteroptera	Miridae	*Cyrtorhinus lividipennis* Reuter
	Veliidae	*Microvelia douglasi atrolineata* Bergoth
	Reduvidae	*Polytoxus* sp.
Odonata	Coenagrionidae	*Agriocnemis pygmea* (Rambur) *Agriocnemis femina femina* (Brauer)
Aranea	Lycosidae, Linyphidae Oxyopidae, Salticidae Sparassidae, Ctenidae Tetragnathidae, Thomisidae	Nine species (List in Table 23)
2) Parasitoids		
Hymenoptera	Aphelinidae, Bethylidae Braconidae, Ceraphronidae Chalcididae, Cynipidae Diapridae, Drynidae, Elasmidae, Encyrtidae, Eucoilidae, Eulophidae, Eupelmidae, Eurytomidae, Formicidae, Ichneumonidae, Mymaridae, Platygastridae, Petromalidae, Scelionidae,Torymidae,Trichogrammatidae	77 species (22 families) Lists in Table 19 and 20.

important chrysomelid beetles collected were *Haltica cyanea* Web., *Oides affines* J. and *Leptispa pygmea* Baby (Chrysomdlidae). The root grub *Echinocnemus oryzae* Marshall (Curculionidae), *Dicladispa armigera* Oliv (Hispidae) were the other beetle pests present in the rice fields. Three species of grasshoppers of the families Acridiidae and Tettigoniidae were also recorded as pests under the order Orthoptera. The important dipteran pests of paddy obtained in the sweep net collections were the rice gall midge *Orseolia oryzae* (Wood-Mason) (Cecidomyiidae) and whorl maggot *Hydrellia philippina* Ferino. (Ephydridae).

4.1.2 Entomophages

Parasitoids and predators were the two categories of natural enemies (entomophages).

4.1.2.1 Predators

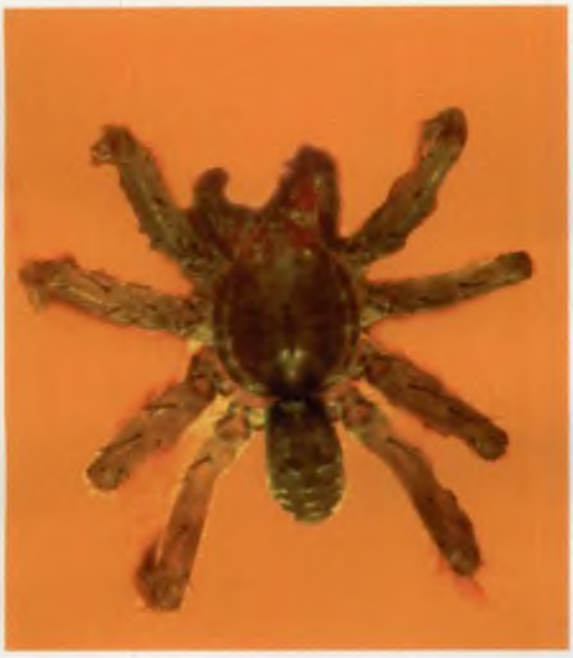
Three coccinellid predators identified were *Micraspis* spp., *Brumoides* spp. and *Coccinella transversalis*. Another important group of entomophages were the predatory bugs in the families Miridae (*Cyrtorhinus lividepennis* Reuter), Veliidae (*Microvelia douglasi atrolineata* Bergoth and Reduvidae (*Polytoxus* sp.) (Plate 1). Under Odonata two species of damselflies identified as predators were *Agriocnemis pygmea* (Rambur), *Agriocnemis femina femina* (Brauer) (Coenagrionidae).

Another important group of non insect predators observed in the paddy field was spiders (Aranea). Nine species belonging to eight families of spiders were identified in the present study. The list of identified species are given in Table 23.

Plate 1.**Common predators in the rice ecosystem**

1a. *Cyrtorhinus lividipennis*

1b. *Tetragnatha* sp.



1c. *Oxyopes* sp.

1d. *Ophionea nigrofasciata*

1e. *Brumoides* sp.

1f. *Micraspis* sp.

4.1.2.2 Parasitoids

Parasitoids were the single largest group of entomophages found in paddy ecosystem. Parasitoids were primarily represented by Hymenoptera. About 77 species belonging to 22 families were identified. The list of species identified are given in Table 19 and 20. Some important hymenopteran parasitoids are given in Plate 2.

4.2 Observations on pests and natural enemies

4.2.1 Non-kole area

The pests and natural enemies collected in sweep net samples from all the locations of non-kole area were grouped into relevant orders and families and the mean numbers recorded under different guilds as taxa are presented.

4.2.1.1. Quantification of pest and natural enemies

In non-kole area, the mean number of the total phytophages varied between 30.17 and 131.50 (Table 3). The highest value was recorded at Pattikkad (131.50) and lowest at Vilvattom (30.17). A relatively high population of Cicadellidae (leafhoppers) was observed in all the three locations of Vilvattom panchayat (16.83 to 52.83). The population of Delphacidae (planthoppers) was maximum in Mannuthy (10.67) and Vilvattom recorded the minimum mean value (1.17). A comparatively high population of Thysanoptera (Thrips) was observed in all the three locations of Pananchery panchayat (49.50 to 86.00) when compared to Vilvattom panchayat (0.00 to 25.67). The plant bugs belonging to the order Heteroptera was low in both the panchayats. In Vilvatoom, the mean number varied from 1.5 to 7.33 and in Pananchery it was in the range of 2.83 to 12.17. The population of Lepidoptera, Orthoptera and Coleoptera collected in the sweep net samples was very low. The other pests were maximum in Nettissery (47.00) due to

Plate 2. **Important parasitoids in the rice ecosystem**

2a. *Macrotelia* sp.

2b. *Pteromalus* sp.

2c. *Propicroscytus mirificus*

2d. *Telenomus* sp.

2e. *Cardiochilus philippinensis*

2f. *Goniozus* sp.

Table 3. Mean number (±SE) of pests and natural enemies by taxa in six locations of non-kole area

Guilds/taxa	Vilvattom panchayat			Pananchery panchayat		
	Mannuthy	Vilvattom	Nettissery	Tekkumpadam	Pattikkad	Pananchery
PHYTOPHAGES	**101.17±15.53**	**30.17±4.49**	**119.50±30.34**	**86.5±36.50**	**131.5±46.41**	**120.17±29.85**
Cicadellidae	52.83±16.18	16.83±3.18	29.67±3.24	8.00±2.67	8.50±1.82	12.83±2.56
Delphacidae	10.67+3.46	1.17±0.75	7.83±2.79	2.50±0.89	2.33±1.23	2.17±0.60
Heteroptera	7.33±3.47	1.50±0.62	3.83±2.81	12.17±3.64	5.00±1.69	2.83±1.67
Lepidoptera	3.00±0.89	4.00±0.97	2.00±1.48	2.67±0.76	3.00±1.21	2.00±0.68
Orthoptera	3.33±1.02	4.67±1.23	1.50±0.76	0.33±0.21	0.67±0.33	0.50±0.34
Coleoptera	1.67±0.33	2.00±0.86	2.00±0.86	1.33±0.80	1.11±0.01	1.33±0.02
Thysanoptera	21.17±12.68	0.00±0.00	25.67±12.43	49.50±26.59	86.00±4.36	76.67±3.08
Other pests	1.17±0.477	0.00±0.00	47.00±31.95	10.00±6.83	24.83±9.17	22.17±0.34
ENTOMOPHAGES	**144.83±25.65**	**74.17±14.43**	**131.17±30.57**	**155.00±21.96**	**212.33±44.40**	**187.33±36.36**
Predators	69.67±16.64	11.67±30.04	31.00±7.47	63.67±10.53	62.83±7.14	49.17±6.56
Aranea	21.67±7.67	4.00±1.84	12.67±6.08	6.33±1.76	20.00±8.69	17.50±2.03
Coccinellidae	9.83±7.67	0.67±0.21	4.17±2.82	17.67±4.71	12.83±3.57	6.50±0.67
Odonata	19.50±5.59	6.67±1.78	3.17±1.28	18.33±4.98	12.33±2.87	5.00±1.09
Miridae	9.00±3.65	0.00±0.00	4.00±2.53	13.667±5.27	9.17±6.11	12.67±1.98
Veliidae	0.83±0.48	0.00±0.00	0.50±2.53	0.66±0.49	0.83±0.83	1.17±0.83
Others	9.00±2.45	0.33±0.211	6.67±1.87	6.50±2.71	7.67±3.52	6.33±2.72
Parasitoids						
Hymenoptera	75.17±14.82	62.50±15.71	100.17±26.09	91.33±13.45	149.50±39.52	138.17±35.90
MISCELLANEOUS						
Diptera	78.83±18.82	4.50±2.29	34.33±15.97	38.83±8.76	58.83±11.25	20.83±3.94

high incidence of *S. mauritia*. In Pattikkad and Pananchery, other pests observed were mainly whiteflies (mean numbers 24.83 and 22.17 respectively).

The population of entomophages including parasitoids and predators was higher than the total phytophages in all the six locations. Between the two panchayats, entomophages population was highest in Pananchery which ranged from 155.00 to 212.33. The major predators collected were spiders, coccinellids, Odonata, mirid bugs and veliid bugs. Spiders (Aranea) were the predominant predators in almost all the locations. The maximum mean number of spiders was recorded in Mannuthy (21.67) and minimum in Vilvattom (4.00). High population of coccinellids was observed in Tekkumpadam (17.67). The mirid bug *C. lividipennis* and veliid bug *M. d. atrolineata* were absent in Vilvattom and in all other locations their mean number ranged from 4.00 to 13.67 and 0.50 to 1.17 respectively. The other predators including *Ophionea* spp. and *P. fuscipes* were maximum in Mannuthy (9.00) and minimum in Vilvattom (0.33). Hymenoptera was the prominent group of entomophages in all the locations and the mean number ranged between 62.50 and 149.50 in six locations. A comparatively high population of Diptera was observed in Mannuthy (78.33) when compared to other locations.

4.2.1.2 Relative abundance of pests and natural enemies by taxa

The relative occurrence and the proportion of different taxa in the respective guild categories were compared and the mean percentage values for all the locations in non kole area were assessed.

The phytophages constituted about 27.72 to 41.91 per cent of all the arthropods sampled in different locations (Table 4). Among the phytophages Cicadellidae (leafhoppers) were most dominant in all the three locations in Vilvattom panchayat and the mean percentage ranged from 24.83 to 55.80, the

lowest being in Nettissery and the highest in Vilvattom. However, in Pananchery panchayat, Thysanoptera was the most predominant phytophages, the proportion of which ranged from 57.23 to 65.39 percentage of all the phytophages. In Vilvattom panchayat, population of thrips was relatively low in Mannuthy and Nettissery representing about 21 per cent while it was absent in Vilvattom. Planthoppers (Delphacidae) were highest in Mannuthy which constituted 10.54 per cent of the phytophages followed by 6.56 in Nettissery and 3.87 in Vilvattom. It was very low in Pananchery panchayat, the mean percentage ranged from 1.77 to 2.89. The population of plant bugs in the suborder Heteroptera (Pentatomidae, Alydidae) varied between 2.36 and 14.07 of all the phytophages sampled. A relatively low per cent of Lepidoptera, Orthoptera and Coleoptera was also observed. Other pests comprised of whiteflies and some noctuid caterpillars, proportion of which ranged between 0.00 to 39.33 in Vilvattom panchayat and 11.54 to 18.88 in Pananchery panchayat. Due to high incidence of *S. mauritia* other pests recorded was maximum (39.33) in Nettissery.

The mean percentage of the entomophages constituting the predators and parasitoids was higher than the total phytophages in all the six locations of non-kole area and the mean per cent varied from 44.62 to 68.15 of the total arthropods (Table 5). The predators constituted between 10.72 and 22.71 per cent of the total entomophages collected. The most dominant predators were spiders, which constituted 31.03 to 40.64 per cent of all the predators in all the sites except in Tekkumpadam where they were substantially low (9.99 per cent). In Vilvattom Odonata (damselflies) was the most dominant predator (57.14) and its proportion in other locations varied from 10.16 to 29.58 per cent. Coccinellids constituted 13.36 to 27.75 per cent in all the locations except in Vilvattom where it was relatively low (5.71). The mirid bug *C. lividipennis* represented 12.89 per cent of the predators collected in Mannuthy, 12.83 per cent in Nettissery, 21.47 per cent in

Table 4. Relative abundance of pests and natural enemies by taxa in six locations of non – kole area (percentage)

Guilds/Taxa	Vilvattom panchayat			Pananchery panchayat		
	Mannuthy	Vilvattom	Nettissery	Thekkumpadam	Pattikkad	Pananchery
PHYTOPHAGES	**31.13**	**27.72**	**41.91**	**30.86**	**32.66**	**36.59**
Cicadellidae	52.22	55.80	24.83	9.25	6.46	10.68
Delphacidae	10.54	3.87	6.56	2.89	1.77	1.80
Heteroptera	7.25	4.97	3.21	14.07	3.80	2.36
Lepidoptera	2.97	13.26	1.67	3.08	2.28	1.66
Orthoptera	3.29	15.47	1.26	0.39	0.51	0.42
Coleoptera	1.65	6.63	1.67	1.54	0.89	0.83
Thysanoptera	20.92	0.00	21.67	57.23	65.39	63.80
Other pests	1.153	0.00	39.33	11.54	18.88	18.45
ENTOMOPHAGES	**44.62**	**68.15**	**46.05**	**55.29**	**52.73**	**57.06**
Predators	21.49	10.72	10.93	22.71	15.61	14.97
Aranea	31.03	34.29	40.64	9.99	31.83	35.59
Coccinellidae	14.08	5.71	13.36	27.75	20.42	13.22
Odonata	27.92	57.14	10.16	29.58	19.63	10.17
Miridae	12.89	0.00	12.83	21.47	14.59	25.76
Veliidae	1.19	0.00	1.60	1.05	1.33	2.37
Others	12.89	2.86	21.39	10.21	12.20	12.88
Parasitoids						
Hymenoptera	23.13	57.43	35.12	32.58	37.12	42.08
MISCELLANEOUS						
Diptera	24.26	4.13	12.04	13.85	14.61	6.35

Tekkumpadam, 14.59 in Pattikad and 25.76 per cent in Pananchery. Veliid bug population was found to be very low in all the sites.

Among the entomophages collected in sweep nets, Hymenoptera was the most abundant single order in all the three locations of Pananchery panchayat and their proportion ranged from 32.58 to 42.08. They represented 23.13 to 57.43 per cent of all the arthropods in other three locations.

The population of Diptera varied from 4.13 to 14.61 per cent in all the sites except for Mannuthy, where it was relatively high (24.26).

4.2.1.3 Relative abundance of major species of arthropods

The relative abundance and the proportion of different species of phytophages and entomophages in six locations of non-kole area was assessed based on mean percentage and is presented in Table 5.

Nephotettix spp. comprising of *N. virescens* and *N. nigropictus* were predominant in all the three locations of Vilvattom panchayat, representing 43.26 to 94.06 of all leafhoppers sampled (Table 5). However, in Pananchery panchayat, proportion of *C. spectra* was found to be high in Pattikkad (56.86) and in Tekkumpadam (52.08) as compared to 29.41 and 41.67 percentage respectively for *Nephotettix* spp. *Recilia dorsalis* was the poorly represented leafhopper species which accounted only 0.32 to 17.42 per cent of all the leafhoppers and it was absent in Vilvattom. *Sogatella furcifera* was the delphacid present in all the sites, the proportion of which varied from 32.81 to 100 per cent in the six locations. The Bph, *N. lugens* was maximum at Mannuthy (67.19) while it was absent in other locations of Vilvattom panchayat. In Pananchery panchayat a low population of Bph was recorded in Pattikkad (14.29) and Pananchery (15.38), whereas it was absent in Tekkumpadam.

Table 5. Proportion of major species of pest and natural enemies in non-kole area (percentage)

Taxa/Species	Vilvattom panchayat			Pananchery panchayat		
	Mannuthy	Vilvattom	Nettissery	Tekkumpadam	Pattikkad	Pananchery
PHYTOPHAGES						
Homoptera						
Cicadellidae						
Nephotettix spp.	60.57	94.06	43.26	41.67	29.41	48.05
C. spectra	39.12	5.94	39.33	52.08	56.86	45.45
R. dorsalis	0.32	0.00	17.42	6.25	13.73	6.49
Delphacidae						
N. lugens	67.19	0.00	0.00	0.00	14.29	15.38
S. furcifera	32.81	100.00	100.00	100.00	85.71	84.62
Heteroptera						
Pentatomidae						
M. histrio	75.00	77.77	100.00	78.08	73.33	64.70
T. histeroides						
Alydidae						
L. acuta	25.00	22.22	0.00	21.92	26.66	35.29
Thysanoptera						
Thripidae						
B. biformis	100.00	0.00	100.00	100.00	100.00	100.00
Other phytophages						
S. mauritia	5.6	0.00	96.04	0.00	0.00	0.00
White flies (unidentified)	94.33	0.00	3.96	100.00	100.00	100.00
ENTOMOPHAGES						
Predators						
Coccinellidae						
Micraspis spp.	96.61	80.00	57.14	95.28	96.16	71.79
Brumoides sp.	0.00	20.00	32.14	3.77	1.29	5.13
C. transversalis	3.39	0.00	10.71	0.94	2.59	23.08

Contd.

Table 5. Continued

Taxa/Species	Vilvattom panchayat			Pananchery panchayat		
	Mannuthy	Vilvattom	Nettissery	Tekkumpadam	Pattikkad	Pananchery
Miridae						
C. lividipennis	100.00	100.00	100.00	100.00	100.00	100.00
Odonata						
A. pygmea	57.26	75.00	73.68	84.07	78.88	73.33
A. femina femina	42.74	25.00	26.32	15.93	21.62	26.66
Aranea						
Tetragnatha sp.	96.15	79.17	84.21	78.95	90.83	95.24
Others	3.85	20.83	15.79	21.05	9.17	4.76
Parasitoids - Hymenoptera						
Tetrastichus sp. I (Eulophidae)	4.66	0.00	3.49	3.29	2.68	0.97
Gonatoceras sp. (Mymaridae)	9.31	8.00	9.65	2.37	6.58	4.83
Fidiohia sp. (Platygasteridae)	0.00	13.60	1.16	3.47	6.91	7.24
Platygaster spp. (Platygasteridae)	16.19	19.73	3.66	6.39	9.36	7.72
P. mirificus (Ptermalidae)	7.32	4.80	4.16	8.94	4.35	4.95
Telenomus sp. - I (Scelionidae)	11.75	16.00	11.15	7.66	7.36	5.30
Telenomus sp. - II (Scelionidae)	13.97	9.33	11.48	9.12	6.69	4.83
Trichogramma spp. (Trichogrammatidae)	1.33	0.00	0.50	2.56	2.89	2.65
Oligosita spp. (Trichogrammatidae)	0.00	0.00	3.66	8.21	3.90	3.26
Others	49.44	2854	51.091	45.29	49.28	58.25

Three species belonging to two families viz., Pentatomidae and Alydidae were observed under the sub order Heteroptera. Among these *M. histrio* and *T. histeroides* (Pentatomidae) together constituted about 64.70 to 100 per cent of the total heteropteran population. The proportion of earhead bug *L. acuta* (Alydidae) varied from 0.00 to 35.29 per cent and it was absent in Nettissery. Under Thysanoptera, *B. biformis* (Thripidae) was the single species recorded in all the locations of non-kole area, while it was absent in Vilvattom.

In case of predators *Micraspis* spp. contributed about 57.14 to 96.61 per cent of the family Coccinellidae. Other species recorded under Coccinellidae were *Brumoides* spp. and *C. transversalis* in the proportion of which ranged between 0.00 and 20.00 and 0.00 to 23.08 percentage respectively. The mirid bug *C. lividipennis* was the only species observed under the family Miridae. Among the two species of damselflies *A. pygmea* was predominant in all the sites, the proportion ranged from 57.26 to 84.07 per cent. Spiders were represented by nine species belonging to eight families, of which *Tetragnatha* sp. was the most abundant one contributing 78.95 to 96.15 per cent. Parasitic Hymenoptera were represented by 77 species in all over the locations. The major species accounted were *Tetrastichus* spp. I., *Gonatocerus* spp., *Fidiobia* sp., *Platygaster* spp., *Propicroscytus mirificus* Girault, *Telenomus* sp. I, *Telenomus* sp. II, *Trichogramma* spp. and *Oligosita* spp.

4.2.1.4 Abundance of phytophages in non-kole area as affected by different locations

The abundance of phytophages in six locations of non-kole area was compared and presented in Table 6.

