MANAGEMENT OF THE LEAF ROLLER COMPLEX ON RICE, *Oryza sativa* L.

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DECLARATION

I hereby declare that this thesis entitled "**Management of the leaf roller complex on rice, *Oryza sativa* L.**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

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*Dedicated to My
Achan, Amma and
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LIST OF ABBREVIATIONS

%	Per cent
°E	Degree East
μg	Micro gram
°N	Degree North
°S	Degree South
°W	Degree West
@	At the rate of
^{0}C	Degree Celsius
a.i	Active ingredient
CD	Critical difference
cm	Centimetre(s)
DAT	Days after transplanting
EC	Emulsifiable concentrate
et al.	And others
Fig.	Figure
g	Gram
h	Hour
ha^{-1}	Per hectare
HAS	Hours after spraying
kg	Kilogram
m	Metre
/m^2	Per square metre
ml	Millilitre
mm	Millimetre
RLR	Rice leaf roller
SL	Soluble liquid
spp.	Species
viz.	Namely
WAS	Weeks after spraying

INTRODUCTION

1. INTRODUCTION

Rice is unique among the world's major food crops by virtue of the extent and variety of its uses and adaptability to a broad range of climatic edaphic and cultural regimes. Today, rice is the staple food for nearly three billion people, most of whom are Asians and therefore ninety per cent of the world's rice crop is grown and consumed in Asia. Among the Asian countries, India is one of the major producers of rice wherein, the total rice production was 895 lakh tonnes (FIB, 2002).

Kerala is one of the producers of rice in India and over the centuries, rice has sculpted the culture of Kerala. Annual rice production in Kerala is approximately 7.51 lakh tonnes from an area of 3.47 lakh ha and with a productivity of 2203 kg ha^{-1} (FIB, 2002). The per hectare yield of rice is low compared to the other states in India. One of the major factors attributed to the low yields is the infestation and damage by pests. With the advent of the green revolution and cultivation of high yielding varieties of rice in the mid sixties, the insect pest scenario has become more complex. Pests like stem borer, leaf roller, brown plant hopper, gallfly and caseworm has assumed the status of major pests causing approximately 20 to 30 per cent yield loss in rice.

Among the major pests of rice, leaf rollers have become increasingly abundant and serious as they can cause damage throughout the growth of the crop. The scraping, discolouration, folding and removal of green mesophyll tissues reduce their photosynthetic ability and affects the general vigour of rice plants resulting in yield loss. Large scale outbreaks of rice leaf rollers have been reported from almost all rice growing countries in Asia from sixties onwards and most frequently from India (Khan *et al.*, 1988). Hitherto chemical pesticides are used for the control of rice pests including leaf folders. KAU (2002) recommends the application of insecticides like quinalphos, carbaryl, methyl parathion, monocrotophos, phosalone and triazophos against rice leaf roller. However the widespread application of chemical pesticides have resulted in problems like harmful effects to natural enemies and non-target organisms, pest resistance to insecticides, pest resurgence, pesticide residues in food and contamination of the environment. This has necessitated the requirement for development and use of alternate pest control strategies.

Knowledge on the occurrence, extent of damage caused by different species of leaf roller, their host range and feeding potential of their natural enemies are needed for developing an effective management strategy. In order to avoid the after effects of chemical pesticides, use of biopesticides and biocontrol agents would be a desirable option. Knowledge on the species composition of leaf rollers in Kerala is limited. Therefore the identification and conservation of potential indigenous natural enemies of the leaf roller are of paramount importance in pest management. Research must seek to integrate a range of complementary pest control methods which would contain the leaf rollers and at the same time provide a sustainable, productive and equitable agriculture. This calls for a detailed investigation on the effect of botanicals and safer synthetic insecticides on rice leaf rollers and defenders in rice ecosystems which inturn enable us to evolve ecofriendly pest management options against leaf rollers. Hence the present project was undertaken with the following objectives :

1) To identify the different species of rice leaf rollers present in Thiruvananthapuram district of Kerala

2) To determine the occurrence and distribution of rice leaf rollers at different growth stages of the rice crop

3) To assess the extent of damage caused by rice leaf roller

4) To record the natural enemies in the rice ecosystem

5) To evaluate the efficacy of botanicals and safer synthetic insecticides on the population of rice leaf roller and natural enemies in the rice ecosystem and formulate a 'safe' pest management strategy.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The leaf rollers were earlier considered as minor pests of rice. However, over the past four decades they have become increasingly abundant and serious pests and often caused significant yield loss due to the intensification of rice cultivation with modern rice varieties both in upland and lowland rice fields. Extended rice areas with assured irrigation system, multiple rice cropping, reduced genetic variability of high yielding varieties and application of high levels of nitrogenous fertilizers have further compounded the leaf roller problem (Litsinger *et al.*, 1987). Literature on species composition, seasonal abundance, nature and extent of damage of different species of leaf rollers, their natural enemies and the effect of insecticides on the pest and natural enemies are reviewed.