Among the six different locations surveyed, the mean number of leafhoppers was significantly high at Mannuthy (46.42). However, it was on par with Nettissery (29.31), of the same panchayat. Vilvattom recorded the lowest

Table 6. Mean number of phytophages in six locations of non - kole area

Location	Leafhoppers	Planthoppers	Plant bugs	Lepidoptera	Orthoptera	Coleoptera	Thysanoptera	Others	Total pests
Vilvattom Panchayat									
Mannuthy	6.85 [a] (46.42)	3.05 [a] (8.80)	2.39 [ab] (5.71)	1.81 [a] (2.78)	1.88 [ab] (3.03)	1.45 [a] (1.60)	3.41 [a] (11.13)	1.22 [ab] (0.99)	9.90 [a] (97.51)
Vilvattom	4.07 [bc] (16.06)	1.14 [c] (0.80)	1.32 [b] (1.24)	2.06 [a] (3.74)	2.14 [a] (4.08)	1.48 [a] (1.69)	0.71 [b] (0.004)	0.71 [b] (0.004)	5.45 [b] (29.20)
Nettissery	5.46 [ab] (29.31)	2.62 [ab] (6.36)	1.59 [b] (2.03)	1.29 [a] (1.16)	1.29 [bc] (1.16)	1.48 [a] (1.69)	3.91 [ab] (14.79)	4.82 [ab] (22.73)	10.47 [a] (109.12)
Pananchery Panchayat									
Tekkumpadam	2.78 [c] (7.23)	1.63 [bc] (2.16)	3.37 [a] (10.86)	1.72 [a] (2.46)	0.88 [c] (0.27)	1.21 [a] (0.96)	5.64 [a] (31.31)	2.29 [ab] (12.74)	8.39 [ab] (69.89)
Pattikkad	2.91 [c] (7.97)	1.50 [bc] (1.71)	2.17 [b] (4.21)	1.72 [a] (2.46)	1.025 [c] (0.55)	1.2 [a] (0.94)	7.53 [a] (56.20)	4.27 [ab] (17.73)	10.38 [a] (107.24)
Pananchery	3.57 [c] (12.24)	1.56 [bc] (1.93)	1.69 [b] (2.36)	1.49 [a] (1.72)	0.94 [c] (0.08)	1.13 [a] (0.78)	7.32 [a] (43.08)	4.07 [ab] (16.06)	10.45 [a] (108.70)

Values in paranthesis are means in the original scale
Values having different superscripts differ significantly at 5% level

leafhopper population (16.06) in Vilvattom panchayat, but it was on par with Nettissery. Leafhopper population was found to be significantly low in all the three locations of Pananchery panchayat which were on par and varied from 7.23 to 12.24.

Planthopper population was also significantly high at Mannuthy (8.08) than all other locations except Nettissery (6.36) which was statistically on par. No significant difference was observed in the case of plant- hoppers in the three locations of Pananchery panchayat. A significantly high population of plant bugs was recorded in Thekkumpadam (10.86) and it was statistically on par with Mannuthy (5.71). There was no significant difference in plant bug population in the other locations of Pananchery and Vilvattom. The population of Lepidoptera and Coleoptera was statistically on par in all the six locations.

Vilvattom recorded significantly high population of Orthoptera (4.08), and it was on par with Mannuthy (3.03). However, Mannuthy and Nettissery did not vary significantly in the case of Orthoptera. In all the three locations of Pananchery panchayat, Orthoptera was on par.

Thysanoptera was highest at Pattikkad (56.20) and it was significantly low at Vilvattom (0.004). In all other locations thysanopteran population was on par. Other pests recorded were significantly low in Vilvattom (0.004). However, in all other locations it was comparable. The total pest population was significantly highest at Nettissery (109.12) however, it was closely followed in all other locations and the lowest was recorded in Vilvattom.

4.2.1.5 The abundance of entomophages in kole area as affected by different locations

The predatory complex of rice pests comprised of the mirid *C. lividipennis*, spiders, coccinellids, damselflies (Odonata) and veliid bugs. The

Table 7. Mean number of Entomophages in six locations of non-kole area

Locations	Spiders	Coccinellids	Odonata	*C. lividipennis*	Veliids	Other predators	Hymenoptra	Diptera
Vilvattom panchayat								
Mannuthy	4.40 [a] (18.86)	2.66 [ab] (6.58)	4.17 [a] (16.89)	2.67 [ab] (6.63)	1.07 [ab] (0.64)	2.92 [a] (8.03)	8.45 [ab] (70.90)	8.49 [a] (71.58)
Vilvattom	1.89 [b] (3.07)	1.05 [b] (0.60)	2.54 [bc] (5.95)	0.71 [b] (0.004)	0.71 [b] (0.004)	0.88 [b] (0.18)	7.47 [b] (55.03)	1.94 [c] (3.26)
Nettissery	3.16 [ab] (9.49)	1.80 [b] (2.74)	1.73 [c] (2.49)	1.65 [ab] (2.22)	0.90 [ab] (0.31)	2.53 [a] (5.90)	9.37 [ab] (87.30)	4.75 [bc] (20.06)
Pananchery panchayat								
Thekkumpadam	2.43 [ab] (5.40)	4.07 [a] (16.06)	4.24 [a] (17.48)	3.34 [a] (10.66)	0.99 [ab] (0.48)	2.38 [a] (5.16)	9.44 [ab] (88.61)	6.09 [ab] (36.59)
Pattikkad	3.65 [ab] (12.82)	3.49 [a] (11.68)	3.46 [ab] (11.47)	2.22 [ab] (4.43)	0.98 [ab] (0.46)	2.42 [a] (5.36)	11.52 [a] (132.21)	7.47 [ab] (55.30)
Pananchery	4.21 [ab] (17.22)	2.63 [ab] (6.42)	2.84 [bc] (7.57)	3.57 [a] (12.24)	1.13 [a] (1.78)	2.27 [a] (4.65)	11.14 [ab] (123.60)	4.49 [bc] (19.60)

Values in paranthesis are means in the original scale
Values having different superscripts differ significantly at 5% level

population level of these predators in six locations were compared and presented in Table 7.

The maximum population of spiders was observed at Mannuthy (18.86) followed by Pananchery (17.22), Pattikkad (12.82), Nettissery (9.49) and Tekkumpadam (5.40). Vilvattom recorded a significantly low population (3.07).

A significantly high population of coccinellid predators was observed in Tekkumpadam (16.06) and Pattikkad (11.68) but it was statistically on par with Mannuthy (6.58) and Pananchery (6.42). The mean population of coccinellids in Nettissery (2.74) and Vilvattom (0.60) was compratively low. Tekkumpadam (17.48) recorded the maximum population of Odonata followed by Mannuthy (16.89) and Pattikkad (12.33). Minimum population was observed in Nettissery (2.49). The maximum population of *C. lividipennis* was observed in Pananchery (12.24), followed by Tekkumpadam (10.66), Mannuthy (6.63), Pattikkad (4.43) and Nettissery (2.22). A significantly low population was observed in Vilvattom (0.004). There was no significant difference in the population of veliids among the six locations compared.

Vilvattom recorded a significantly low population (0.18) of other predators as compared to the other locations.

Pattikkad recorded the maximum population of Hymenoptera (132.21) followed by Pananchery (123.60), Tekkumpadam (88.61), Nettissery (87.30) and Mannuthy (70.90). A significantly low population was observed in Vilvattom (55.03).

Maximum population of Diptera was observed in Mannuthy (71.58) and it was statistically on par with Pattikkad (55.30) and Tekkumpadam (36.59). Vilvattom recorded (3.26) the significantly low population of Diptera.

4.2.2 Kole area

The observations on pest and natural enemies sampled in six locations of kole areas are presented in Table 8.

4.2.2.1 Quantification of pest and natural enemies

The mean number of phytophages varied from 58.83 (Nedupuzha) to 251.50 (Jubilipadam) (Table 8). Avinissery recorded the maximum population of Cicadellidae (35.60) followed by Mullakkara (26.00), Jubilipadam (23.50), Parallam (19.50), Kanimangalam (16.33) and Nedupuzha (15.00). A comparatively high population of Delphacidae was obtained in Parallam panchayat (16.17 to 24.00) as compared to Koorkenchery panchayat (8.00 to 10.00). Mean number of Heteroptera ranged between 2.33 and 11.00 in different locations. A very low population of Lepidoptera, Orthoptera and Coleoptera was also observed. The mean population of Thysanoptera attained an extra-ordinary high level in Jubilipadam of Parallam panchayat (176.00). In Koorkenchery panchayat the highest mean number was in Kanimangalam (91.83) followed by Nedupuzha (17.00). The other pests recorded were maximum in Parallam (16.17) and minimum in Nedupuzha and Avinissery (5.00).

In the kole lands also entomophages were higher than phytophages in all the locations and their mean number varied between 107.83 and 263.67. Among the entomophages, the mean number of predators was in the range of 44.33 to 106.83, the maximum in Jubilipadam and minimum in Nedupuzha. Jubilipadam recorded the maximum population of spiders (Aranea) (32.83) and in other locations it ranged between 10.67 and 21.50. The mean population of predatory coccinellids and damselflies (Odonata) ranged between 3.67 and 15.83 and 0.50 and 9.00 respectively. The mirid bug (Miridae) was highest in Jubilipadam (62.50) and minimum in Kanimangalam (11.00). The mean population of veliids and other predators were relatively low in all the locations. The mean densities of

Table 8. Mean number (±SE) of pest and natural enemies by taxa in six locations of kole area

Guild/taxa	Koorkenchery panchayat			Parallam panchayat		
	Nedupuzha	Avinissery	Kanimangalam	Jubilipadam	Parallam	Mullakkara
PHYTOPHAGES	**58.83±14.83**	**83.30±15.73**	**145.17±33.03**	**251.50±135.46**	**89.83±32.52**	**107.33±21.50**
Cicadellidae	15.00±3.09	35.00±9.86	16.33±1.82	23.50±8.07	19.50±3.66	26.00±3.83
Delphacidae	8.00±2.39	10.00±3.62	8.33±3.54	24.00±8.63	18.33±7.11	16.17±6.61
Heteroptera	6.33±4.14	6.67±2.78	11.00±4.84	4.33±2.56	3.17±2.10	2.33±1.48
Lepidoptera	5.33±2.62	8.50±3.99	4.67±0.88	15.00±13.21	2.17±0.70	3.33±0.88
Orthoptera	0.83±0.65	1.33±0.62	1.17±0.31	1.00±0.52	1.67±0.71	0.67±0.422
Coleoptera	1.33±0.72	3.33±1.41	2.50±0.56	1.17±0.60	0.83±0.48	1.67±0.80
Thysanoptera	17.00±9.75	13.50±6.25	91.83±38.02	176.0±114.99	27.50±22.20	45.83±21.11
Other pests	5.00±2.89	5.00±2.88	8.33±5.83	6.50±4.79	16.17±8.26	11.33±3.84
ENTOMOPHAGES	**107.83±22.84**	**213.50±46.42**	**215.17±20.87**	**263.67±20.39**	**218.00±16.77**	**187.67±25.78**
Predators	44.33±11.58	67.83±23.51	46.5±9.88	106.83±31.91	72.17±16.72	75.83±12.95
Aranea	14.50±3.41	16.50±6.45	10.67±2.61	32.83±7.49	18.33±4.06	21.50±3.04
Coccinellidae	3.67±1.28	4.33±1.49	15.83±4.35	4.67±1.43	5.83±2.04	6.00±1.88
Odonata	0.50±0.22	5.00±1.69	6.50±1.67	4.16±1.58	5.67±1.12	9.00±2.48
Miridae	22.33±8.91	37.67±20.91	11.00±6.83	62.50±28.55	39.00±18.48	36.67±12.68
Veliidae	1.17±1.17	1.67±0.84	1.67±1.31	0.83±0.54	0.500±0.500	31.17±0.83
Others	1.83±0.87	2.67±0.72	3.67±1.23	2.17±0.95	2.83±0.65	1.50±0.619
Parasitoids						
Hymenoptera	63.50±21.76	145.67±32.39	168.67±22.66	156.83±29.69	145.83±29.11	111.83±22.33
MISCELLANEOUS						
Diptera	18.83±4.21	26.33±5.89	43.83±5.96	32.00±8.81	30.50±13.28	38.50±9.58

Hymenoptera was in the range of 63.50 to 168.67, highest in Kanimangalam and lowest in Nedupuzha. The mean number of Diptera varied between 18.83 and 43.83.

4.2.2.2 Relative abundance of pests and natural enemies by taxa

Of all the arthropods sampled in different locations of kole area the phytophages constituted about 25.79 to 45.94 per cent of all arthropods as against a relatively high proportion of entomophages in all the locations which ranged from 48.22 to 66.07 percentage (Table 9). Among the phytophages, Thysanoptera was relatively higher than all other taxa in all the locations except in Avinissery which recorded the lowest (16.20). In Kanimangalam and Jubilipadam, it was exceedingly high recording 63.26 and 69.98 per cent of all the phytophages, whereas in these locations leafhoppers were proportionately low with 11.25 and 9.34 respectively. The proportion of planthoppers (Delphacidae) varied from 6.09 to 20.97 per cent in all the sites. The proportion of Heteroptera (plant bugs) was 10.77 in Nedupuzha recording the highest as against 1.17 (lowest) in Jubilipadam. Lepidoptera, Orthoptera, Coleoptera and other pests were relatively low in all the sites.

Entomophages constituted more than 50 per cent of the total arthropods in all the three locations of Koorkenchery panchayat accounting 53.05 to 66.07 per cent. In Parallam panchayat also it varied from 48.22 to 64.43 per cent. Among the entomophages, hymenopteran parasitoids were comparatively higher than the predators in all the locations of kole area and the values ranged from 28.65 to 45.08 per cent. Predators constituted about 12.12 to 23.76 per cent of total entomophages. The mirid bug, *C. lividipennis* was the most dominant predator constituting 48.35 to 58.32 per cent in all the locations except in Kanimangalam where it was substantially low (22.30), but it was compensated with an exceptionally high proportion of predatory coccinellids (32.10). Spiders (Aranea)

Table 9. Relative abundance of pests and natural enemies by taxa in six locations of kole area (percentage)

Guilds/Taxa	Koorkenchery panchayat			Parallam panchayat		
	Nedupuzha	Avinissery	Kanimangalam	Jubilipadam	Parallam	Mullakkara
PHYTOPHAGES	**31.77**	**25.79**	**35.67**	**45.94**	**26.55**	**32.18**
Cicadellidae	25.50	42.00	11.25	9.34	21.71	24.22
Delphacidae	13.60	12.00	6.09	9.54	20.97	15.06
Heteroptera	10.77	8.00	7.58	1.72	3.53	2.17
Lepidoptera	9.07	10.20	3.22	5.96	2.41	3.11
Orthoptera	1.42	1.60	0.80	0.39	1.86	0.62
Coleoptera	2.27	4.00	1.72	0.46	0.93	1.55
Thysanoptera	28.90	16.20	63.26	69.98	30.61	42.70
Other pests	8.50	6.00	6.09	2.58	17.99	10.56
ENTOMOPHAGES	**58.05**	**66.07**	**53.65**	**48.22**	**64.43**	**56.27**
Predators	23.76	20.99	12.12	19.57	21.33	22.74
Aranea	32.95	24.32	21.62	30.64	25.04	28.35
Coccinellidae	8.33	6.39	32.10	4.35	8.08	7.91
Odonata	1.14	7.37	13.18	3.88	7.85	11.87
Miridae	50.75	55.53	22.30	58.32	54.04	48.35
Veliidae	2.65	2.46	3.38	0.78	0.70	1.54
Others	4.17	3.93	7.43	2.03	3.92	1.98
Parasitoids						
Hymenoptera	34.29	45.08	41.44	28.65	43.10	33.53
MISCELLANEOUS						
Diptera	10.18	8.14	10.77	5.84	9.02	11.55

were the next most dominant group of predators which constituted between 21.62 and 32.95 per cent of predators in all the six sites. The proportion of coccinellids ranged between 4.35 and 8.33 per cent in all the sites except in Kanimangalam, where it was relatively high (32.10), Odonata represented 1.14 to 13.18 per cent of the total predators. Population of veliid bugs were negligible in all the six locations. Proportion of dipterans ranged from 5.84 to 11.54 per cent of the total predators sampled.

4.4.2.3 Relative abundance of major species of arthropods

In kole area also, leafhoppers (Cicadellidae) were dominated by *Nephotettix* spp. and their proportion in different locations ranged from 53.33 to 74.49 per cent (Table 10). *Cicadella spectra* was the next important species accounting for 19.66 to 39.05 per cent of all leafhoppers. In all the six locations, representation of *R. dorsalis* was low and its proportion ranged from 5.10 to 16.67 percentage. More than 80 per cent of the planthoppers were represented by *S. furcifera* in Parallam panchayat (84.72 to 95.88). In Koorkenchery panchayat also white-backed planthopper was dominant (58.33 to 93.33 per cent). In all the locations of kole area plant bugs were primarily represented by *M. histrio* and *T. histeroides* accounting 62.12 to 100 per cent. *Leptocorisa acuta* was absent in Mullakkara and in other locations its proportion ranged from 5.26 to 37.88 per cent. *Micraspis* spp. of coccinellid predators were to the extent of 78.57 to 86.35 per cent as compared to the low proportion of *Brumoides* spp. and *C. transversalis*, the maximum being 13.64 and 14.28 per cent respectively. The other predominant predators were the mirid *C. lividipennis*, damselfly, *A. pygmea* and the spider, *Tetragnatha* spp. Among the hymenopteran parasitoids the species representing six families were important. Of these the stem borer egg parasitoids *Telenomus* sp. I and *Telenomus* sp. II were more compared to *Tetrastichus* spp., *Trichogramma* spp. were present in all the locations of kole lands and its proportion ranged from 5.53 to 12.24 per cent. The egg parasitoids of leaf and planthoppers were also

Table 10. Proportion of major species of pest and natural enemies in kole area (Percentage)

Taxa/Species	Koorkenchery panchayat			Parallam panchayat		
	Nedupuzha	Avinissery	Kanimangalam	Jubilipadam	Parallam	Mullakkara
PHYTOPHAGES						
Homoptera						
Cicadellidae						
Nephotettix spp.	53.33	55.24	74.49	56.03	73.50	65.38
C. spectra	30.00	39.05	20.41	31.21	19.66	20.51
R. dorsalis	16.67	5.71	5.10	12.77	6.84	14.10
Delphacidae						
N. lugens	41.66	6.66	22.67	15.28	7.08	4.12
S. furcifera	58.33	93.33	77.36	84.72	92.92	95.88
Heteroptera						
Pentatomidae						
M. histrio	94.74	75.00	62.12	69.23	69.29	100.00
T. histeroides						
Alydidae						
L. acuta	5.26	25.00	37.88	30.76	30.76	0.00
Thysanoptera						
Thripidae						
B. biformis	100.00	100.00	100.00	100.00	100.00	100.00
Other phytophages						
S. mauritia	0.00	0.00	0.00	0.00	0.00	0.00
White flies (unidentified)	100.00	100.00	100.00	100.00	100.00	100.00
ENTOMOPHAGES						
Predators						
Coccinellidae						
Micraspis spp.	86.35	84.62	85.26	78.57	78.57	86.11
Brumoides sp.	13.64	3.83	4.21	7.14	7.14	11.11
C. transversalis	0.00	11.54	10.53	14.28	14.28	2.78

Contd.

Table 10. Continued

Taxa/species	Koorkenchery panchayat			Parallam panchayat		
	Nedupuzha	Avinissery	Kanimangalam	Jubilipadam	Parallam	Mullakkara
Miridae						
C. lividipennis	100.00	100.00	100.00	100.00	100.00	100.00
Odonata						
A. pygmea	100.00	83.33	79.49	80.00	79.41	61.11
A. femina femina	0.00	16.67	20.51	20.00	20.58	38.89
Aranea						
Tetragnatha sp.	84.88	83.67	60.32	87.18	91.81	90.69
Others	15.12	16.33	39.68	12.82	8.19	9.31
Parasitoids - Hymenoptera						
Tetrastichus sp. I (Eulophidae)	4.19	3.09	1.28	1.59	1.83	4.17
Gonatoceras sp. (Mymaridae)	9.45	2.73	5.83	13.18	7.43	6.26
Fidiohia sp. (Platygasteridae)	7.35	11.21	6.72	8.29	10.74	14.46
Platygaster spp. (Platygasteridae)	6.82	9.61	7.90	9.14	10.51	14.90
P. mirificus (Ptermalidae)	4.19	3.89	6.42	3.83	3.77	1.64
Telenomus sp. - I (Scelionidae)	10.24	14.65	7.21	5.95	11.89	11.62
Telenomus sp. - II (Scelionidae)	6.29	8.69	5.83	4.78	6.51	5.51
Trichogramma spp. (Trichogrammatidae)	8.66	12.24	5.53	5.63	5.71	9.24
Oligosita spp. (Trichogrammatidae)	4.19	9.38	5.24	5.31	4.45	3.43
Others	41.32	24.49	48.04	42.20	37.16	28.77

present in almost all the locations and they were mainly *Gonatocerus* sp. The proportion of larval pupal parasitoid of gallfly, *Platygaster* spp. ranged between 6.82 and 14.90 in all the locations.

4.2.2.4 The abundance of phytophages in kole area as affected by different locations

Avinissery recorded a significantly high population of leafhoppers (31.76) and it was statistically on par with Mullakkara (25.20), Jubilipadam (20.29) and Parallam (18.51). A significantly low population was observed in Nedupuzha (14.25) and Kanimangalam (16.15) (Table 11).

Maximum population of planthoppers was observed in Jubilipadam (20.48) followed by Parallam (14.55) and Mullakkara (13.41). A significantly low population was found in Kanimangalam (6.79), Nedupuzha (6.84) and Avinissery (8.38).

There was no significant difference in the population of plant bugs, Lepidoptera and Orthoptera among the six locations surveyed.

Avinissery recorded the maximum mean population of Coleoptera (2.53) followed by Kanimangalam (2.36) and it was statistically on par with Mullakkara (1.24), Nedupuzha (0.99) and Jubilipadam (0.89). Parallam recorded the lowest population (0.64) of Coleoptera.