2.1 RICE LEAF ROLLERS

2.1.1 Species Composition and Identification of Different Species of Leaf Rollers in Rice

Two genera of pyraustid moths, *Cnaphalocrocis medinalis* (Guenee) and *Marasmia patnalis* Bradley were reported as leaf folder pests of rice (Leader, 1863). Bradley (1981) reported *M. patnalis* as a leaf roller pest of rice in South East Asia. Four different species of leaf rollers, *viz.*, *C. medinalis*, *Marasmia exigua* (Butler), *M. patnalis* and *Marasmia ruralis* (Walker) were identified based on wing markings by Barrion and Litsinger (1985b). A taxonomic key for the identification of different species of rice leaf roller was developed by Reissig *et al.* (1986). According to Barrion *et al.* (1987) the leaf roller complex consist of eight species *viz.*, *C. medinalis*, *M. exigua*, *Marasmia bilinealis* (Hampson), *Marasmia suspicalis* (Walker), *M. patnalis*, *M. ruralis*, *Marasmia trapezalis* (Guenee) and *Marasmia venilialis* (Guenee). The taxonomy of *C. medinalis* and *M. patnalis* were studied by Barrion *et al.* (1991). Ray and Mandal (1997) studied the larval chaetotaxy of rice leaf folder, *C. medinalis*.

Rajendran and Gopalan (1987) reported that *C. medinalis, M. patnalis* and *M. ruralis* were the common species of rice leaf roller seen in Tamil Nadu. Rice leaf rollers include an overlapping complex of different species (Babu *et al.*, 1998).

Rajamma and Das (1969) recorded severe incidence of leaf roller, *C. medinalis* and Khaire and Bhapkar (1972) explained the species composition of rice leaf roller in Kerala. Mathew and Menon (1984 and 1986) gave a complete picture of the pyralid fauna of Kerala and identified some leaf rollers *viz.*, *C. medinalis, M. patnalis* and *Bradinia* sp. According to Nadarajan and Skaria (1988), the predominant species of rice leaf roller in Pattambi, Kerala were *C. medinalis, M. patnalis* and *Brachmia atrotraea* (Meyrick).

2. 1.2 Distribution and Seasonal Abundance of Rice Leaf Roller

Wei (1990) found that the infestation by rice leaf roller was the greatest in June and the least during May in China, due to higher mortality of larvae and greater number of predators. The distribution of leaf folder varied widely in the rice growing tracts of 29 humid tropical and temperate countries in Asia, Australia and Africa between 48° N and 24° S latitude and 0° E to 172° W longitude and was reported to be seasonal (Khan *et al.*, 1988).

The first record of leaf roller in India was that of Lefroy (1909). Light to heavy incidence of *C. medinalis* was reported from several centres where All India Coordinated Rice Improvement Project trials were in progress (Anon, 1971 and 1972). According to Velusamy and Subramanian (1974), rice leaf roller, *C. medinalis* has been found in almost all rice growing states of India. Studies conducted at CRRI, Cuttack, during 1982 revealed the predominance of *C. medinalis* during

Kharif and Rabi seasons. *B. atrotraea* and *M. exigua* were active from September to December and November to December having peaks during first week of October (53.90 %) and November (96.00 %) respectively. Subramanian (1990) found that rice planted during January, August and September had more leaf folder damage than rice planted during other periods. Rice leaf folders have specialized on different stages of rice crops, as *C. medinalis* was often the first species to colonize a rice field, while *M. patnalis* dominated during the later crop stages (Barrion *et al.*, 1991). Studies on the population fluctuations of rice leaf folder, *C. medinalis* were conducted by Kaul and Singh (1999) in a rice field of Kangra valley, India. Monitoring indicated that peak activity of adults occurred in the fourth week of August and of the larvae during the second week of September. Faliero *et al.* (2000) found that the incidence of rice leaf roller first occurred from 28 days after transplanting (DAT) and continued up to 70 DAT in India. According to Manisegaran and Letchoumanane (2001), the population of rice leaf roller *C. medinalis* and *M. patnalis* was the lowest from June to July and the highest during August to September in Karaikal, Union territory of Pondicherry. A random larval distribution of *C. medinalis* was observed at 30 and 50 DAT on broad leaved and narrow leaved cultivars (Ramasubramanian *et al.*, 2001). Patnaik (2001) reported that a fall in minimum temperature (<20°C) during the last week of September and first week of October increased infestation in rice regardless of planting date. Rai *et al.* (2002) reported that the peak incidence of rice leaf roller occurred during July to August and October.

The highest incidence of leaf roller (0.36 damaged leaf/ hill) was observed at four weeks after transplanting in Kerala (Nandakumar *et al.*, 2002).