A significantly high population of Thysanoptera was found in Jubilipadam (106.21), and it was statistically on par with Kanimangalam (73.80) and Mullakkara (30.19). A significantly low population was observed in Avinissery (8.26), Parallam (13.26) and Nedupuzha (9.49). There was no significant difference in the population of other pest in all the locations studied.

Table 11. Mean number of phytophages in six locations of kole area

Location	Leafhoppers	Planthoppers	Plant bugs	Lepidoptera	Orthoptera	Coleoptera	Thysanoptera	Others	Total pests
Kookenchery Panchayat									
Nedupuzha	3.84^{b}	2.71^{b}	1.94^{a}	2.07^{a}	1.03^{a}	1.22^{ab}	3.16^{b}	1.91^{a}	7.40^{b}
	(14.25)	(6.84)	(3.26)	(3.78)	(0.56)	(0.99)	(9.49)	(3.15)	(54.26)
Avinissery	5.68^{a}	2.98^{b}	2.33^{a}	2.55^{a}	1.26^{a}	1.74^{a}	2.96^{b}	1.90^{a}	8.91^{ab}
	(31.76)	(8.38)	(4.93)	(6.00)	(1.09)	(2.53)	(8.26)	(3.11)	(78.89)
Kanimangalam	4.08^{b}	2.70^{b}	3.04^{a}	2.33^{a}	1.26^{a}	1.69^{a}	8.62^{ab}	2.19^{a}	11.72^{ab}
	(16.15)	(6.79)	(8.74)	(4.93)	(1.09)	(2.36)	(73.80)	(4.30)	(136.86)
Parallam Panchayat									
Jubilipadam	4.56^{ab}	4.58^{a}	1.79^{a}	2.73^{a}	1.13^{a}	1.18^{ab}	10.33^{a}	2.05^{a}	13.77^{a}
	(20.29)	(20.48)	(2.70)	(6.95)	(0.78)	(0.89)	(106.21)	(3.70)	(189.11)
Parallam	4.36^{ab}	3.88^{ab}	1.52^{a}	1.55^{a}	1.39^{a}	1.07^{b}	3.71^{b}	3.25^{a}	8.91^{ab}
	(18.51)	(14.55)	(1.81)	(1.90)	(1.43)	(0.64)	(13.26)	(10.06)	(78.89)
Mullakkara	5.07^{ab}	3.73^{ab}	1.43^{a}	1.86^{a}	0.99^{a}	1.32^{ab}	5.54^{ab}	3.13^{a}	10.16^{ab}
	(25.20)	(13.41)	(1.54)	(2.96)	(0.48)	(1.24)	(30.19)	(9.30)	(102.73)

Values in parenthesis are means in the original scale

Values having different superscripts differ significantly at 5% level

Nedupuzha recorded a significantly low population of total pests (54.26) than Jubilipadam (189.11) and in all other locations it was statistically on par.

4.2.2.5 The abundance of Entomophages in kole area as affected by different locations

Among the six locations surveyed, the mean number of spiders was significantly high at Jubilipadam (30.08), and it was statistically on par with Mullakkara (20.94) and Parallam (17.31). A significantly low population was observed in Avinissery (13.94), Nedupuzha (13.41) and Kanimangalam (10.06) all of which belonged to Koorkenchery panchayat (Table 12).

A significantly high population of coccinellid predators was observed in Kanimangalam (13.41) and in all other locations it was statistically on par. Nedupuzha recorded a significantly low population of Odonata (0.44), than all other locations which were statistically on par.

The maximum population of *C. lividipennis* was found in Jubilipadam (43.32) and it was statistically on par with Mullakkara (32.03).

There was no significant difference in the population of veliid bug, other predators and Diptera among the six locations studied.

In the case of Hymenoptera, Nedupuzha recorded a significantly low population (55.30) and in all other locations it was statistically on par.

4.3 Comparison of pests and natural enemies by taxa under two agro-ecological situations (Non-kole and Kole area)

The mean number of phytophages and entomophages over six locations of non-kole and kole area was worked out separately for each taxa for comparison between the two agro-ecological situations.

Table 12. Mean number of Entomophages in six locations of kole area

Locations	Spiders	Coccinellids	Odonata	*C. lividipennis*	Veliids	Other predators	Hymenoptera	Diptera
Koorkenchery panchayat								
Nedupuzha	3.73 [b] (13.41)	1.86 [b] (2.96)	0.97 [b] (0.44)	4.30 [ab] (17.99)	1.04 [a] (0.58)	1.39 [a] (1.43)	7.47 [b] (55.30)	4.29 [a] (17.94)
Avinissery	3.80 [b] (13.94)	1.99 [b] (3.46)	2.24 [b] (4.52)	4.91 [ab] (23.61)	1.32 [a] (1.24)	1.73 [a] (2.49)	11.75 [a] (137.56)	4.99 [a] (24.40)
Kanimangalam	3.25 [b] (10.06)	3.73 [a] (13.41)	2.53 [a] (5.90)	2.71 [a] (6.84)	1.22 [a] (0.99)	1.86 [a] (2.96)	12.86 [a] (164.88)	6.56 [a] (42.53)
Parallam panchayat								
Jubilipadam	5.53 [a] (30.08)	2.15 [b] (4.12)	1.97 [b] (3.38)	6.62 [a] (43.32)	1.05 [a] (0.60)	1.49 [a] (1.72)	12.13 [a] (146.64)	5.44 [a] (29.09)
Parallam	4.22 [ab] (17.31)	2.29 [b] (4.74)	2.43 [b] (5.40)	5.62 [ab] (31.08)	0.90 [a] (0.31)	1.75 [a] (2.56)	11.67 [a] (135.69)	5.13 [a] (25.82)
Mullakkara	4.63 [ab] (20.94)	2.41 [b] (5.31)	2.45 [b] (5.50)	5.66 [ab] (32.03)	1.13 [a] (0.78)	1.32 [a] (1.24)	10.39 [ab] (107.45)	5.96 [a] (35.02)

Values in paranthesis are means in the original scale
Values having different superscripts differ significantly at 5% level

4.3.1 Phytophages

A significant difference in pest population between non-kole and kole area was seen in the case of planthoppers, the mean numbers were 3.19 and 11.27 respectively (Table 13).

4.3.2 Entomophages

Among the predators, a significant difference in the mean densities was noticed in the case of spiders, Odonata, the mirid *C. lividipennis* and total predators. The occurrence of spiders, *C. lividipennis* and total predators was significantly more in kole area while Odonata was significantly more in non-kole area. There was no significant difference in the population of Hymenoptera and Diptera between the two agro-ecological situations (Table 14).

4.4 Correlation coefficients of pests and natural enemies

The correlation coefficients between the total pests with the total predators and parasitoids and also with specific pests and their natural enemies were worked out and given in Table 15. A highly significant positive correlation was noticed between planthoppers and their major predator *C. lividipennis* (0.787), leaf and planthoppers and spiders (0.498) and total pests and predators (0.419). Correlation between leaf and planthoppers and *C. lividipennis* (0.358) and planthoppers and spiders (0.289) was also significant at five per cent level.

4.5 Quantitative estimate of abundance of pests and natural enemies

4.5.1 Phytophages

The quantitative estimates on species richness, species diversity and species evenness of all the phytophages in kole and non-kole area were done and the data are presented in Table 16. Among the 12 locations surveyed, the total number of individuals (total of six observations) was found to vary to a great

Table 13. Comparison of phytophages between non-kole and kole area

Phytophages	Mean number		CD at 5%
	Non-kole area	Kole area	
Leafhopper	4.27 (17.73)	4.59 (20.57)	0.792
Planthopper	1.92 (3.19)	3.43 (11.27)	0.710*
Plant bugs	2.09 (3.87)	2.01 (3.54)	0.650
Lepidoptera	1.68 (2.32)	2.17 (4.21)	0.566
Orthoptera	1.36 (1.35)	1.17 (0.87)	0.283
Coleoptera	1.33 (1.27)	1.37 (1.38)	0.283
Thysanoptera	4.75 (22.06)	5.72 (32.22)	2.400
Other pests	2.89 (7.85)	2.41(5.31)	1.220
Total pests	9.17 (83.59)	10.15 (102.52)	2.000

*Significantly different
Values in parenthesis are means in the original scale

Table 14. Comparison of entomophages between non-kole and kole area

Entomophages	Mean number		CD at 5%
	Non-kole area	Kole area	
Predators			
Spiders	3.29 (10.32)	4.19 (17.06)	0.790*
Coccinellids	2.62 (6.36)	2.40 (5.26)	0.650
Odonata	3.07 (8.92)	2.18 (4.25)	0.570*
C. lividipennis	2.36 (5.07)	4.97 (24.20)	1.245*
Veliidae	0.96 (0.42)	1.11 (0.72)	0.283
Total predators	6.58 (42.80)	7.92 (62.23)	1.189*
Parasitoids			
Hymenoptera	9.56 (90.89)	11.04 (121.38)	1.600
Miscellaneous			
Diptera	5.54 (30.19)	5.39 (28.35)	1.186

*Significantly different
Values in parenthesis are means in the original scale

Table 15. Correlation coefficients of pests and natural enemies

Particulars	Correlation coefficients
Pests and predators	0.419**
Pests and Parasitoids	0.085
Pests and dipterans	0.137
Leaf and planthoppers and *C. lividipennis*	0.358*
Leafhoppers and *C. lividipennis*	0.138
Planthoppers and *C. lividipennis*	0.787**
Leaf and planthoppers and spiders	0.498**
Leafhoppers and spiders	0.163
Planthoppers and spiders	0.289*
Leaf and planthoppers and coccinellid predators	0.039

** Significant at 1%
* Significant at 5%

extent from 181 (Vilvattom) to 1509 (Jublipadam). Seventeen species of phytophages were detected at Vilvattom though the number of individuals was very low and hence the species evenness attained the maximum of 2.99. In the non-kole area the maximum number of individuals recorded was 789 in Pattikkad, the number of species being 20 and species richness 6.558. The total number of individuals in Mannuthy was 607. However, Mannuthy has recorded the maximum number of species (22), species richness (7.545) and species diversity (2.082). In terms of species richness (7.087) and species diversity (1.956) Vilvattom was next to Mannuthy. In Pananchery panchayat the species richness as well as species diversity were low.

In the kole area, species diversity and species evenness was lowest in Jubilipadam recording 1.268 and 1.509 respectively in spite of a very high count of total individuals. The total number of individuals was lowest in Nedupuzha (353) as with the number of species also (18). Maximum number of species recorded was 23 in Kanimangalam and Jubilipadam. Species richness was highest at Avinissery (7.801) and lowest in Nedupuzha (6.672). Species evenness was found to be the lowest in Jubilipadam (1.509).

4.5.2 Predators

Species richness, diversity and evenness of predators in 12 locations including non-kole and kole area is given in Table 17. In non-kole area, Vilvattom recorded the minimum number of individuals (70) number of species (9), species richness (4.330), species diversity (0.952) and species evenness (1.496) than the other locations. Among the six locations Mannuthy recorded the maximum number of species (17) and species richness (6.102). Total number of individuals (877) and species diversity (1.603) was high at Pattikkad. Species evenness in all the locations except Vilvattom was almost the same and the values were in the range of 2.006 to 2.176 only.

Table 16. Species richness, species diversity and species evenness of phytophages.

Locations	Total no: of individuals in all the species (N)	Number of species detected (S)	Species richness ($\sqrt{ma}$)	Species diversity (H′)	Species evenness (J′)
Non – kole area					
Mannuthy	607	22	7.545	2.082	2.372
Vilvattom	181	17	7.087	1.956	2.99
Nettissery	717	19	6.300	1.749	2.188
Tekkumpadam	519	18	6.261	1.639	2.057
Pattikkad	789	20	6.558	1.271	1.556
Pananchery	721	18	5.948	1.283	1.657
Kole area					
Nedupuzha	353	18	6.672	2.336	2.833
Avinissery	500	22	7.801	2.357	2.645
Kanimangalam	871	23	7.483	1.512	1.723
Jubilipadam	1509	23	6.921	1.268	1.509
Parallam	539	20	6.956	2.027	2.406
Mullakkara	644	20	6.764	1.856	2.235

Table 17. Species richness, species diversity and species evenness of predators

Locations	Total no: of individuals in all the species (N)	Number of species detected (S)	Species richness ($\sqrt{ma}$)	Species diversity (H′)	Species evenness (J′)
Non – kole area					
Mannuthy	419	17	6.102	1.576	2.006
Vilvattom	70	9	4.330	0.952	1.496
Nettissery	187	14	5.720	1.527	2.018
Tekkumpadam	382	15	5.420	1.556	2.120
Pattikkad	877	16	5.820	1.603	2.096
Pananchery	295	14	5.264	1.569	2.176
Kole area					
Nedupuzha	264	11	4.129	1.196	1.943
Avinissery	407	14	4.980	1.257	1.802
Kanimangalam	296	12	4.450	1.605	2.475
Jubilipadam	643	19	6.409	1.056	1.309
Parallam	433	15	5.310	1.243	1.718
Mullakkara	455	16	5.643	1.304	1.735

Among the six locations studied in kole area, Jubilipadam was richer in the number of individuals (643), number of species (19) and species richness (6.409). Species diversity (1.605) and species evenness (2.475) was high at Kanimangalam. Nedupuzha recorded the lowest value of number of individuals (264), number of species (11) and species richness (4.129). Jubilipadam recorded the minimum value of species diversity (1.056) and species evenness (1.309).

4.5.3 Hymenopteran parasitoids

Species richness, diversity and evenness of hymenopteran parasitoids in non-kole and kole area are given in Table 18. The total number of individuals under Hymenoptera varied from a minimum of 375 (Vilvattom) to 1012 (Kanimangalam) in all the 12 locations. In non-kole area, Pattikkad recorded the maximum number of individuals (897). Number of species (77), species richness (25.70) and species diversity (3.818) was highest at Pananchery. Species richness varied greatly among different locations recording maximum at Pananchery (25.70) and minimum at Vilvattom (9.320). Tekkumpadam recorded the maximum value of species evenness (2.914).

In kole area, Kanimangalam was richer in number of individuals (1012), number of species (75), species richness (24.624) and species diversity (3.439). Species evenness was high at Nedupuzha (2.812) and Parallam (2.709) and it ranged between 2.407 and 2.472 in remaining locations.

4.6 Species diversity and abundance of hymenopteran species

Majority of the hymenopteran insects collected in sweep nets from all the locations on each sampling date were identified separately. Altogether 77 species of Hymenoptera could be identified which represented 22 families. Except Formicidae all the 21 were reported to be parasitoid families. Based on the total

Table 18. Species richness, species diversity and species evenness of hymenopteran parasitoids.

Locations	Total no: of individuals in all the species (N)	Number of species detected (S)	Species richness ($\sqrt{ma}$)	Species diversity (H′)	Species evenness (J′)
Non – kole area					
Mannuthy	451	31	11.302	2.854	2.710
Vilvattom	375	25	9.324	2.552	2.632
Nettissery	601	39	13.935	2.873	2.511
Tekkumpadam	548	41	14.605	3.393	2.914
Pattikkad	897	72	24.045	3.609	2.614
Pananchery	829	77	25.700	3.818	2.708
Kole area					
Nedupuzha	381	37	13.948	3.218	2.812
Avinissery	874	45	14.958	2.889	2.458
Kanimangalam	1012	75	24.624	3.439	2.472
Jubilipadam	941	72	23.876	3.384	2.462
Parallam	875	48	15.296	3.209	2.709
Mullakkara	671	51	17.688	3.002	2.407

numbers, under each species they were categorised as less abundant (upto 25), abundant (26-75) and most abundant (76-130).

4.6.1 Non-kole area

The species of Hymenoptera identified in six locations of non-kole area are presented in Table 19. The species diversity and abundance was found to vary according to the location. Maximum number of species were seen at Pananchery (77) followed by Pattikkad (72), Tekkumpadam (41), Nettissery (39), Mannuthy (31) and Vilvattom (25). Fourteen species were found to be present in all the six locations. They were *Encarsia* sp., *Apanteles opacus* Ashmead, *Cardiochilus philippinensis* Ashmead, *Cotesia recini* Bhatnagar, *Cylloceriinae* sp., *Xanthopimpla immaculata* Bingham, *Gonatocerus*, *Mymar* sp., *Platygaster* sp., *Propicroscytus mirificus* (Girault), *Pteromalus* sp. I., *Macrotelia* sp. I., *Telenomus* sp. I and *Telenomus* sp. II. Among this *Telenomus* sp. I and *Telenomus* sp. II were abundant (as accounted by their number, which ranged between 25 to 75) in all the locations. *Platygaster* spp., *P. mirificus*, *Telenomus* sp.I and *Telenomus* sp. II were present on multiple sampling dates in all the six locations of non-kole area.

4.6.2 Kole area

The species diversity and abundance of parasitic Hymenoptera in kole area is given in Table 20. Among the six locations surveyed Kanimangalam recorded the maximum number of species (75) followed by Jubilipadam (72), Mullakkara (51), Parallam (48), Avinissery (45) and Nedupuzha (37). Twenty one species were found to be present in all the locations. They were *Goniozus* sp. I, *Bracon lefroyi*, *Brachymeria excarinata* Gahal, *Elasmus kollimalainus* Mani & Saraswath, *Tetrastichus schoenobii* Ferriere, *Tetrastichus* sp.I., *Eurytoma apanteles* Narendran, *Eurytoma* sp., *Amauromorpha* sp., *Gonatocerus* spp., *Mymar* spp., *Fidiobia* sp., *Platygaster* spp., *P. collaris*, *P. mirificus*, *Pteromalus* sp. I., *Plebiaporus* sp., *Telenomus* sp. I, *Telenomus* sp. II, *Trichogramma* spp. and

Table 19. Species diversity and abundance of Hymenoptera in non-kole area

Sl. No.	Family	Species	Vilvattom panchayat			Pananchery panchayat		
			Mannuthy	Vilvattom	Nettissery	Thekkumpadam	Pattikkad	Pananchery
1	2	3	4	5	6	7	8	9
1	Aphelinidae	*Encarsia* sp.	+	+	++	+	+	++*
2	Bethylidae	*Goniozus* sp.I	+	-	-	-	+	+
		Goniozus sp.II	-	-	+	-	+	+
3	Braconidae	*Apanteles opacus* Ashmead	+*	+*	+*	+*	+	+*
		Bracon lefroyi	+*	-	+	+	+	+
		Cardiochilus philippinensis Ashmead	+*	+	+	+	+	+
		Cotesia parasae	-	-	+	-	+	+
		Cotesia recini Bhatnagar	+	+*	+	+	+	+
		Macrocentrus sp.	+	-	-	-	+	+
		Tropobracon sp.I	-	+	+	-	-	+
		Tropobracon sp.II	-	-	-	-	-	+
4	Ceraphronidae	*Aphanogmus* sp.	-	+	-	+	+	+
5	Chalcididae	*Antrocephalus dividens* Walker	-	-	-		-	+
		Brachymeria excarinata Gahan	+	+	+	–	+	+
		Brachymeria wittei Schmitz	-	-	-	-	+	+
		Hockeria sp.	-	-	-	-	+	+
6	Cynipidae	Unidentified	+	-	+	+	+	+
7	Diapridae	*Trichopria* sp.	-	-	-	-	+	+
8	Drynidae	*Pseudogonatopus* sp.	+	-	-	-	+	+
9	Elasmidae	*Elasmus kollimalainus* Mani & Saraswath	-	-	+*	+	+*	+*
		Elasmus sp.I	+	-	-	+	+*	+*
		Elasmus sp.II	-	-	-	+	+*	+*
		Elasmus sp.III	-	-	+*	-	+*	+*
10	Encyrtidae	*Anagyrus* sp.	-	-	+	-	+*	+*
		Coccidencyrtus sp.	-	-	+*	-	+	+
		Doliphoceras sp.	-	+	++*	++*	+*	+*
11	Eucoilidae	*Esmarus* sp.	-	-	-	-	+	+
12	Eulophidae	*Aprostocetus* sp.	-	-	-	+	+*	+*
		Chrysonotomia sp.	-	-	-	-	+	+
		Oomyzus sp.	+*	-	+	+*	+	+
		Pediobius inexpectatus Kerrich	-	-	-	+	+	+
		Tetrastichus schoenobii Ferriere	-	-	+	+	+	+
		Tetrastichus sp.I	+*	-	+*	+*	+*	+
		Tetrastichus sp.II	+	-	-	+	+	+
13	Eupelmidae	*Eupelmus* sp.I	-	-	-	-	+	+
		Eupelmus sp.II	-	-	-	-	+	+
14	Eurytomidae	*Eurytoma apanteles* Narendran	+*	-	+*	+	+	+
		Eurytoma apara Narendran	-	-	-	+	+	+
		E. manilensis Ashmead	-	-	-	+	+	+
		E. rajeevi Narendran	-	-	-	-	-	+
		E. sheelae Narendran	-	-	-	-	+	+
		Eurytoma sp.	-	-	-	+	+	+
15	Formicidae	*Hypoponera* sp.	-	+	+	+	+	+
		Monomorium dichrorum Forel	+*	-	-	+	+	+
		Unidentified	-	+	-	-	+	-

Contd.

Table 19. Continued

1	2	3	4	5	6	7	8	9
16	Ichneumonidae	*Amauromorpha* sp.	-	-	+	-	+	+
		Charops sp.	-	+	-	-	+	+
		Cylloceriinae sp.	+*	+	+	+	+	+
		Isotima sp.	+	+	-	-	+	+
		Temelucha sp.	-	-	+	-	+	+
		Xanthopimpla immaculata Bingham	+*	+	+	+	+	+
17	Mymaridae	*Gonatocerus* spp.	++*	++*	++*	+	++*	++*
		Mymar sp.	+	+*	+	+	+	+
18	Platygasteridae	*Fidiobia* sp.	-	++*	+*	+	++*	+*
		Platygaster spp.	++*	++*	+*	++*	++*	++*
		Synopeas indicus Mani	-	-	-	-	+	+
19	Pteromalidae	*Callitula* sp.	-	-	-	-	+	+
		Panstenon collaris Boucek	-	-	-	+	+	+
		Propicroscytus mirificus (Girault)	++*	+*	++*	++*	++*	++*
		Pteromalus sp.I	+	+	+	++*	++*	++*
		Pteromalus sp.II	+*	+*	-	+	+	++*
		Pteromalus sp.III	-	-	++*	+	+	+
		Pteromalus sp.IV	-	-	-	-	-	+
20	Scelionidae	*Gryon* sp.	+*	-	+	-	+	+
		Idris sp.I	-	-	-	-	+	+
		Idris sp.II	+	-	-	-	+	+
		Macrotelia lamba Saraswath	-	-	-	-	+	+
		Macrotelia sp.I	+	+*	+	+	+	+
		Macrotelia sp.II	-	-	-	+	+	+
		Plebiaporus sp.	-	+	-	-	+	+
		Telenomus cyrus	-	-	-	+	+	+
		Telenomus sp.I	++*	++*	++*	++*	++*	++*
		Telenomus sp.II	++*	++*	++*	++*	++*	++*
		Trissolcus sp.	-	-	-	-	-	+
		Psix sp.	-	-	-	-	+	+
21	Torymidae	*Torymoides kiesenwetteri* Mayr.	-	-	+	-	+	+
22	Trichogram-matidae	*Trichogramma* spp.	+	-	+	+	++*	+*
		Oligosita spp.	-	-	+*	++*	++*	++*
Total number of species			31	25	39	41	72	77

+ less abundant (up to 25); ++ abundant (26-75);
- not present, * present on multiple sampling dates

Table 20. Species diversity and abundance of Hymenoptera in kole area

Sl. No.	Family	Species	Koorkenchery panchayat			Parallam panchayat		
			Nedupuzha	Avinissery	Kanimangalam	Jubilipadam	Parallam	Mullakkara
1	2	3	4	5	6	7	8	9
1	Aphelinidae	*Encarsia* sp	-	-	+	+*	-	-
2	Bethylidae	*Goniozus* sp.I	+	+	+	+*	+	+
		Goniozus sp.II	+*	-	+	+*	+	+
3	Braconidae	*Apanteles opacus* Ashmead	+	+	-	+*	+*	+*
		Bracon lefroyi	+	+	+*	+	+	+*
		Cardiochilus philippinensis Ashmead	-	-	+	+	+*	-
		Cotesia parasae	+	+	+	+*	+	-
		Cotesia recini Bhatnagar	+	-	+	+	+	+
		Macrocentrus sp.	-	+	+	+	+	-
		Tropobracon sp.I	-	+*	+	+	+	+
		Tropobracon sp.II	-	-	+	+	+	-
4	Ceraphronidae	*Aphanogmus* sp.	-	+	+	+	-	-
5	Chalcididae	*Antrocephalus dividens* Walker	-	-	+	+	-	-
		Brachymeria excarinata Gahal	+	+*	+	+	+	+
		Brachymeria wittei Schmitz	+	-	+	+	-	-
		Hockeria sp.	-	+	+	+	-	-
6	Cynipidae	Unidentified	-	+	+	+	+	+
7	Diapriidae	*Trichopria* sp.	-	+	+	+	-	+
8	Drynidae	*Pseudogonatopus* sp.	-	-	+	+	+	-
9	Elasmidae	*Elasmus kollimalainus* Mani & Saraswath	+*	+	++*	+*	+*	+
		Elasmus sp.I	-	-	+*	+*	-	+
		Elasmus sp.II	+*	+	+	+	-	+
		Elasmus sp.III	-	-	+	-	+*	+
10	Encyrtidae	*Anagyrus* sp.	+*	+*	++*	+	+	_
		Coccidencyrtus sp.	+*	+*	+	+*	-	-
		Doliphoceras sp.	-	-	+	+	+	++*
11	Eucoilidae	*Esmarus* sp.	-	-	+	+	-	+
12	Eulophidae	*Aprostocetus* sp.	-	+	+	++*	+	+
		Chrysonotomia sp.	-	-	+	+	+	+
		Oomyzus sp.	-	+	+	+	+	+
		Pediobius inexpectatus Kerrich	-	-	+	+	+	-
		Tetrastichus schoenobii Ferriere	+*	+*	+*	++*	+*	+
		Tetrastichus sp.I	+*	++*	+	+*	+*	++*
		Tetrastichus sp.II	-	-	+	+	+	+
13	Eupelmidae	*Eupelmus* sp.I	-	-	+	+	+	-
		Eupelmus sp.II	-	-	+	+	-	-
14	Eurytomidae	*Eurytoma apanteles* Narendran	+*	+	+*	+	+	+
		Eurytoma apara Narendran	-	-	+	-	-	-
		E. manilensis Ashmead	-	-	+	+	-	-
		E. rajeevi Narendran	-	+*	+	+	-	-
		E. sheelae Narendran	-	-	+	+	-	+
		Eurytoma sp.	+	+	+	+	+	+
15	Formicidae	*Hypoponera* sp.	-	-	+	+	-	-
		Monomorium dichrorum Forel	-	+*	+	+	-	+
		Unidentified	-	-	-	-	+	-

Contd.

Table 20. Continued

1	2	3	4	5	6	7	8	9
16	Ichneumonidae	*Amauromorpha* sp.	+*	+	+	+	+	+
		Charops sp.	+	-	+	+	+	+
		Cylloceriinae sp.	+	-	+	+	+*	+*
		Isotima sp.	+	-	+	+	-	+
		Itoplectus sp.	+	-	+	-	-	+
		Temelucha sp.	-	-	+	+	-	-
		Xanthopimpla immaculata Bingham	+	+	+	-	+	+
17	Mymaridae	*Gonatocerus* spp.	++*	+*	++*	+++*	++*	++*
		Mymar sp.	+	+	+	+*	+*	+
18	Platygasteridae	*Fidiobia* sp.	++*	+++*	++*	+++*	+++*	+++*
		Platygaster sp.	++	+++*	++*	+++*	+++*	+++*
		Synopeas indicus Mani	-		+	+		-
19	Pteromalidae	*Callitula* sp.	-	-	-	+	-	+
		Panstenon collaris Boucek	+*	+*	++*	+*	+*	+
		Propicroscytus mirificus(Girault)	+*	++*	++*	++*	++*	+*
		Pteromalus sp.I	+*	+*	++*	+*	++*	+*
		Pteromalus sp.II	+*	-	++*	+	++*	-
		Pteromalus sp.III	-	+*	+	+	-	+
		Pteromalus sp.IV	-	+	+*	+	-	-
20	Scelionidae	*Gryon* sp.	-	+*	+	+	+	+*
		Idris sp.I	-	+	+	+	-	-
		Idris sp.II	-	+	+	+	-	+*
		Macrotelia lamba Saraswath	+	+	+	+	+	+*
		Macrotelia sp.I	-	+	+	+	-	+
		Macrotelia sp.II	+	+	+	+	-	-
		Plebiaporus sp.	+	+	+	+	+	+
		Telenomus cyrus	-	-	-	-	-	-
		Telenomus sp.I	++*	++*	++*	++*	+++*	+++*
		Telenomus sp.II	+*	+++*	++*	++*	++*	++*
		Trissolcus sp.	-	-	+	+	+	+
		Psix sp.	-	-	+	-	-	-
21	Torymidae	*Torymoides kiesenwetteri* Mayr.	-	-	+	+	-	+
22	Trichogram-matidae	*Trichogramma* spp.	++*	+++*	++*	++**	++*	++*
		Oligosita spp.	+*	+++*	++*	++**	++*	+*
Total number of species			37	45	75	72	48	51

+ less abundant (up to 25); ++ abundant (26-75); +++ most abundant (76-130);
- not present, * present on multiple sampling dates

Oligosita spp. The most abundant species (total number ranged between 75-130) recorded under different locations were Avinissery (*Fidiobia* sp., *Platygaster* sp., *Telenomus* sp. II, *Trichogramma* spp. and *Oligosita* spp.), Jubilipadam (*Gonatocerus* spp., *Fidiobia* spp. and *Platygaster* spp.), Parallam (*Fidiobia* spp., *Platygaster* spp., *Telenomus* sp.I) and Mullakkara (*Fidiobia* spp., *Platygaster* spp., *Telenomus* sp.1).

4.7 Relative abundance of predators in non-kole and kole area

The relative abundance of all the predators identified in different locations is depicted in Tables 21 & 22. Based on the total numbers they were grouped into less abundant (1-50), abundant (51-100) and most abundant (101-375). Predators were primarily represented by *Micraspis* spp., *Brumoides* spp., *C. transversalis*, *C. lividipennis*, damseflies (*A. pygmea*, *A. f. femina*) and spiders.

4.7.1 Non-kole area

In Mannuthy, Pattikkad and Pananchery, spiders were the most abundant (the total number ranged between 101-375) as compared to other predators (Table 21). In Mannuthy, the other predators like *Agriocnemis* spp., *C. lividipennis* and the coccinellid *Micraspis* spp. were next in abundance (51-100), while *Brumoides* sp. and *A. f. femina* were only less abundant and *C. transversalis* was very low. In Vilvattom *C. lividipennis* and *C. transversalis* were absent and the other predators were of low abundance. In Nettissery except spiders other predators were low in numbers. In Tekkumpadam *Micraspis* spp. were predominant.

4.7.2 Kole area

Spiders and *C. lividipennis* were found to be the important predators in kole area. Except in Kanimangalam, *C. lividipennis* was the most abundant predator in all other locations (Table 22). Spiders were found to be the most

Table 21. Abundance of predators in non-kole area

Predators	Mannuthy	Vilvat-tom	Nettis-sery	Tekkum-padam	Pattik-kad	Panan-chery
1. Coccinellidae						
Micraspis spp.	++	+	+	+++	++	+
Brumoides sp.	-	+	+	+	+	+
C. transversalis	+	-	+	+	+	+
2. Miridae						
C. lividipennis	++	-	+	++	++	++
3. Odonata						
A. pygmea	++	+	+	++	++	+
A. f. femina	++	+	+	+	+	+
4. Spiders	+++	+	++	+	+++	+++

+ less abundant - 1-50; ++ abundant - 51-100; +++ most abundant - 101-375

Table 22. Abundance of predators in kole area

Predators	Nedu-puzha	Avinis-sery	Kaniman-galam	Jubili-padam	Parallam	Mulla kkara
1. Coccinellidae						
Micraspis spp.	+	+	++	+	+	+
Brumoides sp.	+	+	+	+	-	+
C. transversalis	-	+	-	+	-	+
2. Miridae						
C. lividipennis	+++	+++	++	+++	+++	+++
3. Odonata						
A. pygmea	+	+	+	+	+	+
A. f. femina	-	+	+	+	+	+
4. Spiders	++	++	++	+++	+++	+++

+ less abundant - 1-50; ++ abundant - 51-100; +++ most abundant - 101-375

abundant predator in all the three locations of Parallam panchayat. However in Koorkencherry panchayat spiders were abundant (51-100). In Kanimangalam the abundant predators recorded were *Micraspis* spp., *C. lividipennis* and spiders.

4.8 Spiders identified from different locations

The different species of spiders as obtained in the sweep net collections and *in situ* collections are listed out in Table 23.

The study revealed the presence of nine species of spiders belonging to eight families (Table 24). They were *Tetragnatha maxillosa* Thorell, *Lycosa pseudoannulata* Boesenberg & Strand, *Pardosa pesudonnulata, Oxyopes ratnae, Zygoballus* sp., *Phidippus* sp., *Sparassus* sp., *Labotla* sp. and *Ctenus* sp. Of these *T. maxillosa, L. pseudoannulata* and *O. ratnae* were present in all the 12 locations. *Ctenus* sp. was recorded from all the six locations of kole area while it was not present in non-kole area.

4.9 *In situ* population count of leaf and planthoppers and their natural enemies

In situ population of leaf and planthoppers and their natural enemies in 20 hills in non-kole and kole area is presented in Table 24. In non-kole area, Mannuthy recorded the maximum mean population of brown planthopper (12.50) followed by Pattikkad (2.63) and Tekkumpadam (2.5). Green leafhopper population was also high at Mannuthy (11.13) followed by Nettissery (4.88) and Vilvattom (4.13). *C. lividipennis* was the major predator in the field with a highest mean population of 14.75 in Mannuthy. Mean population of *Tetragnatha* spp. ranged between 0.50 and 3.88 recording maximum at Pananchery and minimum at Vilvattom. Mannuthy recorded a high population of *Lycosa* (3.63), than other locations. Mean population of *M. d. atrolineata* was maximum in Tekkumpadam (21.63), while it was absent in Vilvattom. Tekkumpadam recorded the maximum

Table 23. Diversity and distribution of spiders in twelve rice growing sites of non -kole and kole area

Locations	Non-kole						Kole					
	Vilvattom panchayat			Pananchery panchayat			Koorkenchery panchayat			Parallam panchayat		
	Mannu-thy	Vilvat-tom	Nettis-sery	Tekku-mpadam	Pattikad	Panan-chery	Nedu-puzha	Avinis-sery	Kanima-galam	Jubili-padam	Parallam	Mulla-kkara
Telragnathidae												
Tetragnatha maxillosa	+	+	+	+	+	+	+	+	+	+	+	+
Lycosidae												
Lycosa pseudoannulata	+	+	+	+	+	+	+	+	+	+	+	-
Pardosa atropalpis	-	-	-	-	-	+	+	+	+	+	-	+
Oxyopidae												
Oxyopes ratnae	+	+	+	+	+	+	+	+	+	+	+	+
Salticidae												
Zygobàllus sp.	+	-	+	-	+	+	-	+	-	+	-	+
Phidippus sp.	+	+	+	-	+	+	+	-	-	-	+	+
Sparassidae												
Sparassus sp.	+	+	-	+	-	+	+	+	-	+	+	+
Linyphidae												
Labotla sp.	+	-	-	+	+	-	-	+	+	+	-	+
Thomisidae unidentified	+	-	+	-	-	+	+	-	+	-	+	-
Ctenidae												
Ctenus sp.	-	-	-	-	-	-	+	+	+	+	+	+

+ present, - absent

Table 24. *In situ* count of leaf and planthoppers and their natural enemies (Mean number of 8 observations)

Location	BPH	Green jassid	*Lycosa*	*Tetragnatha*	*Ophionea*	Staphylinid	*C. lividipennis*	*Micraspis* spp.	*M.d. atrolineata*
Non-kole area									
Mannuthy	12.50	11.13	3.63	2.63	0.88	0.88	14.75	3.00	14.13
Vilvattom	0.00	4.13	0.13	0.50	0.13	0.00	0.00	0.88	0.00
Nettissery	1.25	4.88	0.25	2.38	0.13	0.13	1.13	0.75	7.00
Tekkumpadam	2.50	2.63	1.00	1.63	5.63	3.25	3.63	2.33	21.63
Pattikad	2.63	2.38	1.63	3.50	0.13	0.75	3.75	2.25	3.75
Pananchery	1.73	3.36	1.00	3.88	0.00	0.00	4.25	1.13	3.13
Kole area									
Nedupuzha	2.25	3.63	1.13	3.25	0.13	0.00	6.75	0.63	14.50
Avinissery	2.13	3.25	1.38	3.00	0.25	0.13	3.88	1.50	7.13
Kanimangalam	2.63	6.13	1.50	4.13	0.25	0.13	3.50	1.13	2.13
Jublipadam	6.13	5.25	1.25	4.63	0.50	0.50	9.38	1.03	9.00
Parallam	3.50	4.88	2.50	3.75	0.25	0.50	9.63	1.00	9.25
Mullakkara	3.00	6.25	2.00	4.88	1.13	1.13	8.88	1.25	6.75

mean population of *Ophionea* spp. (5.63). But in all other locations it was very low. Staphylinid population was also high at Tekkumpadam (3.25).

Among the six locations surveyed in kole area, Bph population was maximum at Jubilipadam (6.13). In all other locations it ranged between 2.13 and 3.50. Mullakkara recorded a high population of green jassid (6.25). *In situ* count of *Lycosa* ranged from 1.13 to 2.5 while it was 3.00 to 4.88 for *Tetragnatha* sp. over six location of kole area. *Ophionea* and Staphylinid count were low. *C. lividipennis* was maximum at Parallam (9.63) followed by Jubilipadam (9.38). Nedupuzha recorded the maximum population of *M. d. atrolineata* (14.5).

4.10 Parasitism of key pests in the field

4.10.1 Egg parasitoids of stem borer

Stem borer egg masses collected from the field were maintained in the laboratory and observed for the emergence of parasitoids. Three species of parasitoids, *Telenomus* spp., *Tetrastichus* spp. and *Trichogramma* spp. were obtained from the parasitised eggs (Table 25). The extent of total parasitism (egg mass wise) in different locations of non-kole and kole area is presented in Table 25.

A very high egg parasitism on stem borer eggs could be noticed, the maximum percentage being in Tekkumpadam (93.70) and the lowest (75) in Avinissery. A single egg mass was found to be parasitised by more than one species. *Trichogramma* spp. usually occurred in association with two other parasitoids especially *Telenomus* spp.

4.10.2 Larval and pupal parasitoids of leaf folder

Six species of parasitoids emerged from leaf folder larvae and pupae collected from different locations (Table 26). They were *Cotesia* (=*Apanteles*) spp.

Table 25. Egg parasitism of stem borer *S. incertulas*

Location	Total egg mass collected	No. of egg mass parasitised	Percentage egg parasitism	Major parasitoids collected
Non-kole area				
Mannuthy	27	24	88.80	*Telenomus* spp., *Tetrastichus* spp., *Trichogramma* spp.
Vilvattom	8	7	87.50	*Telenomus* spp., *Tetrastichus* spp., *Trichogramma* spp.
Nettissery	16	14	87.50	*Telenomus* spp., *Trichogramma* spp.
Tekkumpadam	16	15	93.70	*Telenomus* spp., *Tetrastichus* spp.
Pattikkad	12	10	83.33	*Telenomus* spp., *Tetrastichus* spp.
Pananchery	12	11	91.66	*Telenomus* spp., *Tetrastichus* spp., *Trichogramma* spp.
Kole area				
Nedupuzha	18	15	83.33	*Telenomus* spp., *Tetrastichus* spp., *Trichogramma* spp.
Avinissery	12	9	75.00	*Telenomus* spp., *Trichogramma* spp., *Tetrastichus* spp.
Kanimangalam	16	14	87.50	*Telenomus* spp., *Tetrastichus* spp., *Trichogramma* spp.
Jubilipadam	23	20	86.90	*Telenomus* spp., *Tetrastichus* spp., *Trichogramma* spp.
Parallam	22	20	90.90	*Telenomus* spp., *Tetrastichus* spp., *Trichogramma* spp.
Mullakkara	20	18	90.00	*Telenomus* spp., *Tetrastichus* spp., *Trichogramma* spp.

Table 26. Parasitism on *C. medinalis* larvae and pupae

Location	No. of leaf folder larvae/ pupae collected	No. of parasitoids larvae/ pupae	Percentage parasitism	Major parasitoid species
Non-Kole area				
Mannuthy	40	12	30.00	*Cotesia* (=*Apanteles*).sp., *Cardiochilus philippinensis* Ashmead, *Macrocentrus philippinensis*, *Xanthopimpla* sp.
Vilvattom	16	5	31.50	*Cotesia* (=*Apanteles*) sp., *C. philippinensis*, *M. philippinensis*, *Xanthopimpla* sp.
Nettissery	20	8	40.00	*Cotesia* (=*Apanteles*) sp., *C. philippinensis*, *M. philippinensis*, *Xanthopimpla* sp.
Thekkumpadam	30	9	30.00	*Cotesia* (=*Apanteles*) sp., *C. philippinensis*, *M. philippinensis*
Pattikkad	24	8	33.33	*Cotesia* (=*Apanteles*) sp., *Brachymeria excarinata* Gahal, *C. philippinensis*, *M. philippinensis*, *Xanthopimpla* sp.
Pananchery	22	8	36.36	*Cotesia* (=*Apanteles*) spp., *B. excarinata*, *C. philippinensis*, *M. philippinensis*, *Xanthopimpla* sp.
Kole area				
Nedupuzha	26	11	42.00	*Cotesia* (=*Apanteles*) sp., *B. excarinata*, *C. philippinensis*, *M. philippinensis*, *Xanthopimpla* sp.
Avinissery	20	9	45.00	*Cotesia* (=*Apanteles*) sp., *B. excarinata*, *C. philippinensis*, *M. philippinensis*, *Xanthopimpla* sp.
Kanimangalam	21	9	42.85	*Cotesia* (=*Apanteles*) sp., *B. excarinata*, *Goniozus* sp., *C. philippinensis*, *M. philippinensis*, *Xanthopimpla* sp.
Jubilipadam	24	12	50.00	*B. excarinata*, *Goniozus* sp., *C. philippinensis*, *M. philippinensis*, *Xanthopimpla* sp.
Parallam	20	7	35.00	*C. philippinensis*, *M. philippinensis*, *Xanthopimpla* sp.
Mullakkara	20	9	47.00	*Cotesia* (=*Apanteles*) sp., *Goniozus* sp., *C. philippinensis*, *M. philippinensis*, *Xanthopimpla* sp.