2.1.3 Nature and Extent of Damage

Fraenkel *et al.* (1981) reported that the first and early second instar larvae were gregarious and generally fed within the slightly folded basal region of the tiller and the late second instar larvae regularly rolled up the leaves and became solitary. The larvae of rice leaf roller fed by scraping the green mesophyll tissue of rice leaf within the fold which resulted in a linear pale white stripe damage (Khan *et al.*, 1988). Palis *et al.* (1988) reported that due to leaf folder damage the general vigour and photosynthetic ability of an infested rice plant was greatly reduced and damaged leaves served as entry point for bacterial and fungal infection. Rice yield was seriously affected by leaf folder defoliation when plants were at the panicle initiation stage. The young larvae on hatching crawled to the base of the youngest unopened leaves and began to feed. They migrated to older leaves from second larval stage onwards. Only one larvae fed within a tubular feeding chamber. The larvae remained within the folded leaves, feeding by scraping the leaf surface tissue. Each larvae fed three to four leaves during its life time of five stadia (Arida *et al.*, 1990).

According to Murugesan and Chelliah (1983), the leaf roller *C. medinalis* infestation was common at maximum tillering or flag leaf stage. The leaf area damage was 50.00 to 70.00 per cent resulting in 47.00 to 70.00 per cent yield loss per tiller. Srivastava (1989) found that the infestation by *C. medinalis* affected the length and weight of the panicle of eight rice varieties in Madhya Pradesh, India. Dodia *et al.* (1997) determined the economic threshold level for rice leaf folder, *C. medinalis* in Gujarat. The yield loss was greater when the infestation occurred at 40 days after sowing than at 30, 60 and 80 days after sowing. The damage and yield loss were not concomitant with the larval population (Pandi *et al.*, 1998). Saikia and Parameswaran (1999) reported that with no protection at the reproductive stage, there was higher leaf folder damage and lower grain yield, with minimum avoidable yield loss of 4.20 and 5.50 per cent for rice varieties, IR-50 and CO-45 respectively. Goud *et al.* (2001) revealed that the most vulnerable stage of the crop to damage by leaf folder under field condition was at 45 and 60 DAT.

The nature of larval feeding and the damage caused were described by Rajamma and Das (1969) in Kerala.

2.2 NATURAL ENEMIES OF RICE LEAF ROLLER

Vincens (1920) reported that natural enemies including parasitoids and predators kept the population of leaf folder under check and no additional control measures were needed. The importance of conserving natural enemies and their utilization in integrated control programmes in Thailand was reported by Yasumatsu *et al.* (1976). According to Li (1982), in an IPM programme in China, the use of insecticides was limited to a very low level and as a result, 97.90 per cent of the leaf folder was controlled by its natural enemies. According to Hu and Wu (1987) the mean generation mortality of *C. medinalis* was 95.00 to 98.00 per cent of which 50.00 to 60.00 per cent was caused by parasitism and predation and concluded that the parasitoids could suppress the pest population below economic threshold level. Arida and Shepard (1990) reported that there were no significant difference in the rates of parasitism and predation on eggs of leaf folder, *C. medinalis* and *M. patnalis*. Forty natural enemy taxa of leaf folder were identified from the arthropod samples collected from rice fields of Philippines which included 24 predators and 16 parasitoids.

Rice leaf folders had a large and diverse complex of natural enemies, which included more than 200 different species of parasitoids, predators and pathogens, recorded from all over Asia and Pacific (Khan *et al.*, 1988). Saikia and Parameswaran (2002) developed an ecofriendly strategy for the management of rice leaf folder, *C. medinalis* in Tamil Nadu by including four to six releases of *Trichogramma chilonis* Ishi., egg parasitoid of rice leaf roller.

Reghunath *et al.* (1990) reported different types of natural enemies present in the Vellayani kayal ecosystem, which belonged to Araneae, Coleoptera, Odonata, Hemiptera and Hymenoptera. Nalinakumari *et al.*

(1996) and Nandakumar and Pramod (1998) observed orb spider, *Araneus inustus* (L. Koch), damselfly, *Agriocnemis* spp. and ichneumonid wasp like *Trichomma* sp. and *Xanthopimpla flavolineata* Cameron as natural enemies of rice leaf folder from the rice ecosystem. Among the natural enemies, predators constituted about 90 per cent population (Nalinakumari and Hebsybai, 2002).

2.2.1 Parasites

2.2.1.1 Larval Parasites

Larvae of *C. medinalis* were parasitised by *Apanteles* sp., *Apanteles angustibasis* (Gahan), *Bracon* sp., *Goniozus* sp., *Macrocentrus* sp., *Temelucha philippinensis*(Ashmead), *Copidosomopsis nacoleiae* (Eady) and *Trichomma cnaphalocrocis* Uchida (CRRI, 1982). Pati and Mathur (1982) obtained the parasitised leaf roller larvae from the field and it was parasitised by braconids *Apanteles* sp., *A. angustibasis* and *Bracon* sp. Rajapakse and Kulasekare (1982) reported that *Apanteles ruficrus* (Haliday), *Apanteles flavipes* Cameron, *Bracon* sp., *Elasmus* sp. and *Argyrophylax fransseni* (Baranov) as larval parasitoids and the parasitism ranged between 38.00 to 70.00 per cent in Sri Lanka. Ahmed *et al.* (1989) recorded *Trichogramma* sp., *A. angustibasis* and *Brachymeria* sp.as the main parasitoids of leaf roller. According to Borah and Saharia (1989), the rate of parasitisation of *C. medinalis* by *Aulosaphes* sp., *Goniozus* sp. and *Bracon* sp. increased with an increase in pest numbers and peaked either coincidently or after the peak incidence of the pyralid. Reissig *et al.* (1986) reported that many species of wasps, braconids, ichneumonids, chalcids, elasmids and encyrtids parasitised the larval stages of rice leaf folders. Important ones included were *Trichomma* sp, *A. angustibasis*, *Apanteles cypris* (Nixon), *Chelonus munakatae* (Munakata), *Cardiochiles philippinensis* Ashmead, *Macrocentrus philippinensis* Ashmead, *T. philippinensis*, *Temelucha stangli* (Ashmead), *T. cnaphalocrocis*, *Brachymeria excarinata* Gahan, *Elasmus* sp. and *C. nacoleiae*. According to Rajapakse (1990), *Goniozus* sp, *Elasmus* sp., *Macrocentrus* sp. and *Argyrophylax* sp. were the main parasitoids recorded from larvae of *C. medinalis* in rice fields of Sri Lanka. According to the field studies conducted by Guo and Heong (1992), 15 primary larval parasitoids were recorded on the leaf folder complex, *C. medinalis*, *M. patnalis* and *M. exigua* and the dominant species were *C. philippinensis*, *Macrocentrus* sp. and *T. philippinensis*, which mainly attacked the second and third instar larvae. The efficacy of *Goniozus* sp., a gregarious ectoparasitoid of rice leaf roller, *C. medinalis* was tested and found that on an average, a female had parasitised upto 16 host larvae. Manisegaran *et al.* (1997) reared seven parasitoids from natural populations of *C. medinalis* in rice fields in the Karaikal region, Pondicherry, India, of which *Goniozus* sp. and *Elasmus* sp. were the most effective.

The parasites recorded on the larvae of leaf roller were *Goniozus* sp., *Xanthopimpla* sp., *Apanteles syleptae* Ferr., *Elasmus* sp., *Leptobatopsis* sp., *Veraphron* sp. and *Coelenius* sp. (Abraham *et al.*, 1973). Ichneumonid wasp, *Itoplectis narangae* (Ashmead) was reported from the rice ecosystem (Nair, 1990 and Reghunath *et al.*, 1990). Nalinakumari *et al.* (1996) and Ambikadevi (1998c) reported *Trichomma* sp. as one of the major parasites in the rice ecosystem of Kuttanad. Ajayakumar *et al.* (2002b) reported that the parasites were found established after the development of their host in the rice ecosystem. The important parasites observed from Thiruvananthapuram were *Cotesia flavipes* (Cameron) and *Tetrastichus schoenobii* Ferriere.

2.2.1.2 Pupal Parasites

Pupae of rice leaf roller were parasitised by *X. flavolineata* and *Ctenopelma* sp. (Pati and Mathur,1982). Reissig *et al.* (1986) reported that many species of wasps, braconids, ichneumonids, chalcids, elasmids and encyrtids parasitised the pupal stages of rice leaf folders . Bharati and Kushwaha (1989) reported four pupal parasitoids of *C. medinalis viz.*, *X. flavolineata*, *Xanthopimpla* sp., *Brachymeria* sp. nr. *Lasus* and *Tetrastichus* sp. from Haryana. The pupae were parasitised by

Tetrastichus israeli (Mani & Kurien), *Brachymeria excarinata* Gah. and *Brachymeria* sp. (Abraham *et al.*, 1973).

2.2.2 Predators

In a field experiment conducted by Tiwari *et al.* (2001), the important predators recorded on rice leaf roller at various crop growth stages were spiders, dragonfly (*Crocothemis* sp.), damsel fly (*Agriocnemis* sp.), predatory cricket (*Metioche vittaticollis* Stal.), rove beetle (*Paederus fuscipes* Curtis), ground beetle (*Ophionea indica* Habu, *Casnoidea* sp.), predatory grass hopper (*Conocephalus* sp.) and brown bug (*Andrallus spinidens* Fabricius). Ajayakumar *et al.* (2002b) reported that the important predators observed in the paddy field of Thiruvananthapuram were *Agriocnemis* spp., *Crocothemis* sp., *Lycosa pseudoannulata* (Boes. et Str.), *Tetragnatha maxillosa* Thorell, *Micraspis crocea* (Mulsant), *Ophionea nigrofasciata* Schmidt-Goebel and *Cyrtorhinus lividipennis* Reuter. Among the natural enemies, the predators observed were spiders, damsel/ dragon flies, lady bird beetles and ground beetles (Nandakumar *et al.*, 2002).