Table 27. Parasitism of gallfly *P. oryzae*

Location	No. of galls collected	No. of galls parasitised	Percentage	Species
Non-Kole area				
Mannuthy	8	3	37.5	*Platygaster* sp.
Vilvattom	2	-	-	
Nettissery	4	1	25	*Platygaster* sp.
Thekkumpadam	6	2	33.33	*Platygaster* sp.
Pattikkad	4	-	-	
Pananchery	4	1	25	*Platygaster* sp.
Kole area				
Nedupuzha	16	4	25	*Platygaster* sp.
Avinissery	6	2	33.33	*Platygaster* sp.
Kanimangalam	5	1	20	*Platygaster* sp.
Jubilipadam	10	4	40	*Platygaster* sp.
Parallam	7	3	42.85	*Platygaster* sp.
Mullakkara	5	2	40	*Platygaster* sp.

B. excarinata, C. philippinensis, Goniozus sp., *M. philippinensis* and *Xanthopimpla* spp. Among these *B. excarinata* was a pupal parasitoid. The extent of larval and pupal parasitism ranged from 30 to 50 per cent in different locations. The larval parasitoids *C. philippinensis* and *M. philippinensis* was present in all the 12 locations, while *Cotesia* (=*Apanteles*) sp. was present in all the six locations of non-kole area and absent in Jubilipadam and Parallam of kole area. *Brachymeria excarinata* was the only one pupal parasitoid recorded in the present study. *Xanthopimpla* sp. was found to occur in all the locations except in Tekkumpadam. *Brachymeria excarinata* was less common and was recorded only in five locations, *Goniozus* sp. was present only in three locations in kole lands.

4.10.3 Larval-pupal parasitoids of gall fly

Only *Platygaster* spp. was obtained as the parasitoid of gall midge, *O. oryzae*. The percentage parasitism ranged from 0.00 to 42.85. No parasitism was noticed in Vilvattom and Pattikkad. The highest percentage of parasitism was recorded at Parallam (42.85 per cent) and lowest being at Kanimangalam (20 per cent) (Table 27).

DISCUSSION

5. DISCUSSION

5.1 Species composition of pest and natural enemies

The arthropods obtained from sweep net collections were categorized into different guilds as used by Heong *et al.* (1991) with some modification. These were phytophages, entomophages (predators and parasitoids) and miscellaneous. All the important species of phytophages and entomophages identified under each taxa are presented in Table 2.

5.1.1 Phytophages

In the present study seven orders belonging to 19 families and 29 species were detected as phytophages. All the species of phytophages identified and presented in Table 2 have already been recorded as the common pests of paddy in Kerala (Nair and Visalakshi, 1999) and other parts of India (Regupathy, 1989). The important homopteran pests of rice identified were *Nephotettix* spp., *R. dorsalis, S. furcifera* and *N. lugens*. The brown planthopper *N. lugens* has been known to cause huge losses to the production (Dyck and Thomas, 1979). Thresh (1989) reported that *N. virescens* transmits the tungro disease of rice. *Baliothrips biformis* was the only species observed under Thysanoptera. Many authors have reported the severe outbreaks of thrips from India (Mammen and Nair, 1977, Nath and Sen, 1978, Velusamy and Chelliah, 1980 and Gubbaiah, 1984).

5.1.2 Entomophages

A total of 19 species of predators and 77 species of parasitoids were recorded in the present study from all the locations. The insect predators encountered in the present study were spiders, coccinellids, carabids, mirid bugs, reduvids and veliid bugs. Altogether nine species of spiders belonging to eight families were identified. The occurrence of a number of species of spiders have already been reported from different rice growing regions of India (Samal and Misra, 1975, Chatterjee and Dutta, 1979, Gupta *et al.*, 1986 and Kamal *et al.*,

1990). The important species of spiders identified in the present study were *T. maxillosa, L. pseudoannulata, P. atropalpis, O. ratnae, Zygoballus* sp., *Phidippus* spp., *Sparassus* sp., *Labotta* sp. and *Ctenus* sp. Similar reports on the occurrence of spiders were of *T. maxillosa, L. pseudoannulata, Oxyopes* sp. (Thomas *et al.*, 1979) and *Pardosa* sp. (Rao *et al.*, 1978). *Cyrtorhinus lividipennis* was the single species observed under Miridae. Many studies have shown the widespread occurrence of *C. lividipennis* in Kuttanad (Abraham, 1980 and Ambikadevi, 1998), Vellayani lake ecosystem (Regunath *et al.*, 1990) and in Kottankkara watershed ecosystem (Nandakumar and Pramod, 1998). In Coccinellidae three species were identified as predators viz. *Micraspis* spp., *Brumoides* spp. and *C. transversalis*. Several authors have reported that these predatory beetles were associated with rice pests (Manjunath, 1979, Garg and Sethi, 1983, Kaushik *et al.*, 1986 and Bhaskar, 1999). Two species of damselflies identified were *A. pygmea* and *A. f. femina.* Ambikadevi (1998) has already reported the occurrence of these species from Moncompu, Kerala. Other predators found were *O. indica, P. fuscipes* (Carabidae) *M.d.atrolineata* (Veliidae) and *Polytoxus* sp. (Reduvidae). The occurrence of these predators have already been reported by Regunath *et al.* (1990) and Ambikadevi (1998) from Kerala.

Altogether 77 species of hymenopteran parasitoids were identified from 12 locations. They belonged to 54 genera and 22 families Table 19 and 20. Except Formicidae all the 21 were reported to be parasitoid families. Hymenoptera is very rich and diverse in the rice ecosystems. The major hymenopteran parasitoids associated with the major pest of rice had been identified and reported by several authors (Rao *et al.*, 1963; Ramaiah, 1970; Abraham *et al.*, 1974; Chandra, 1980; Patnaik and Sathpathy, 1984; Bentur and Kalode, 1985; Patel and Patel, 1989; and Beevi *et al.*, 2000a). Based on a general survey on short duration paddy crop, Hymenoptera was found to be the most abundant and diverse of the arthropods present (Bhalla, 1997).

5.2 Observation on pests and natural enemies in two different rice ecosystems

5.2.1 Non-kole area

The details of the pests and natural enemies collected from six rice growing sites of non-kole area are presented in Tables 3 to 5. The population of pests (phytophages) and natural enemies (entomophages) are given by their respective orders and families (Table 3 and Fig.1a & 1b). The total phytophages population was found to be highest in Pattikkad (131.50) and lowest in Vilvattom (30.17). Among the phytophages a comparatively high population of leafhoppers (Cicadellidae) was observed in all the three locations of Vilvattom panchayat ranging from 16.83 to 52.83 whereas in Pananchery panchayat, its highest mean number was only 12.83. Interestingly, in all the three locations of Pananchery panchayat, the highest mean count of phytophages was in the case of Thysanoptera which ranged from 49.50 to 86.00. In Vilvattom panchayat also next to leafhoppers, thysanopteran population was found to be high in Mannuthy (21.77) and Nettissery (25.67) while it was not present in Vilvattom.

The population of entomophages comprising of parasitoids and predators has outnumbered the total phytophages in all the six locations of non-kole area, the lowest mean number recorded being in Vilvattom (74.17) and highest in Pattikkad (212.33) (Table 3). The major predators recorded in the present study were spiders (Aranea) coccinellid beetles (Coccinellidae) damselflies (Odonata) mirid bugs (Miridae) and veliid bugs (Veliidae). Other minor predators recorded were *Ophionea* sp. and staphylinid *P. fuscipes*. Mirid bugs and *Microvelia* were not present in Vilvattom. The parasitoids belonging to the order Hymenoptera was found to be the single largest group of entomophages in all the six locations studied.

From the total arthropod population count, the relative occurrence of phytophages and entomophages under different taxa in the respective guilds in the

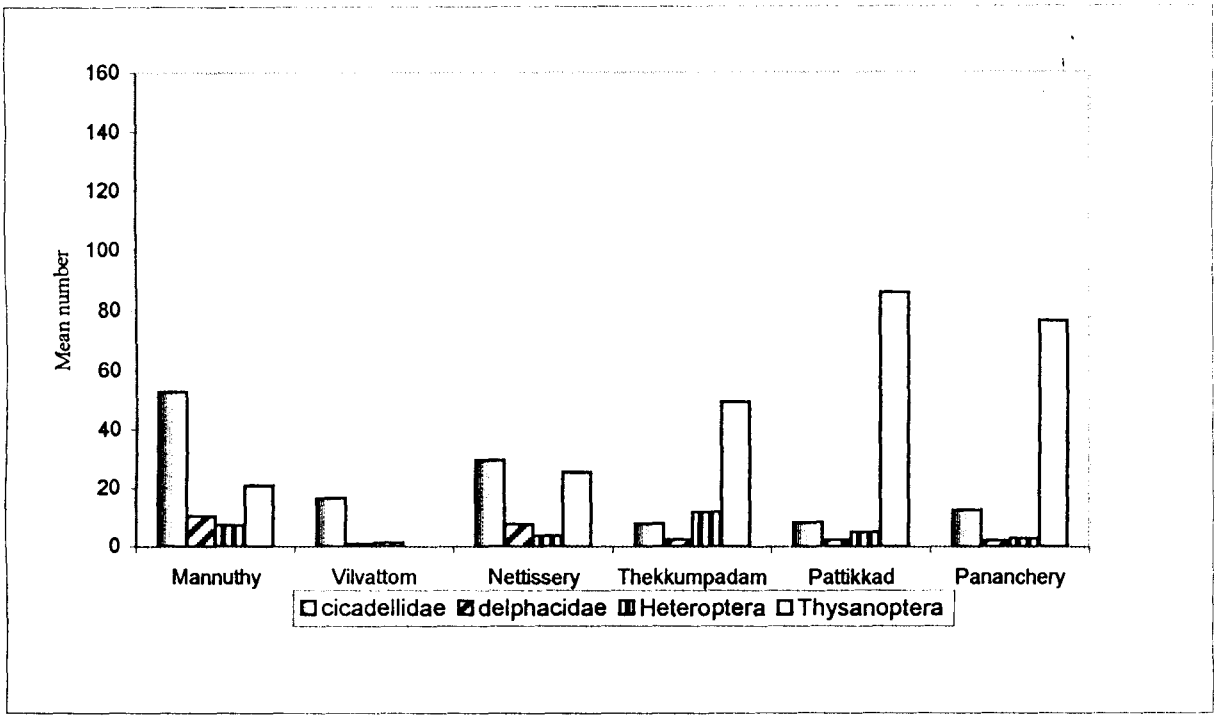


Fig.1a A comparison of major phytophages in different locations of non-kole area

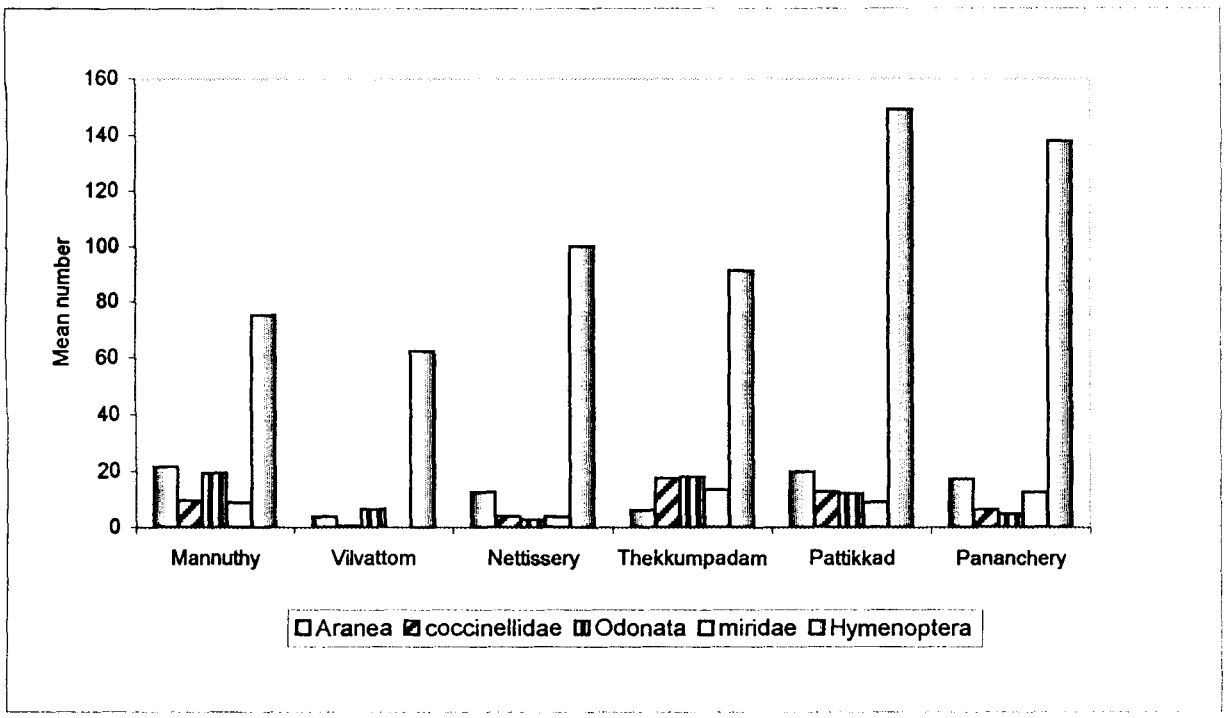


Fig.1b A comparison of major entomophages in different locations of non-kole area

non-kole area were also assessed and presented in Table 4 and Fig.2. Phytophages constituted about 28 to 42 per cent of all the arthropods sampled in different locations. Cicadellidae (leafhopper) were the major phytophages in Vilvattom panchayat contributing about 25 to 56 per cent of all the phytopages in all the locations. The population of Thysanoptera in Pananchery panchayat has ranged from 57 to 65 per cent of phytophages sampled. In Vilvattom panchayat also, except in one location, the Thysanoptera has reached nearly to 22 per cent of all the phytophages sampled. The proportion of entomophages was found to be much higher varying nearly from 45 to 68 per cent of total arthropods in all the six locations. The predatory fauna has assumed only 11 to 23 per cent of the entomophages population against a relatively high percentage of 23 to 57 of parasitoids (Hymenoptera). Among the predators, spiders were in the range of 31 to 41 per cent, except in Tekkumpadam where it was only 10 per cent of total entomophages. However, Odonata, Coccinellidae and Miridae were substantially high in Tekkumpadam. In Vilvattom about 57 per cent of the predator population was of damselflies while its proportion in all other locations varied from 10 to 30 per cent only.

The relative proportion of different species of phytophages and entomophages has been assessed and presented in Table 5. Among the leafhoppers *Nephotettix* spp. and *C. spectra* were the important species present in all the locations. Among the planthoppers *S. furcifera* was relatively high in all the locations (85-100 per cent) except in Mannuthy where *N. lugens* was found to be high (67.19%). Among the heteropteran pests *M. histrio* and *T. histeroids* (Pentatomidae) together constituted 64.70 to 100.00 per cent in all the locations. Sweep net sampling was not taken after the panicle emergence and hence the population of *L. acuta* was not adequately represented.

Micraspis spp. was the predominant predators present in all the locations which recorded 57.14 to 96.61 per cent of the coccinellid predators. *Brumoides* spp. and *C. transversalis* were less abundant. *Cyrtorhinus lividipennis*

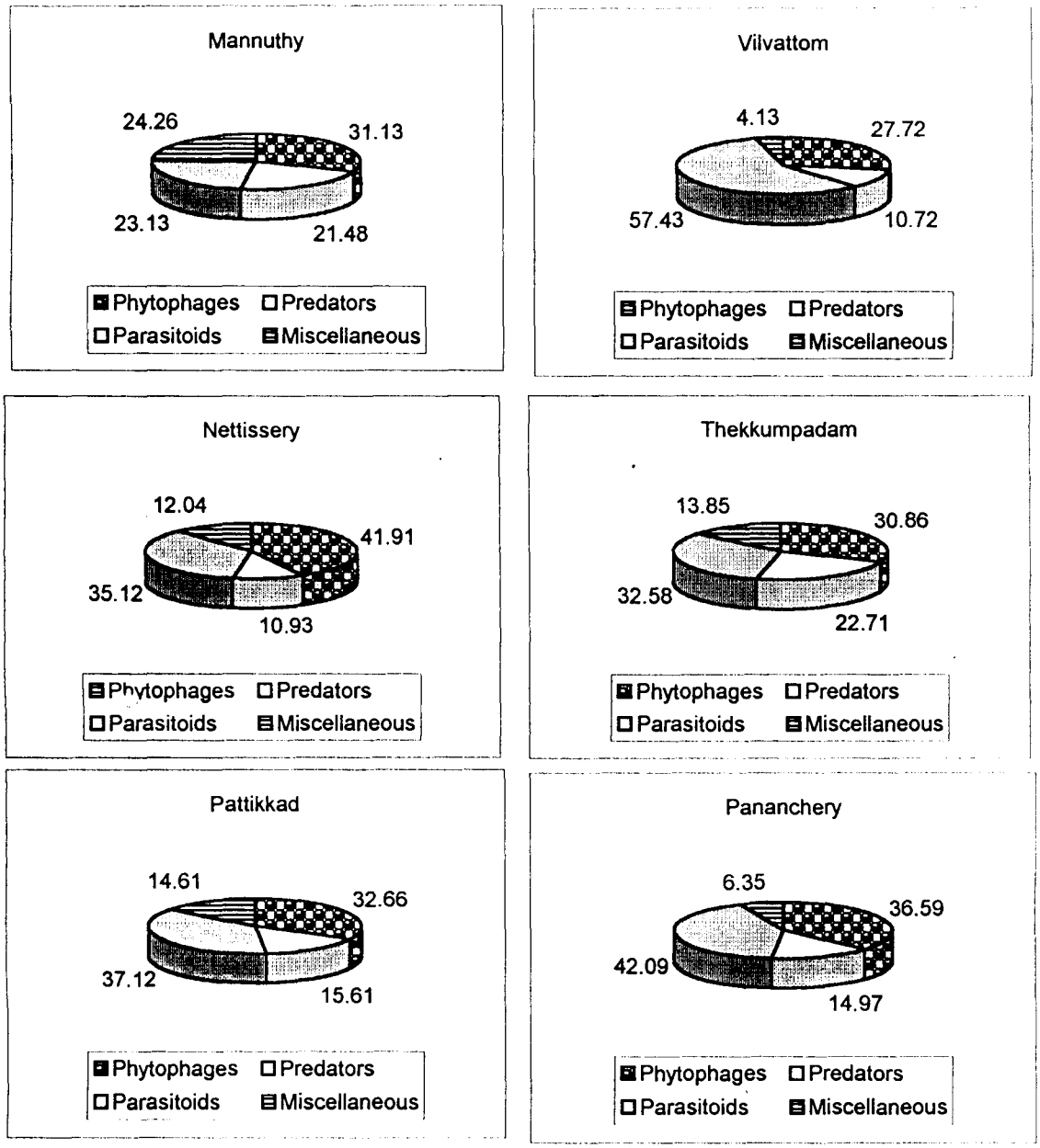


Fig.2 Percentage of phytophages and entomophages in non-kole area

was the only predatory mirid bug found in all the locations. Under Odonata *A. pygmea* was more predominant as compared to *A. f. femina*. *Tetragnatha* sp. was the most predominant (78.95 to 96.15) spider found in all the locations.

The major hymenopteran species recorded were *Tetrastichus* sp-I, *Gonatocerus* sp., *Fidiobia* sp., *Platygaster* sp., *P. mirificus*, *Telenomus* sp.-I, *Telenomus* sp.-II, *Trichogramma* spp. and *Oligosita* sp.

From the present sweep net sample studies and the data presented in Tables 3 to 5, it could be inferred that the arthropod community structure as represented by the economically important taxonomic groups are mostly same in all the rice fields. The pests coming under Homoptera (leafhoppers, planthoppers), Heteroptera, Lepidoptera, Orthoptera and Coleoptera were present in all the locations of non-kole area and can be considered as the regular common pests having widespread occurrence though their population varied in different locations. Very few species of phytophages like whitefly (unidentified) and army worm (*S. mauritia*) were found in certain locations, which are to be considered as the minor pests of less common occurrence. Based on mean densities and the nature of damage, homopteran pests was found to be the major pests in almost all the locations. The predominant homopteran pests were primarily the leafhoppers comprising of *Nephotettix* spp. and *C. spectra* (Cicadellidae). The population of Thysanoptera was also found to be high in most of the locations. The status of the pests in different rice growing states in India has been reported (Mammen and Nair, 1977, Nath and Sen 1978, Velusamy and Chelliah, 1980 and Gubbaiah, 1984). In Kerala, the intensity of infestation by the major homopteran pests like white-backed planthoppers and brown planthopper has been reported to be moderate to severe. Leaf and planthoppers are considered as the major pests which cause severe yield reduction in rice (Mathur *et al.*, 1999). Similar survey and sampling studies on the arthropod community structure in different rice ecosystems had been conducted by earlier workers (Heong *et al.*, 1991, Bhalla, 1997 and Beevi

et al., 2000a). Among the phytophages, Homoptera particularly *Nephotettix* spp. has been reported as the predominant pest by these workers.