2.2.2.1 Egg predators

The egg predators of *C. medinalis* included the spider, *Tetragnatha japonica* (Audouin), the coccinellid beetles, *Coccinella arcuata* Fab., *M. crocea* and *Harmonia octomaculata* Fab., the ant *Solenopsis geminata* (Fab.), the crickets *M. vittaticollis* and *Anaxipha* sp. and mirid bug *C. lividipennis* (Kamal, 1981; Reissig *et al.*, 1986, Bandong and Litsinger, 1986). Manley (1985) and Deng & Jin (1985) found that the tettigonid, *Conocephalus* sp., was the only active biological control agent in West Malaysia, and it fed on eggs of the pyralid. Reissig *et al.* (1986) reported that crickets (*viz.*, *M. vittaticollis*, and *Anaxipha* sp.) preyed on the eggs. Rubia and Shepard (1987) found that the cricket, *M. vittaticollis* preyed on the eggs of *C. medinalis*. Kraker *et al.* (2000) assessed the relative importance of egg predators of rice leaf folders and found that *P. fuscipes*, *O. nigrofasciata*, *Micraspis* sp., *Conocephalus* sp. and *M. vittaticollis* consumed pyralid eggs in no choice situations. Chitra *et al.* (2002) reported that the orthopteran predator, *M. vittaticollis* was an effective predator on the eggs of rice leaf folders, *C. medinalis* and *M. patnalis*.

2.2.2.2 Larval Predators

Different species of ants such as *Pheidole* sp.(Das *et al.*, 1974), *Diacamma sp.*, *Componotus* spp., *Odontomachus* sp. and *S. geminata* have been reported as larval predators of *C. medinalis* (Barrion and Litsinger, 1980). Kamal (1981) reported the role of predators in the larval mortality of leaf folders in the Philippines. The beetles *Chlaenius posticalis* (Motschulsky), *C. circumdatus*, *Ophionia ishii* Habu and *P. fuscipes* and the earwig, *Proreus simulans* (Stal) have been reported as larval predators of rice leaf roller (Barrion and Litsinger;1985a, Reissig *et al*;1986 and Barrion and Litsinger;1985c) Damsel fly, ants (*Odontoponera transversa* Smith) and beetles (*O. ishii, P. fuscipes*) preyed on the larvae of rice leaf roller (Reissig *et al.*1986). Ahmed *et al.* (1989) recorded *Componotus* sp., *S. geminata* and *Ischnura* sp. as the predators of rice leaf roller. Luo *et al.* (1989) investigated on the predatory effect of *P. fuscipes* on *C. medinalis*. Rai *et al.* (2002) investigated on the seasonal incidence and feeding potential of *P. fuscipes* and revealed that the peak incidence of *P. fuscipes* occurred during July to August and October, coinciding with the peak incidence of rice leaf folder.

2.2.2.3 Adult Predators

Spiders *viz.*, *L. pseudoannulata* and *Oxyopes javanus* Thorell captured adult leaf roller moths (Reissig *et al.* 1986). Xu *et al.* (1987) identified 167 species of spiders present in the rice field in China, of which *Erigonidium graminicola* (Sundevall), *Oidothorax* sp., *Pirata subpiraticus* (Boesenberg and Strand), *L. pseudoannulata, T. japonica* and *Oxyopes sertatus* (L. Koch) significantly reduced the number of pyralids. Reddy and Heong (1991) reported that the role of *T. maxillosa* as a rice pest predator was negligible as the main prey were weak fliers.

2.3 EFFICACY OF DIFFERENT BOTANICALS AND SYNTHETIC INSECTICIDES ON RICE LEAF ROLLER

2.3.1 Botanical Insecticides

Several botanicals like neem seed oil, neem seed kernel extract, azadirachtin, illuppai oil, mustard oil, castor oil, pungam oil and their mixtures have been reported to be effective against the rice leaf roller.

2.3.1.1 Neem Seed Oil Emulsion

Neem seed kernel extract (NSKE) five per cent evening spray and NSKE five per cent + activated carbon one per cent (antioxidant) morning and evening sprays effectively controlled leaf roller, *C. medinalis* (Mohan, 1989). Neem oil retarded the growth and development of leaf roller, *C. medinalis* (Jayaraj, 1991) and neem reduced leaf spinning and feeding by *C. medinalis* (Lim, 1991).