On statistical analysis of the data it could be understood that a significant difference existed in the population of important phytophages among the six locations of non-kole area (Table 6 and Fig.3). Mannuthy of Vilvattom panchayat was characterised by a significantly high population of leafhoppers (46.42) than all other locations except Nettissery (29.31) where it was on par. The population of planthoppers also showed the same trend, the highest being in Mannuthy. Other phytophages like Lepidoptera, Coleoptera and other pests did not show a significant difference among the different locations. There was no significant difference in the population of phytophages among the three locations of Vilvattom panchayat except in the case of leafhoppers and planthoppers, so also the total pests. Irrespective of different locations under two panchayats of the non-kole area, Mannuthy was characterised by a significantly high population of leafhoppers, planthoppers and total pests, while Vilvattom was characterised by a low population of leafhoppers, planthoppers and total pests. In Mannuthy, paddy was grown for two consecutive seasons every year while in other locations only the second crop was raised. In Mannuthy, the same variety is growing for many years.

The population of important predators like spiders, coccinellids, Odonata, *C. lividipennis* and veliid bugs were also found to vary in different locations of non-kole area (Table 7 and Fig.4). In Vilvattom, the mean densities of all the predators except Odonata were significantly low. An earlier study on the quantification of pests and natural enemies in six locations of both non-kole and kole area had also indicated a significant difference in the pest and natural enemy population (Beevi *et al.*, 2000a).

The significantly low population of all the phytophages and entomophages in Vilvattom panchayat can be attributed due to the difference in the rice variety. The local variety Chiteni was grown in Vilvattom which may be a less

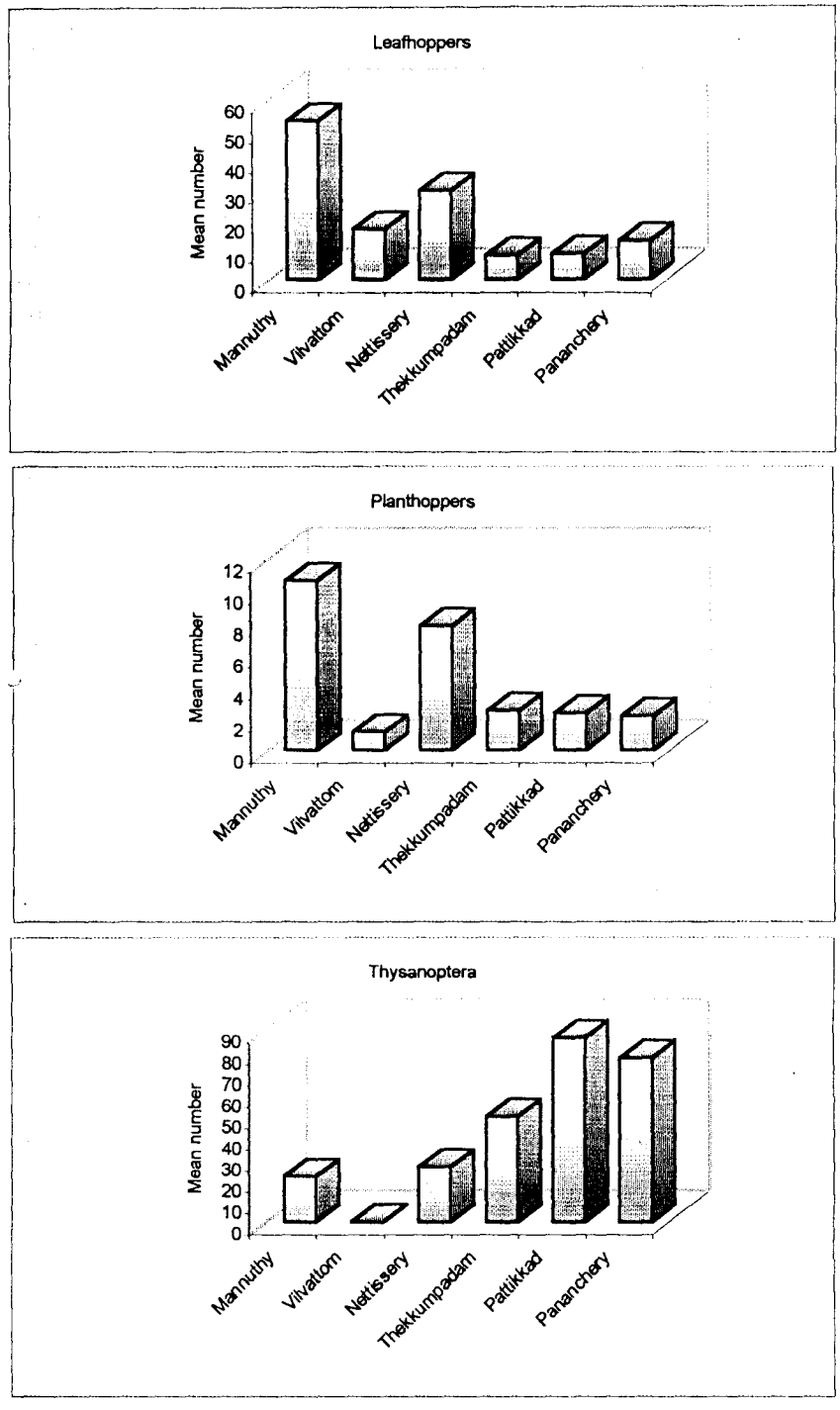


Fig.3 Population of major pests in different locations of non-kole area

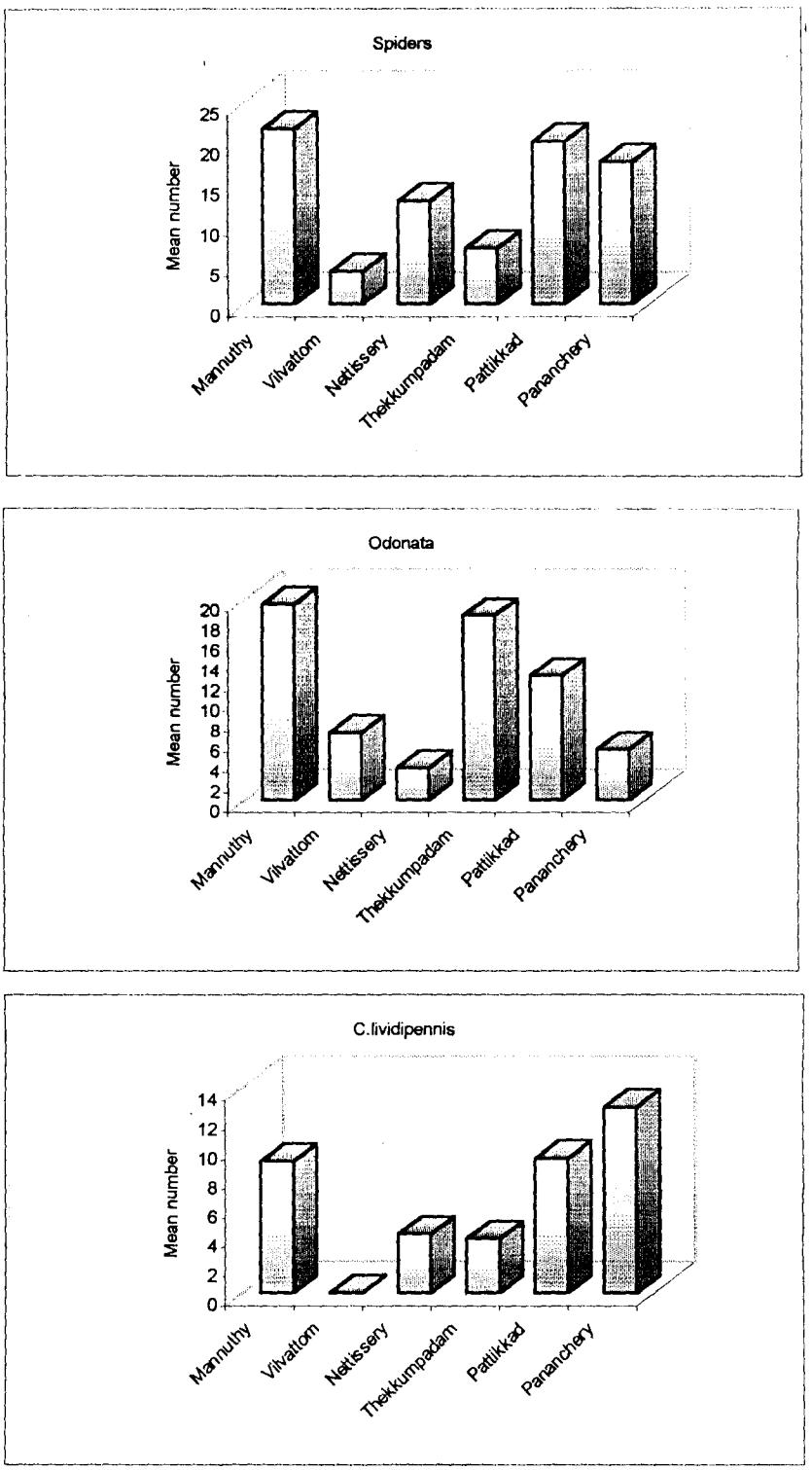


Fig.4 Population of major predators in different locations of non-kole area

susceptible variety as compared to the high yielding variety Jyothi grown in all other locations.

Reports on earlier studies have indicated the phytophages communities were higher than the entomophages in the paddy ecosystem of Philippines (Heong *et al.*, 1991) and Thrissur, Kerala (Beevi *et al.*, 2000a). However, in the present study among the total arthropods sampled the proportion of entomophages was high compared to the phytophages in all the locations. This may be due to the difference in the sampling methods or due to the inadequate representation of micro-hymenopterans in earlier studies.

The widespread occurrence of spiders, coccinellids, mirid bugs and Odonata as predators has already been reported by many workers (Regunath *et al.*, 1990, Gupta and Pawar, 1992, Ambikadevi *et al.*, 1998, Nandakumar and Pramod, 1998, Beevi *et al.*, 2000a). *Micraspis* spp. has been reported as the most important coccinellid predator in different rice ecosystems of Kerala (Regunath *et al.*, 1990, Ambikadevi *et al.*, 1998, Bhaskar, 1999, Beevi *et al.*, 2000a). *Tetragnatha* spp. was the most abundant spider in all the location. This finding is in agreement with Regunath *et al.* (1990), Bastidas (1993) and Murata (1995). The occurrence of important hymenopteran parasitoids viz. *Tetrastichus* sp.-I, *Gonatocerus* sp., *Fidiobia* sp., *Platygaster* sp, *P. mirificus*, *Telenomus* sp. I, *Telenomus* sp. II, *Trichogramma* spp. and *Oligosita* sp. has already been reported from different rice growing locations of Kerala State (Regunath *et al.*, 1990, Ambikadevi, 1998, Nandakumar and Pramod, 1998, Beevi *et al.* (2000b).

5.2.2 Kole area

The details of pests and natural enemies collected from the kole area with their mean count recorded under each taxonomic group are presented in Tables 8 to 10. The different taxonomic groups of phytophages and entomophages and the arthropod community structure in the kole area were found to be the same as that of non-kole area however the mean number of phytophages was found to

vary greatly over six locations, the lowest 58.83 (Nedupuzha) and highest 251.50 (Jubilipadam) (Table 8). The Homoptera comprising of the leaf and planthoppers (Cicadellidae and Delphacidae) was found to be the major phytophages, in Nedupuzha, Avinissery and Parallam (Fig.5a). A comparatively high population of Thysanoptera was recorded in Kanimangalam, Jublipadam and Mullakkara. On analysing the phytophages densities in the kole area, it could be seen that Thysanoptera has assumed a major status in few locations.

The data recorded from the kole lands also indicate the predominance of entomophages in the rice fields as compared to phytophages. The mirid bug *C. lividipennis* was the most abundant predator in all the six locations of kole lands (Fig.5b). However, its densities were found to vary greatly from 11 to 63. Spiders were the important predators next to mirid bugs in all the locations except Kanimangalam where the coccinellid beetles were on a higher side. Similar to that of non-kole area, the hymenopterans were found to be single largest group based on the mean numbers and so also remains to be the predominant entomophages in the kole areas.

The relative proportion of pests and natural enemies by taxa is presented in Table 9 and Fig.6. A relatively high population of Thysanoptera was observed in all the locations of kole area except in Avinissery which recorded a high population of leafhoppers. Among Homoptera, leafhoppers (Cicadellidae) was comparatively more. In case of entomophages, *C. lividipennis* was relatively more in almost all the locations in the kole area followed by spiders.

The relative proportion of different species under each taxa is presented in Table 10. Among the leafhoppers *Nephotettix* spp. were predominant. The order of abundance in all the locations was *Nephotettix* spp. > *C. spectra* > *R. dorsalis* for Cicadellidae and *S. furcifera* > *N. lugens* for Delphacidae.

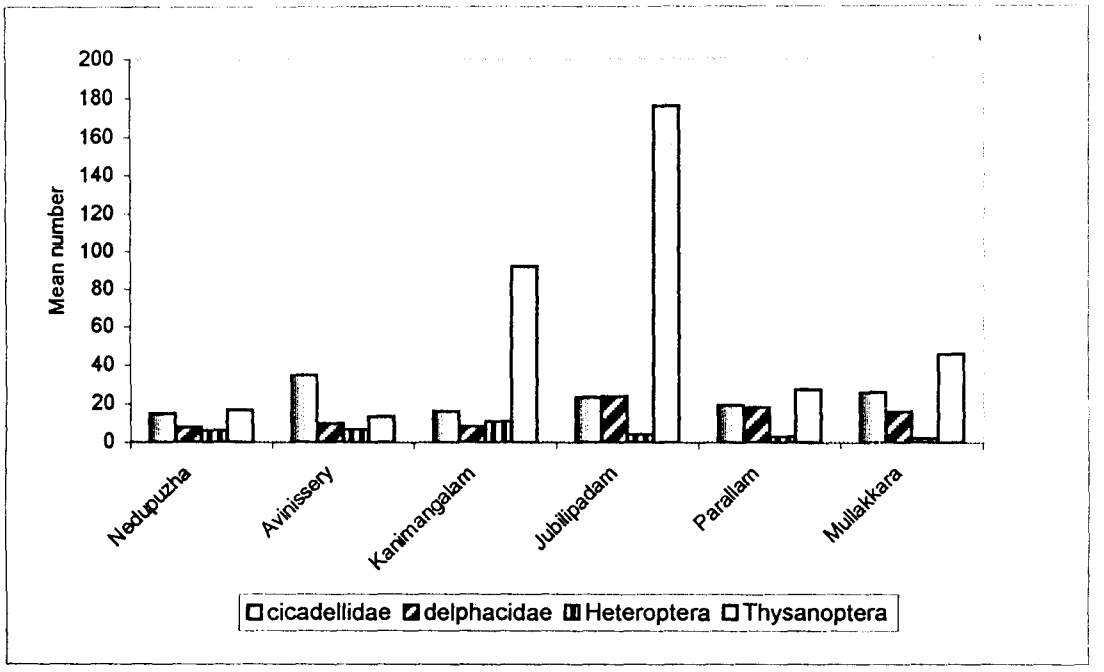


Fig.5a A comparison of major phytophages in different locations of kole area

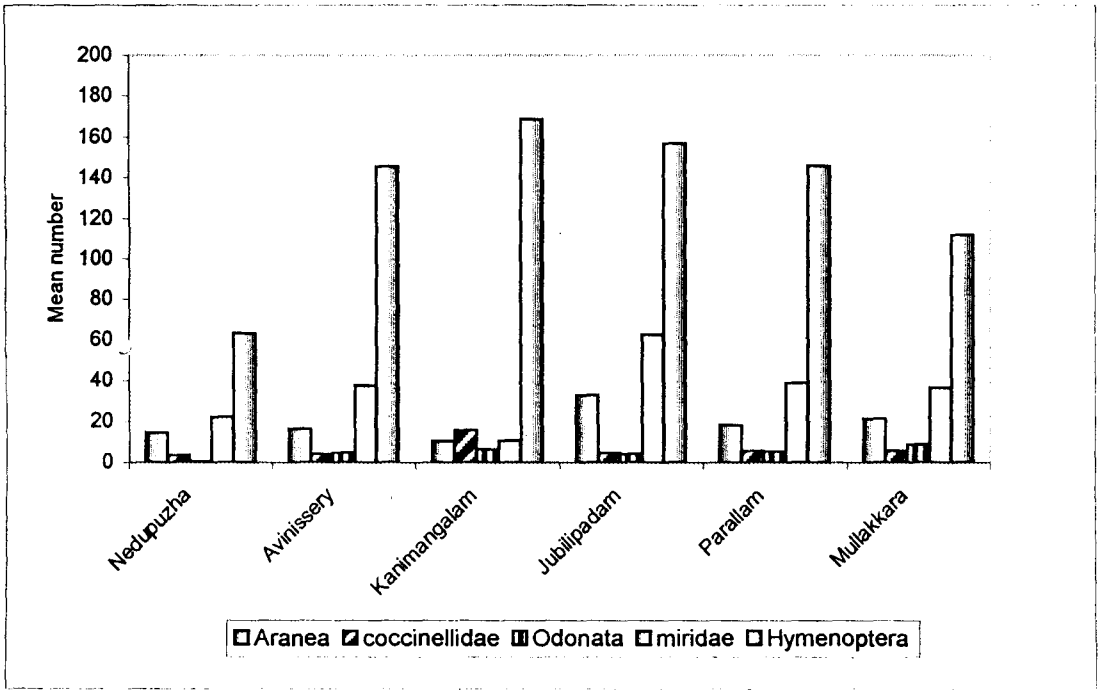


Fig.5b A comparison of major entomophages in different locations of kole area

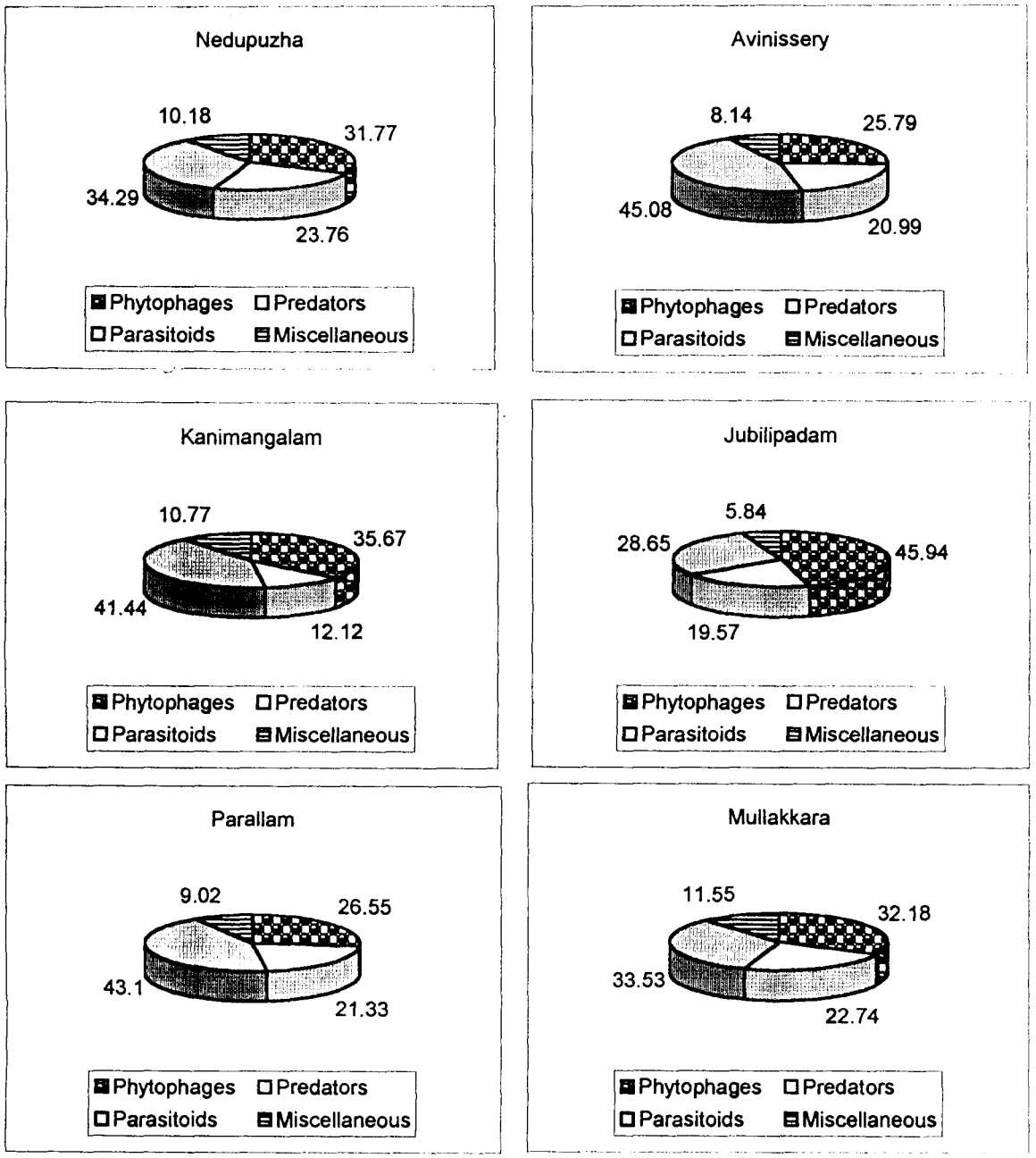


Fig.6 Percentage of phytophages and entomophages in kole area

Similar to that of non-kole area, *Micraspis* spp. (Coccinellidae), *A. pygmea* (Odonata) and *Tetragnatha* spp. (Aranea) were the major species of predators. The major parasitoids recorded under Hymenoptera were found to be same as that of non-kole area.