Krishnaiah and Kalode (1990) reported that soil incorporation of neem cake at 150 kg ha^{-1} followed by a three per cent spray of neem oil was effective against leaf folder, *C. medinalis*. The LC_{50} value of neem oil on third and fourth instar larvae of *C. medinalis* was 1.71 and have higher percentage of mortality of these larval instars (Kannamani, 1992). Reguraman and Rajasekaran (1996) observed that neem oil three per cent and NSKE five per cent were effective in checking *C. medinalis*. Monocrotophos was the most effective insecticide in terms of giving the highest yield (51.30 q ha^{-1}) followed by neem oil (46.20 q ha^{-1}) and nimbecidine (43.70 q ha^{-1}). Safety of neem formulations and insecticides to *Microvelia douglasi atrolineata* (Bergoth), a predator of plant hopper was studied by Lakshmi *et al.* (1997) and reported that Neemax (2.00 and 4.00 per cent) and Rakshak (0.20 and 0.50 per cent) were the safest neem formulations. The maximum mortality was observed in monocrotophos followed by neem oil and lowest in NSKE (Naganagouda *et al.*, 1997 and Baitha *et al.*, 2000). NSKE five per cent caused 63.33 per cent larval mortality of *C. medinalis* (Saikia and Parameswaran, 2001). Sridharan *et al.* (2002) studied the effectiveness of different seed oil mixtures for managing rice leaf roller and found that NSKE four per cent + pungam oil one per cent and neem oil two per cent + pungam oil one per cent was superior compared to recommended dose of NSKE five per cent and neem oil three per cent against the leaf roller.

Neem oil three per cent and neem oil two per cent + garlic three per cent were effective in controlling the rice leaf roller (Ambikadevi and Satheesan, 2002).

2.3.1.2 Azadirachtin

Kannamani (1992) opined that neem formulations effected good mortality of different larval instars of rice leaf roller. According to Naganagouda *et al.* (1997), nimbecidine was least effective in controlling rice leaf roller compared to monocrotophos and neem oil. Neem formulations with lower azadirachtin content (Achook, Neemax and Neemgold) were more effective against *C. medinalis* compared to water based formulations with high azadirachtin content (Krishnaiah *et al.*, 1999). Lingaiah *et al.* (1999) reported that one per cent each of Rakshak. Neemgold and Neem Azal T/S exhibited considerable feeding deterrence of rice leaf roller based on reduced leaf damage.

Singh *et al.* (1999) tried seven neem formulations (Achook, Neemax, Neemgold, Rakshak, Azadirachtin, NSKE and neem oil) against rice leaf folder *C. medinalis* and found Rakshak was the most effective in containing the pest damage. According to Lal (2000), Neemgold and NeemAzal were found to be moderately effective in managing rice leaf roller and increased the yield. NeemAzal (five per cent) recorded 53.33 per cent larval mortality of rice leaf roller (Saikia and Parameswaran, 2001). The incidence of rice leaf folder was minimum in case of monocrotophos which was on par with five per cent NeemAzal (Dhaliwal *et al.*, 2002).

Neemax two per cent, Neem gold two per cent and Achook three per cent were effective in controlling rice leaf roller (Ambikadevi and Satheesan, 2002). Ajayakumar and Nalinakumari (2002) indicated that nimbecidine 4.00 per cent was effective in protecting the leaf against the attack of *C. medinalis*. Significant suppression in the total population of leaf roller was observed in treatments with leaf extracts of neem, *Azadirachta indica* (A. Juss) at one day (6.40) and three days (5.10) after spraying at 40 days after transplanting (Ajayakumar *et al.*, 2002a).

2.3.2 Synthetic Insecticides

Several insecticides of chlorinated hydrocarbons, organophosphates, carbamates, synthetic pyrethroids, neonicotinoids, insect growth regulators and insecticides of microbial origin have been reported to control rice leaf roller.

2.3.2.1 Quinalphos

Quinalphos was quite effective against the leaf folder with 0.70 to 6.20 per cent leaf damage and 0.40 to 7.50 per cent leaf area damage as against 59.40 per cent leaf damage in control at peak activity of leaf folder (Panda *et al.*, 1999).

Godase and Dumbre (1985) reported that quinalphos 0.02 per cent was most effective in controlling *C. medinalis* on rice in Maharashtra giving a larval mortality of 74.48 per cent, 48 hours after application. Of the five insecticides applied at 26 and 38 days after transplanting, the most effective insecticides were quinalphos 1.50 kg a.i. ha^{-1} and monocrotophos at 0.50 kg a.i. ha^{-1} against leaf folder, *C. medinalis* (Bhagat, 1986). Field trials conducted by Sain *et al.* (1987) showed that chlorpyriphos, methyl parathion, monocrotophos and quinalphos were the most effective treatments and dimethoate, the least effective in controlling leaf roller. Raju *et al.* (1988) evaluated the ovicidal activity of nine insecticides against the rice pest, *C. medinalis* and found that phosphamidon (0.045 per cent), quinalphos and monocrotophos (0.05 per cent) caused 100 per cent egg mortality. Bioassay of some selected insecticides against the fourth instar larvae of rice leaf folder, *C. medinalis* was done by Naik *et al.* (1993) who found that on the first day the LC_{50} values were in the order of monocrotophos > deltamethrin > quinalphos > phosphamidon. The relative efficacy of seven insecticides to *C. medinalis* at 57 and 77 DAT was assessed by Kushwaha (1995). As judged from the reduction in damaged leaves due to *C. medinalis,* methyl parathion, monocrotophos, phosphamidon and endosulfan were the most effective followed by quinalphos. Singh *et al.* (1999) tested the efficacy of ten insecticides for the control of *C. medinalis* and found that quinalphos (0.75 kg a.i. ha^{-1}) followed by isazophos (0.60 kg a.i. ha^{-1}) were found to be the best treatments in reducing the pest damage. Verma and Gupta (2001) reported that quinalphos and phosphamidon effectively reduced the pest population upto 88.17 per cent and increased the yield by 17.92 q ha^{-1}.

At Pattambi, parathion was found to be effective in controlling rice leaf roller in virippu season and quinalphos and dicrotophos during mundakan season (Anon, 1971).

2.3.2.2 Imidacloprid

Hai (1996) reported that imidacloprid alone and in mixtures were effective in controlling rice leaf roller, *C. medinalis* and rice plant hopper in China. Mer *et al.* (2001) tested the efficiency of fipronil and imidacloprid and reported that both were effective in controlling the rice leaf roller in China.

Babu *et al.* (2000) found that sprouted rice seed soaked in 0.05 per cent imidacloprid 200 SL for three hours before sowing resulted in a good protection against leaf folder than other treatments in Andhra Pradesh.

Krishnaiah *et al.* (2002) revealed that the insecticides like thiacloprid (@ 240.00 g a.i. ha^{-1}) and chlorpyriphos (@ 500.00 g a.i. ha^{-1}) exhibited efficacy against stem borer and leaf folder and increased the grain yield in Hyderabad. Other insecticides like betacyfluthrin (@ 12.50 g a.i. ha^{-1}), phosphamidon (@ 500.00 g a.i. ha^{-1}), ethiprole (@ 50.00 g a.i. ha^{-1}), imidacloprid (@ 25.00 g a.i. ha^{-1}), and deltamethrin (@ 10.00 g a.i. ha^{-1}) were less effective against stem borer and leaf folder.

2.4 EFFICACY OF BOTANICALS AND SYNTHETIC INSECTICIDES ON NATURAL ENEMIES

2.4.1 Botanical insecticides

2.4.1.1 Parasites

Schmutterer *et al.* (1983) reported that growth and development of endoparasitic hymenopterans on the larvae of *C. medinalis* exposed to rice leaves treated with neem were unaffected. Wu (1986) reported safety of neem seed oil to *A. cypris*, a parasite of brown plant hopper.

According to Saxena *et al.* (1981a) neem oil application in rice field was harmless to parasites of plant hoppers. This also augmented parasitisation of leaf folder larvae by the ichneumonid, encyrtid and braconid parasitoids since neem oil prevented the larvae from folding rice leaves and exposed the larvae to easy parasitisation (Saxena *et al.*, 1981b). Neem seed kernel extract and neem oil have been reported to be safe to *Trichogramma japonicum* Ashmead, *Bracon* sp. and *Apanteles* sp. (TNAU, 1992). Patel and Yadav (1993) found that Neemark was highly toxic to the adult of *Tetrastichus* sp.

2.4.1.2 Predators

Neem seed oil was safe to *L. pseudoannulata* and *C. lividipennis* (Wu, 1986 and Lim, 1991).

According to Saxena *et al.* (1981b), neem and neem products were safe to predators of crop pests. Topical application of neem oil on

L. pseudoannulata caused low mortality at a dose of 50 μg per spider (Saxena *et al.*, 1984) and found neem oil to be toxic to *C. lividipennis*. Mohan *et al.* (1991) found that though there was an initial reduction in number of *L. pseudoannulata* and *C. lividipennis* in neem treated plots, recolonisation was better in these plots. The safety of Neemark to *Menochilus* sp. was reported by Patel and Yadav (1993). Better recolonization of *L. pseudoannulata* in neem treatments was reported by Reguraman and Rajasekaran (1996). The safety of commonly available neem formulations *viz.*, Azadirachtin, Econeem, NeemAzal, Neemgold and Achook were tested against the predators and found that Neemgold at 0.50 per cent and Neemax at two per cent were safe and caused 26.70 per cent and 33.30 per cent mortality respectively, after 72 hour exposure (Lakshmi *et al.*, 1998). Dash *et al.* (2001) reported that plots receiving neem sprays harboured more population of natural enemies, *viz.*, spiders [*L. pseudoannulata, T. maxillosa* and *Argiope catenulate* (Doleschall)] and mirid bugs (*C. lividipennis*) than insecticide treated plots.