Among 22 species of Delphacidae and 34 of Cicadellidae reported to occur in South and South East Asia, the genera *Nephotettix, Recilia, Nilaparvata, Sogatella* and *Laodelphax* are the important pests (Wilson and Claridge, 1991). Both planthoppers and leafhoppers are vectors of a variety of rice diseases. Among these, the rice tungro, transmitted mainly by *N. virescens* and the grassy stunt and ragged stunt transmitted by *N. lugens* are widespread in the tropics (Thresh, 1989).

There are no previous reports on the survey of pests and natural enemies on the whole from a particular rice ecosystem. However, the occurrence of natural enemies particularly parasitoids and predators of important rice pests have been reported from Vellayani kayal lands (Regunath *et al.*, 1990), Kottankara watershed (Nandakumar and Pramod, 1998) and Moncompu, Kuttanad rice fields (Ambikadevi *et al.*, 1998).

On statistical analysis of the data on phytophages in the kole area, a significant difference could be observed on the population of major phytophages like leaf and planthoppers and Thysanoptera (Table 11 and Fig.7). Leafhoppers were significantly high at Avinissery as compared to the other two locations of Koorkenchery panchayat. All the three locations of Koorkenchery panchayat, recorded a significantly low population of planthoppers than Parallam panchayat. In case of coleopteran and thysanopteran pests, Parallam of Parallam panchayat recorded a significantly low population. There was no significant difference in the population of plant bugs, Lepidoptera, Orthoptera and other pests.

Similar to that of non-kole area, the mean population of different entomophages was found to vary in different locations of kole area (Table 12 and

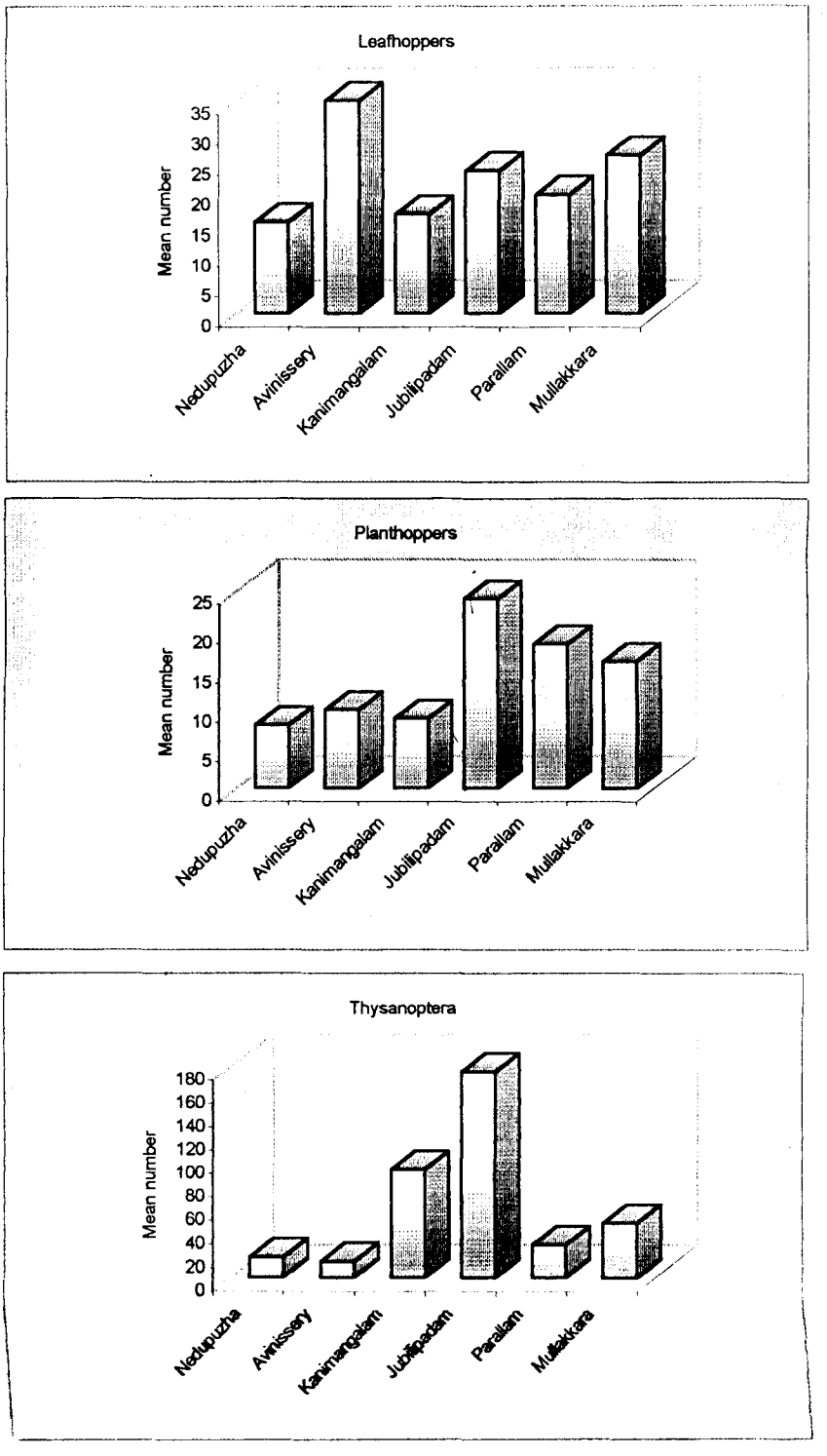


Fig. 7 Population of major pests in different locations of kole area

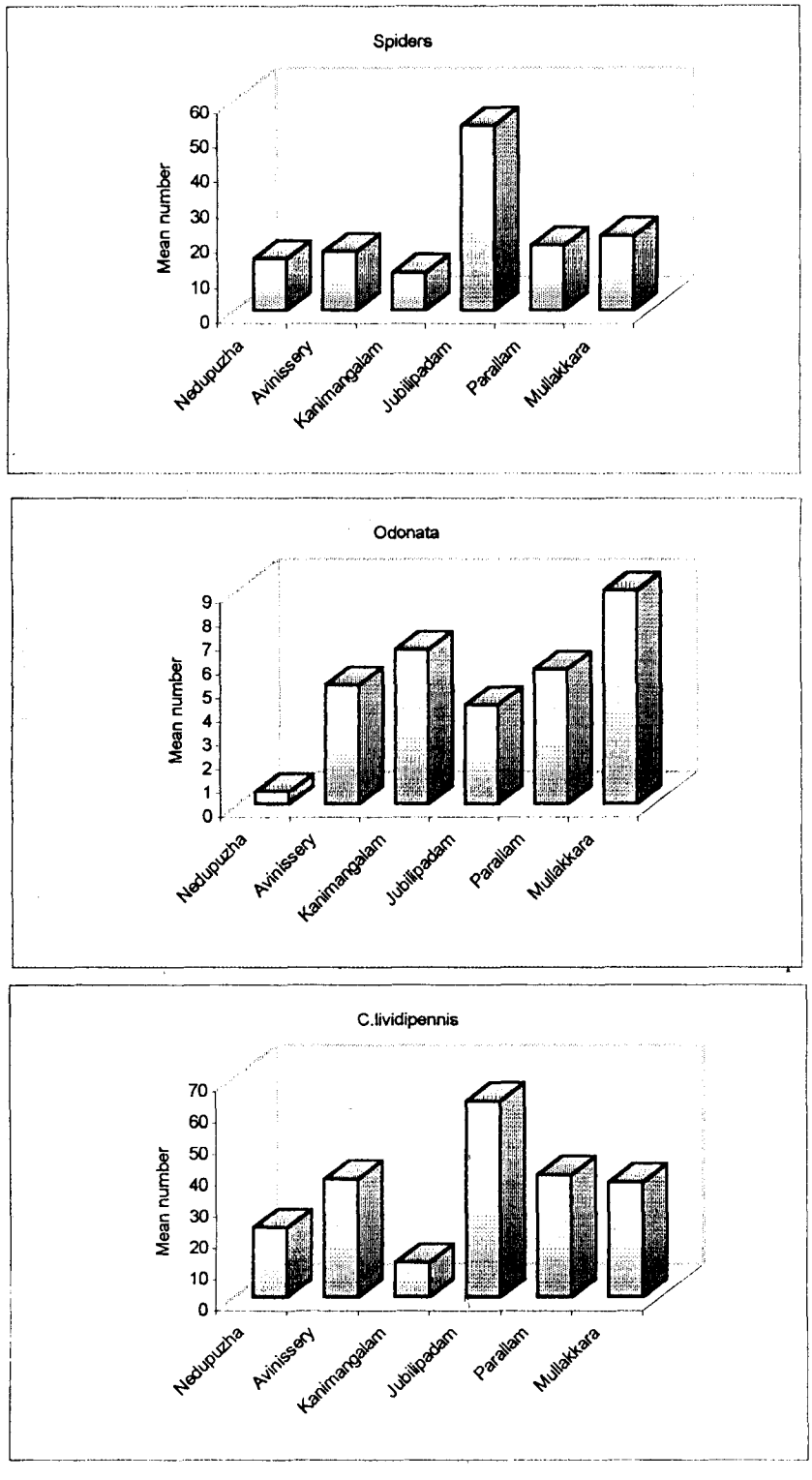


Fig.8 Population of major predators in different locations of kole area

Fig.8). All the three locations of Koorkenchery panchayat recorded a significantly low population of spiders than Parallam panchayat. A significantly high population of coccinellids was observed in Kanimangalam (13.41) of Koorkenchery panchayat. Maximum population of *C. lividipennis* was observed in Jubilipadam (43.32) followed by Mullakkara (32.03). Unlike in non-kole area, *C. lividipennis* was the predominant predator in kole area. Nedumpuzha recorded a significantly low population of Odonata (0.44) and Hymenoptera (55.30). There was no significant difference in the population of veliid bugs, other predators and Diptera.

Similar studies on population dynamics of plant and leafhoppers and their natural enemies, in five rice growing locations in Philippines revealed that the homopteran diversity were highly variable (Heong *et al.*, 1992). Beevi *et al.* (2000a) reported that the adundance and diversity of herbivores and their natural enemies are related to the variation in habitats.

5.3 Comparison of arthropods between the two agro-ecological situations

The arthropods obtained from two agro-ecological situations were compared (Tables 13 and 14). Among phytophages, planthopper population was significantly high in kole area. There was no significant difference in the population of other phytophages between the two agro-ecological situations.

Among the predators, a significantly high population of *C. lividipennis*, spiders and the total predators was present in the kole lands. However, Odonata was significantly high in non-kole area. The present study shows that the unpolluted rice ecosystems possess a rich and diversified phytophage - entomophage fauna, which is obviously a reflection of their vibrancy. The spatial and seasonal variations of the populations are quite natural for such dynamic ecosystems, due to biotic interaction and microclimatic influences. Kuno and Dyck (1984) reported that *C. lividipennis* is closely related to the population of brown planthopper. The predatory mirid, *C. lividipennis* is an effective natural enemy of

rice hopper pests mainly *N. lugens*, *S. furcifera* and *N. virescens* (Bentur and Kalode, 1985) although *N. lugens* eggs are often preferred (Heong *et al.*, 1991).

5.4 Correlation of phytophages and their natural enemies

Linear relationship of pests and various natural enemies were determined. A highly significant (at 1%), positive correlation was obtained between pests and predator; leaf and planthoppers and *C. lividipennis*; planthopper and *C. lividipennis* and leaf and planthoppers and spider (Table 15). Significant positive correlation was noticed between planthoppers and spiders. High positive correlation may indicate that the natural enemy is largely dependent on the pest population. High positive correlations or numerical response of plant and leafhoppers density may indicate that the predator is largely dependent on their population (Kuno and Dyck, 1984). Heong *et al.* (1991) reported that predator - Homoptera correlations were significant in irrigated rice fields of Philippines. Earlier reports also suggest that the population dynamics of generalist predators like *C. lividipennis*, spiders, coccinellids etc. may well depend on the total phytophages homopteran species (Heong *et al.*, 1992). They have also reported a high positive correlation for spiders and *C. lividipennis*. Beevi *et al.* (2000a) reported a highly significant positive correlation between the populations of homopterans and their major predator *C. lividipennis*. The present study shows a density dependent relationship for the major predators, *C. lividipennis* and spiders with homopteran pests. Its suggest that predators in the rice ecosystems play a major role in the management of important pests. There was no density dependent relationship between the population of pest and parasitoids.

5.5 Quantitative estimates of abundance of pests and natural enemies

5.5.1 Phytophages

The quantitative estimates like species richness, diversity and evenness of all the phytophages in different locations were assessed and presented (Table 16). Among the 12 locations surveyed the total number of individuals under

phytophages varied to a great extent from 181 (Vilvattom) to 1509 (Jubilipadom). The number of species detected in 12 different locations varied only from 17 to 23, inspite of a wide variation in the total number of individuals. The species richness and species diversity were considerably high and species evennes was attained maximum of 2.99 in Vilvattom. A high species evenness indicates that none of the phytophages attained high population build up and hence there was no chance for pest build up.

In non-kole area, Pattikkad was characterised by highest total number of individuals but the species diversity and evenness was found to be the lowest. Similar situation existed in Pananchery also. This is an indication of certain insects becoming more in numbers to assume the pest status. The population of thrips was considerably high in these two locations.

In the kole area, the species diversity and species evenness was lowest in Jubilipadam recording 1.268 and 1.509 respectively. In Jubilipadam, the total number of individuals was far higher than all other locations and a single species (*B. biformis*) has accounted for 70 per cent of the total phytophages. This may be the reason for low species diversity and evenness. Avinissery recorded the highest species richness and species diversity among the 12 locations, though the total number of individuals was only 500. Thrips was the single species of phytophages occurred in more number. Species evenness (J') is sensitive to the total number of species. It can be concluded that when J' approaches zero a single species becomes more dominant. A similar study on the quantitative estimate of the total arthropods irrespective of phytophages and entomophages in different locations of Philippines was done by Heong *et al.* (1991).

5.5.2 Predators

The species richness, diversity and evenness of predators in 12 locations are given in Table 17. The total number of individuals collected in various locations ranged from 70 (Vilvattom) to 877 (Pattikkad). It has been noted that the

number of species, species richness and diversity of predators were very low in Vilvattom. The important predators like *C. lividipennis*, *Microvelia d. atrolineata* were not present in Vilvattom. In non-kole area, species richness of predators was found to be high in Mannuthy. And in kole area, Jubilipadam recorded the maximum number of individual, number of species and species richness, however the species diversity and evenness were found to be the lowest. This is due to the high proportion of *C. lividipennis*, in Jubilipadam.

Quantitative estimation of spider species collected from different rice ecosystem was done by several workers (Kamal *et al.*, 1990, Ganeshkumar and Velusamy, 1997 and Anbalagan and Narayanasamy, 1999).

5.5.3 Parasitoids

Species richness, diversity and evenness of hymenopteran parasitoids in non-kole and kole area is given in Table 18. The number of hymenopteran parasitoids collected from different locations ranged from 375 (Vilvattom) to 1012 (Kanimangalm). In non-kole area, maximum number of species was recorded in Pananchery (77) and minimum in Vilvattom (31). Pattikkad and Pananchery were characterised by maximum species richness and species diversity. The very low population of Hymenoptera in Vilvattom can be attributed to the low colonization of phytophages.

In case of kole area, Kanimangalam and Jubilipadam recorded higher values for number of species, species richness and species diversity. Irrespective of the wide variation in the number of species detected over 12 locations it could be seen that there was not much variation in species evenness, the minimum being 2.407 and maximum 2.914. There are no previous reports on the quantitative estimates of phytophages and predators separately in different ecosystems.

5.6 Diversity of hymenopteran species

A very high population of hymenopterans was collected from all the locations. A total of 77 species belonging to 22 families were recorded. A detailed list of identified species is given in Table 19 and 20. Other than Formicidae all the 21 families were reported to be parasitoid families. In the non-kole area, the number of species of Hymenoptera identified were highest (77) in Pananchery followed by Pattikkad (72). In other locations the number of species ranged from 25 to 41. Though the total number of identified species were high, it could be understood that only 14 species viz. *Encarsia* sp., *A. opacus*, *C. philippinensis*, *C. recini*, *Cylloceriinae* sp., *X. immaculata*, *Gonatocerus* sp., *Mymar* sp., *Platygaster* sp., *P. mirificus*, *Pteromalus* sp.II, *Macrotelia* sp.I, *Telenomus* sp.I and *Telenomus* sp.II were abundant in all the six locations of non-kole area. Four species (*Platygaster* spp., *P. mirificus*, *Telenomus* sp.I and *Telenomus* sp.II) were present throughout the period of observation in all the sampling dates.

In case of kole area, Kanimangalam recorded maximum number of species (75) followed by Jubilipadam (72). Twenty one species were found to be present in all the locations. They were *Goniozus* sp.I, *B. lefroyi*, *B. excarinata*, *E. kollimalainus*, *T. schoenobii*, *Tetrastichus* sp.I, *E. apanteles*, *Eurytoma* sp., *Amauromorpha* sp., *Gonatocerus* spp., *Mymar* spp., *Fidiobia* sp., *Platygaster* spp., *P. collaris*, *P. mirificus*, *Pteromalus* sp., *Plebiaporus* sp., *Telenomus* sp.I, *Telenomus* sp.II, *Trichogramma* spp. and *Oligosita* spp. The hymenopteran diversity in the single and double cropped paddy has been studied earlier. Except *C. philippinensis*, *Doliphoceras* sp., *Oomyzus* sp., *Cylloceriinae* sp., *T. cyrus* and *Oligosita* sp. all other species identified in the present study have already been reported to occur from those locations studied (Beevi *et al.*, 2000b). The species *C. philippinensis*, *T. cyrus*, *Plebiaporus* sp., *Doliphoceras* sp., *Oomyzus* sp., *Cylloceriinae* sp. and *Oligosita* sp. are the new reports from this region. All the important parasitoids short listed above have been reported as parasitoids on the common pests of paddy (Heinrichs, 1994).

Though the number of hymenopteran species varied greatly, there was no correlation between the population of pests and the parasitoids in any of the locations. Likewise, there was no significant difference in total hymenopteran population among the six loctions in the non-kole area as well as kole area (Table 7 and 12). The study clearly shows that in rice ecosystems, parasitoids are relatively unimportant in phytophages population regulation, as compared to the predators. The parasitoids being more agile in their flight and dispersion are subject to the hazards from residues lingering on treated crops in the vicinity of untreated plots.

5.7 Relative abundance of predators in non-kole and kole area

The relative abundance of predators in different locations is given in Tables 21 and 22. The predators collected were *Micraspis* spp., *Brumoides* sp., *C. transversalis* (Coccinellidae), *C. lividipennis* (Miridae), *A. pygmea*, *A. f. femina* (Odonata) and spiders (Aranea). However, the most abundant predators were the spiders and *C. lividipennis*. The predatory coccinellid *Micraspis* sp. and Odonata (*A. pygmea* and *A. f. femina*) were also abundant in certain locations. The occurrence of these predators in rice ecosystems has already been reported by many workers (Abraham *et al.*, 1973, Pawar, 1975, Samal and Misra, 1975, Chatterjee and Dutta, 1979, Regunath *et al.*, 1990, Ganeshkumar and Velusamy, 1997, Ambikadevi *et al.*, 1998, Nandakumar and Pramod, 1998, Bhaskar, 1999 and Beevi *et al.*, 2000a).

5.8 Spiders identified from different locations

The present study (*in situ* and sweep net) revealed the occurrence of nine species of spiders belonging to nine genera and eight families (Table 23). Gupta *et al.* (1986) recorded 15 species of spiders comprising 11 genera. Kamal *et al.* (1990) conducted a survey to study the abundance, diversity and food web of spiders in three rice environment viz. seed bed, irrigated rice field and weedy fallow. A detailed survey of spiders distributed in four rice tracts of Tamil Nadu by

Anbalagan and Narayanasamy (1999) recorded the presence of 21 species belonging to 16 genera of 10 families.

The most prevalent species recorded were *T. maxillosa*, *L. pseudoannulata* and *O. ratnae*. The importance of these spiders in rice ecosystem has been reported by many workers (Chatterjee and Dutta, 1979, Nath and Sarkar, 1980, Gupta *et al.*, 1986, Bhathal and Dahliwal, 1990, Ansari and Pawar, 1992, Ganeshkumar and Velusamy, 1997). *Labotla* sp., *Sparassus* sp. and *Ctenus* sp. are the first record from rice ecosystems of Kerala. Of these, *Ctenus* sp. was absent in non-kole area.

5.9 *In situ* population count of leaf and planthoppers and their natural enemies

In situ count of plant and leafhoppers and their natural enemies in non-kole and kole area is given in Table 24 and Appendix I & II.

In non-kole area, maximum mean population of Bph was recorded at Mannuthy (12.50) followed by Pattikkad (2.63) and Tekkumpadam (2.50). A comparatively high population of GLH was observed in all the three locations of Vilvattom panchayat, recording maximum at Mannuthy. The population of the major predator, *C. lividipennis* recorded maximum at Mannuthy, followed by Pananchery and Pattikkad. The mean density of *Lycosa* was maximum at Mannuthy. In the kole area, Jubilipadam recorded a relatively high population of Bph. The population of GLH was high at Kanimangalam followed by Jubilipadam. All the three locations of Parallam panchayat recorded a high population of *C. lividipennis*.

As the population of *N.lugens* increased, the population of the predator *C.lividipennis* also increased, showing a density dependent relationship, suggesting that the mirid is an important factor and major predator regulating the population

of *N.lugens*. A similar observation was made by Bhaskar (1999) in kole area of Thrissur district.

5.10 Field parasitism on key pests of paddy

The occurrence and the extent of parasitism on three key pests of rice viz. stem borer, leaf folder and gall fly were investigated.

5.10.1 Stem borer

The stem borer eggs were parasitised by *Telenomus* spp., *Trichogramma* spp. and *Tetrastichus* spp. (Table 25). Several authors have reported the parasitism of stem borer eggs by these species (Rao *et al.*, 1963, Nath and Hikim, 1979). The highest percentage of parasitism was recorded in Tekkumpadam (93.70 per cent). From the present study it is evident that *Telenomus* spp. are the most common and dominating parasitoid of the stem borer eggs. Similar findings were also reported from Karnataka (Rai and Gowda, 1980). Dominance of *Telenomus* spp. as egg parasitoid of yellow stem borer was also reported from Sri Lanka (Rajapakse and Kulasekera, 1980). Parasitism of egg mass by two or more species of the parasitoid was also observed. This finding is in agreement with Hikim (1988).

5.10.2 Leaf folder

The parasitoids collected from larvae and purpae of leaf folder were *Cotesia (=Apanteles* spp.), *B. excarinata, C. philippinensis, Goniozus* sp., *M. philippinensis* and *Xanthopimpla* spp. (Table 26). Highest parasitism was recorded in Jubilipadam (50 per cent). The parasitism by these species have already been reported by many workers (Abraham *et al.*, 1974, Pati and Mathur, 1982, Ahmed *et al.*, 1989, Arida and Shepard, 1990, Heinrichs, 1994).

5.10.3 Gall fly

The incidence of gall fly was low in all the locations. The only parasitoid recorded from gall fly pupae was *Platygaster* sp. The highest percentage

of parasitism was recorded at Parallam (42.85 per cent) and lowest being at Kanimangalam (20 per cent) (Table 27). The parasitism of gall fly by *Platygaster* sp. has already been reported by many workers (Ramaiah, 1970, Chand, 1981, Rao *et al.*, 1981, Patnaik and Satpathy, 1984, Mathur *et al.*, 1991).

SUMMARY

6. SUMMARY

A pilot study was carried out with the objective of identification, quantification and comparison of pest and natural enemy complex present in two different rice ecosystems viz., non-kole and kole areas in Thrissur district of Kerala. The species composition, abundance and relative occurrence of major pests, parasitoids and predators were studied from the 12 selected plots which were not sprayed with any chemical pesticides.

The survey was conducted from a total of six paddy fields (each with 20 cents) representing two panchayats (three from each panchayat) of one NES block from the non-kole region. Similarly six plots were selected in the kole region. Pest and natural enemies were sampled using a sweep net (32 cm diameter) at weekly intervals starting from 15 days after transplanting till the emergence of panicles. A total of six samples were taken from each plot. All the arthropods collected on each sampling date were counted separately, sorted out and identified. They were then grouped into two major guilds as phytophages and entomophages and another miscellaneous group with unidentified and minor arthropods. For the convenience of analysis, data presentation and interpretation of results, the quantification of pests and natural enemies were done taxa wise and the species wise data presented only to know the relative abundance of the major ones. The quantitative estimates like species richness, diversity and evenness were worked out for the phytophages, parasitoids and predators. *In situ* count of leaf and planthoppers and associated natural enemies were recorded from 20 hills per plot. The extent of parasitism on the field collected immature stages of rice stem borer, leaf folder and gall fly were also studied.

The results are summarised below:

In the sweep net samples taken from 12 locations, altogether 29 species of pests under 19 families of six orders were identified. Among 96 species of

natural enemies identified, 19 were predators and 77 were hymenopteran parasitoids.

The qualitative studies on the species composition and arthropod community structure had revealed that the arthropods as represented by different taxa and the major species under the phytophages and entomophages were almost same in all the 12 locations irrespective of the variations between the agro-ecological situations. However, in Vilvattom location, where the majority of the crop area was under the local variety the pests like brown planthopper, thrips and whiteflies as well as predators like *Cyrtorhinus lividepennis* Reuter and *Microvelia douglasi atrolineata* Bergoth were absent.

An overall comparison of pests and natural enemies in six different locations of non-kole area had revealed that the entomophages comprising of parasitoids and predators were relatively higher than the phytophages and their mean count varied from 74.17 to 212.33 and 30.17 to 131.50 respectively. The phytophages constituted about 27.72 to 41.91 per cent of all the arthropods sampled in six locations, while it was 44.62 to 68.15 per cent for the entomophages.

Leafhoppers (Cicadellidae) of the suborder Homoptera and thrips (Thysanoptera) were the predominant phytophages in the non-kole area. The relative estimates on species abundance showed that *Nephotettix* spp. comprising of *Nephotettix virescens* (Distant) and *Nephotettix nigropictus* (Stal) were predominant in Vilvattom panchayat which constituted 43.26 to 94.06 per cent of all leafhoppers. However, in Pananchery panchayat the proportion of *Cicadella spectra* Distant was found to be high in Pattikkad (56.86%) and Tekkumpadam (52.08%). Spiders, coccinellid beetles, mirid bugs, damselflies and veliid bugs were the predators found in almost all the locations of non-kole area. However, the more predominant predator species were *Tetragnatha* sp. (Aranae), *C. lividipennis* (Miridae), *Micraspis* sp. (Coccinellidae) and *A. pygmea* (Odonata).

The parasitoids represented in the order Hymenoptera was the single largest group of entomophages in all the six locations of non-kole area. Their mean numbers ranged from 62.50 to 149.50 contributing 23.13 to 57.43 of per cent of the total entomophages.

Irrespective of different locations under two panchayats of the non-kole area, Mannuthy was characterised by a significantly high population of leafhoppers, planthoppers and total pests, while Vilvattom was characterised by a low population of leafhoppers, planthoppers and total pests. The population of entomophages was also found to vary in different locations of non-kole area. In Vilvattom the mean densities of all the entomophages except Odonata were significantly low.

In the kole area also the population of entomophages was higher than that of phytophages in all the locations except in Jubilipadam, where the phytophages reached to 251.50 due to an extraordinary high count (176.00) of thrips (Thysanoptera). Homoptera comprising of leaf and planthoppers were the predominant phytophages in most of the locations of kole area. *Sogatella furcifera* (Horvath) was the predominant planthopper constituting 58.33 to 95.88 per cent of Delphacidae.

In the kole area, Avinissery recorded a significantly high population of leafhoppers. A significantly low population of planthoppers was observed in all the three locations of Koorkenchery panchayat. In case of entomophages a significantly high population of spiders was observed in Parallam panchayat.

A comparison made between the two situations (non-kole and kole area), had revealed that among phytophages, a significant difference existed only in the case of planthoppers, which were significantly high in kole area. In the case of entomophages, the spiders, *C. lividipennis* and total predators were significantly high in the kole area, while damselflies (Odonata) were significantly high in the

non-kole area. The density of hymenopteran parasitoids did not vary significantly between the two different ecosystems.

In non-kole area, species richness of phytophages was maximum in Mannuthy, while species evenness was maximum in Vilvattom. Predators were rich in Mannuthy. Richness of hymenopteran species was high in Pananchery.

In kole area, species richness of phytophages was maximum in Avinissery and minimum in Nedupuzha. Species richness of predators was maximum in Jubilipadam, while Hymenoptera was rich in Kanimangalam.

A highly significant positive correlation was noticed between planthoppers and their major predator *C. lividipennis* (0.787); leaf and planthoppers and spiders (0.498) and total pests and predators (0.419). Correlation between leaf and planthoppers and *C. lividipennis* (0.358) and planthopper and spiders (0.289) was also significant.

The total number of hymenopteran species identified from all the six locations of non-kole area varied from 25 to 77, of which 14 species were found to be present in all the six locations. Maximum numbers were recorded in Pananchery and Pattikkad.

In the kole area, the number of hymenopteran parasitoids identified varied from 37 to 75 and 21 species were found to occur in all the six locations. Kanimangalam and Jubilipadam recorded maximum numbers.

In the kole area, *C. lividipennis* was most abundant in the five locations, spiders being next in abundance. Damselflies (Odonata) were found to be less abundant in all the six locations of kole area.

Nine species of spiders belonging to eight families were identified. Among these *Tetragnatha maxillosa* Thorell was most abundant.

In situ population count of leaf and planthoppers and their associated natural enemies revealed a density dependent relationship with their generalist predators. Mannuthy (non-kole) recorded high population of Bph, *C. lividipennis* and *Lycosa*.

From the field collected samples, three species of parasitoids viz. *Telenomus* spp. *Tetrastichus* spp. and *Trichogramma* spp. were obtained from the stem borer eggs. The parasitoids emerged from the leaf folder larvae and pupae were *Cotesia* (=*Apanteles*) spp. *Brachymeria excarinata* Gahal, *Cardiochilus philippinensis* Ashmead, *Goniozus* spp., *Macrocentrus philippinensis* Ashmead and *Xanthopimpla* spp. Only a single species (*Platygaster* sp.) was obtained from gall fly pupae.

From the present study, it is to be concluded that the rice ecosystem possessed a rich and diverse natural enemy fauna in areas where no insecticides were used. The exact reasons for the variations in the quantitative estimates of certain pests and natural enemies within the locations of same ecosystem as well as between the two ecosystems have to be studied in detail. The monitoring of pests and natural enemies should be continued to know the long term changes in the pest and natural enemy fauna.

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* Originals not seen

APPENDICES

APPENDIX-I

In situ population of leaf and planthoppers and their natural enemies in non-kole area

DAT	Bph	Green fassid	*Lycosa* sp.	*Tetragnatha* sp.	*Ophionea* sp.	*Staphylinid*	*Cyrtochimus* sp.	*Micraspis*	*Microvelia*
1) Mannuthy									
15	12	14	4	3	0	2	12	0	31
22	19	21	5	2	1	1	21	1	37
29	16	17	6	5	2	0	20	2	20
36	14	9	3	5	1	0	15	10	14
43	11	7	3	1	2	1	15	3	11
50	8	8	3	2	1	2	14	4	0
57	10	6	2	1	0	0	11	2	0
64	10	7	3	2	0	1	10	2	0
2) Vilvattom									
15	0	3	0	2	0	0	0	1	0
22	0	2	0	1	0	0	0	0	0
29	0	1	0	0	0	0	0	3	0
36	0	10	1	0	1	0	0	0	0
43	0	7	0	0	0	0	0	0	0
50	0	2	0	1	0	0	0	0	0
57	0	5	0	0	0	0	0	2	0
64	0	3	0	0	0	0	0	2	0
3) Nettissery									
15	0	3	0	0	0	0	0	0	16
22	0	7	0	7	0	0	0	0	18
29	0	6	1	3	2	1	4	2	20
36	0	5	0	4	0	0	2	0	2
43	0	3	0	3	0	0	0	1	0
50	0	7	1	0	0	0	3	2	0
57	0	4	0	0	0	0	0	0	0
64	0	4	0	2	0	0	0	1	0
4) Thekkumpadam									
15	0	2	1	-	3	4	5	4	37
22	6	3	2	1	1	2	6	7	39
29	6	4	1	3	1	6	7	1	35
36	3	1	-	2	0	12	2	3	27
43	0	3	2	1	0	6	-	-	20
50	0	2	1	3	2	5	3	2	15
57	2	4	1	1	0	6	2	5	0
64	3	2	0	2	1	4	4	2	0

Contd.

Appendix-I. Continued

DAT	Bph	Green fassid	*Lycosa* sp.	*Tetragnatha* sp.	*Ophionea* sp.	*Staphylinid*	*Cyrtochinus* sp.	*Micraspis*	*Microvelia*
5) Pattikkad									
15	0	5	1	0	0	4	5	4	37
22	0	2	-	0	0	2	6	7	39
29	6	-	3	1	0	6	7	1	35
36	5	2	2	7	0	12	2	3	27
43	1	2	1	8	0	6	-	-	20
50	-	3	1	6	0	5	3	2	15
57	4	2	3	4	0	6	2	5	0
64	5	3	2	2	1	4	4	2	0
6) Pananchery									
15	0	5	0	3	0	0	2	2	7
22	2	7	1	5	0	0	7	2	12
29	4	7	2	5	0	0	8	3	6
36	2	2	1	6	0	0	8	2	0
43	0	2	1	3	0	0	2	4	0
50	0	1	0	4	0	0	1	2	0
57	4	2	2	2	0	0	3	1	0
64	2	1	1	3	0	0	3	1	0

APPENDIX-II

In situ population of leaf and planthoppers and their natural enemies in non-kole area

DAT	Bph	Green fassid	*Lycosa* sp.	*Tetragnatha* sp.	*Ophionea* sp.	*Staphylinid*	*Cyrtochinus* sp.	*Micraspis*	*Microvelia*
1) Nedupuzha									
15	2	2	1	4	1	0	7	0	27
22	3	4	2	4	0	0	8	0	30
29	3	3	1	2	0	0	6	0	31
36	-	8	2	7	0	0	12	0	28
43	-	4	2	5	0	0	4	1	2
50	2	4	0	1	0	0	5	2	0
57	3	2	0	2	0	0	4	1	0
64	5	2	1	1	0	0	8	1	0
2) Avinissery									
15	3	12	3	4	1	0	8	0	12
22	4	2	2	4	1	1	8	2	16
29	3	2	1	5	0	0	3	1	17
36	3	4	1	2	0	0	5	3	12
43	-	0	1	2	0	0	-	2	0
50	-	1	0	3	0	0	2	1	0
57	-	3	1	2	0	0	-	2	0
64	4	2	2	-	0	0	5	1	0
3) Kanimangalam									
15	4	12	2	4	1	0	5	-	10
22	3	8	2	5	0	1	7	2	7
29	3	6	2	6	0	0	4	2	2
36	2	8	3	5	0	0	2	1	0
43	-	2	1	5	0	0	2	1	0
50	-	4	1	4	1	0	-	-	0
57	4	5	-	2	0	0	5	-	0
64	3	4	1	2	0	0	3	3	0
4) Jubilipadam									
15	4	4	2	7	2	2	10	-	20
22	4	3	2	7	0	1	7	-	18
29	3	2	1	7	0	0	7	1	17
36	5	3	1	8	1	0	6	3	17
43	7	17	2	4	0	0	12	1	0
50	8	5	1	2	1	0	9	2	0
57	8	4	0	1	0	0	12	1	0
64	10	4	1	1	0	1	12	1	0

Contd.

Appendix-II. Continued

DAT	Bph	Green fassid	*Lycosa* sp.	*Tetragnatha* sp.	*Ophionea* sp.	*Staphylinid*	*Cyrtochimus* sp.	*Micraspis*	*Microvelia*
5) Parallam									
15	6	8	4	5	0	3	16	0	22
22	6	3	4	5	0	0	14	0	23
29	5	3	3	4	0	1	12	1	15
36	4	6	4	5	1	0	11	2	14
43	2	6	2	5	0	0	5	2	0
50	-	7	1	3	0	0	8	1	0
57	-	3	1	2	1	0	6	0	0
64	3	3	1	1	0	0	5	0	0
6) Mullakkara									
15	4	9	3	7	1	2	8	-	24
22	7	10	2	4	0	2	12	1	25
29	4	8	3	7	1	2	14	2	29
36	2	5	2	6	1	0	7	2	15
43	2	7	2	6	2	1	8	2	0
50	-	3	1	5	0	2	7	2	0
57	3	4	2	2	0	0	7	1	0
64	2	4	1	2	0	0	4	1	0

APPENDIX - III

Meteorological data during the period from October 1998 - April 1999.

Months	Standard week No.	Temperature (°C)		Humidity (%)		Wind speed (Km/hr)	Sunshine (hrs)	Rain (mm)	Rainy days
		Maximum	Minimum	I	II				
Oct.	40	29.3	23.1	93	79	1.5	3.8	51.8	6
	41	27.8	23.0	95	91	2.7	1.5	319.4	6
	42	29.8	22.6	94	73	1.8	4.8	70.2	5
	43	31.1	22.5	92	66	2.0	8.2	10.8	1
	44	31.1	23.2	94	68	1.6	5.5	6.9	1
Nov.	45	30.8	23.6	93	70	1.8	4.1	86.6	5
	46	31.9	22.8	94	63	1.9	8.9	16.9	3
	47	31.7	22.8	93	58	1.3	9.0	0.0	-
	48	32.2	23.0	88	58	1.7	7.9	4.8	1
Dec.	49	31.2	236	78	60	6.0	6.1	1.4	-
	50	29.7	234	82	71	7.1	3.3	27.0	3
	51	31.4	224	79	57	4.3	8.6	0.0	-
	52	31.1	22.0	76	40	4.7	8.2	-	-
Jan.	1	31.9	21.8	75	45	7.4	9.4	0.0	-
	2	32.5	21.9	79	43	5.1	9.5	0.0	-
	3	32.2	22.8	70	40	9.8	10.0	0.0	-
	4	32.5	19.5	74	32	5.5	7.9	0.0	-
	5	33.9	22.1	83	39	3.6	10.1	0.0	-
Feb.	6	34.0	23.4	80	44	4.3	9.2	22.8	-
	7	34.7	23.2	79	39	5.3	10.0	0.0	-
	8	34.2	24.5	70	33	7.9	6.9	0.0	-
	9	36.4	22.2	74	33	5.0	10.4	0.0	-
Mar.	10	36.5	23.8	92	34	3.1	9.9	0.0	-
	11	35.2	25.0	89	54	2.8	8.4	0.0	-
	12	34.8	25.0	91	55	2.4	8.4	0.0	-
	13	34.9	25.1	89	54	2.4	7.5	0.0	-
Apr.	14	34.9	24.5	90	55	3.0	7.8	26.2	2
	15	33.2	25.8	86	59	3.3	7.4	0.0	-
	16	33.1	26.2	89	62	3.2	4.6	7.6	1
	17	32.0	25.9	90	59	3.4	4.2	5.2	1
	18	33.6	25.8	89	59	3.1	6.3	35.0	1

SURVEY AND QUANTIFICATION OF NATURAL ENEMY FAUNA IN THE RICE ECOSYSTEMS IN THRISSUR DISTRICT

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ABSTRACT OF THE THESIS

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ABSTRACT

A pilot study was carried out with the objective of identification, quantification and comparison of the pest and natural enemy complex present in two different rice ecosystems in Thrissur district of Kerala, viz. non-kole and kole area. The species composition, abundance and relative occurrence of pests, parasitoids and predators collected in sweep net samples from six locations each of non-kole and kole area were studied. Six samples were drawn at weekly intervals from each location starting from 15 days after transplanting till the emergence of panicles and the mean data used for analysis. The species richness, diversity and evenness of all the pests and important natural enemies were also assessed. *In situ* count of leaf and planthoppers and associated generalist predators were recorded. The extent of natural parasitism on the field collected immature stages of stem borer, leaf folder and gall fly was recorded and identified the important species.

In the sweep net samples taken from 12 rice fields, altogether 29 species of phytophages representing 19 families of six insect orders could be identified. Among the 96 species of natural enemies (entomophages) identified, 19 species were predators and 77 were the hymenopteran parasitoids. Except in the case of one or two locations, the occurrence of most common and regular pests and the associated natural enemy fauna were found to be the same in the non-kole and kole area. The entomophages comprising of parasitoids and predators were found to be higher than the phytophages in most of the locations. Homoptera comprising of leaf and planthoppers and Thysanoptera (thrips) were the predominant phytophages. *Nephotettix* spp. were dominant among the leaf and planthopper while it was *Sogatella furcifera* (Horvath) among the planthoppers.

A significant difference was observed in the mean count of pests as well as natural enemies within the six locations of each situation. Spiders (8 species) cocinellid beetles (3 species), mirid bug (*Cyrtorhinus lividepennis* Reuter), damselflies (2 species) and veliid bug [*Microvelia douglasi atrolineata* (Bergoth)]

were the important predators. The predominant predator species were *Tetragnatha maxillosa* Thorell (Aranae), *Cyrtorhinus lividipennis* Reuter (Miridae), *Micraspis* spp. (Coccinallidae) and *Agriocnemis pygmea* Rambur (Odonata). Highest diversity was noticed in the case of hymenopteran parasitoids and was the single largest group of entomophages. In the non-kole area, spiders were most abundant followed by Odonata, whereas in kole area *C. lividipennis* was abundant followed by spiders.

In the case of phytophages, between the two situations studied, significant difference was noticed only in the case of planthoppers, which was significantly high in kole lands. Spiders, *C. lividipennis* and the total predators population were significantly high in kole area, whereas Odonata (damselflies) were significantly high in non-kole area. A highly significant positive correlation existed between the leaf and planthoppers with predators like *C. lividipennis* and spiders. *In situ* population count of leaf and planthoppers and their associated natural enemies viz. *C. lividipennis* and *Lycosa* indicated a density dependent relationship.

From the field collected samples, three species of parasitoids viz. *Telenomus* spp. *Tetrastichus* spp. and *Trichogramma* spp. were obtained from the stem borer eggs. The parasitoids emerged from the leaf folder larvae and pupae were *Cotesia* (=*Apanteles*) spp. *Brachymeria excarinata* Gahal, *Cardiochilus philippinensis* Ashmead, *Goniozus* spp., *Macrocentrus philippinensis* Ashmead and *Xanthopimpla* spp. Only a single species (*Platygaster* sp.) was obtained from gallfly pupae.