2.4.2 Synthetic Insecticides

Srinivas and Pasalu (1990) found that synthetic pyrethroids, cypermethrin, fluvalinate and fenvalerate were highly toxic to the predator, *C. lividipennis*, quinalphos was also fairly toxic. Imidacloprid had no effect on spiders but caused significant mortality of Hemiptera (Xin and Xi, 1995). Tanaka *et al.* (2000) evaluated the toxicity of insecticides to predators *viz.*, spiders, the mirid bug and dryinid wasp and found that deltamethrin was most toxic to the spiders.

Monocrotophos was most effective against all the major pests and was relatively safe to predators (Sontakke, 1993). Mandal and Somchoudhury (1994) found that dust formulations were most toxic to predator complex than emulsifiable concentrate and granules. Kumar and Velusamy (1996) reported that etofenprox and fenobucarb were significantly less toxic to *Tetragnatha javana* (Thorell) than other insecticides. Also significantly lower mortality of *L. pseudoannulata* and *O. javanus* were observed. Predators and parasitoids of major rice pests were less adversely affected by granular application of carbofuran, phorate and quinalphos than spray application of monocrotophos, chlorpyriphos and quinalphos (Patel *et al.*, 1997). Singh and Sharma (1998) found that all granular formulations were less toxic to *Telenomus dignoides*. Lakshmi *et al.* (1997) reported that among the insecticides, phorate and carbofuran granular application and quinalphos (0.05 per cent) spray were less toxic to the predators. From the point of view of effectiveness of insecticides against the pests and safety to natural enemies, compounds such as cartap and endosulfan at 0.50 kg a.i. ha^{-1} and imidacloprid at 0.20 kg a.i. ha^{-1} were found to be quite promising (Panda and Mishra, 1998). Katole and Patil (2000) revealed that imidacloprid was effective against rice plant hoppers and safe to its natural enemies. Imidacloprid was found to be safe to natural enemy population of *Cyrtorhinus* sp. and spiders (Satheesan *et al.*, 2002).

MATERIALS AND METHODS

3. MATERIALS AND METHODS

Survey of the rice leaf roller complex and natural enemies was conducted at Kalliyoor panchayat of Thiruvananthapuram district during the Mundakan season of the year 2002. The field experiment was conducted at the Instructional Farm of the College of Agriculture. Vellayani.

3.1 IDENTIFICATION OF DIFFERENT SPECIES OF RICE LEAF ROLLER (RLR)

The occurrence and distribution of different species of rice leaf roller were assessed in the rice ecosystem of Kalliyoor panchayat of Thiruvananthapuram district. A survey was conducted during the 'Mundakan' season of the rice crop.

3.1.1 Survey and Collection of Different Species of Rice Leaf Roller

The survey was conducted at 30, 50 and 70 days after transplanting (DAT) of the crop. Three samples were taken by sweep net collection from 20 cents of each farmer's field by random sampling technique. The methodology of Reissig *et al.* (1986) was adopted. The pests on the upper parts of the plant and inside the canopy were collected in ten net sweeps by moving diagonally across each selected farmer's field. The damaged leaves along with leaf roller larvae were also gathered from 1 m^2 area in each farmer's field for further observations.

The pest specimens collected were then transferred to a polythene bag. One end of a long cotton strip, was moistened with chloroform and the moistened end was introduced into the polythene bag and tied using a rubber band. After ten minutes, the cotton strip was removed from the polythene bag and the specimens were brought to the laboratory for further examination.

3.1.1.1 Laboratory Studies for Identification

Different species of leaf rollers were identified based on the taxonomic key devised by Barrion and Litsinger (1985b). The collected adults of rice leaf rollers were used for species identification based on wing markings. The larvae of different species of leaf roller were identified based on the body colour and also based on the spots present on the pronotum of the larvae.

Larvae collected from the field were reared in the laboratory for adult emergence. Plastic cups (8 x 6 cm) were used for raising seedlings for laboratory studies. They were filled two-third with clayey soil and two numbers of one month old seedlings were planted in each cup. They were kept in the insectary undisturbed for one week and watered daily. The larvae collected from the field were released into the rice plants and covered with a polythene cover which was moistened properly and provided with small holes for proper air circulation (Plate 1). The larval characters and adult emergence pattern was studied. The adults were separated and identified based on the taxonomic key.

3.1.2 Distribution of Rice Leaf Roller at Different Growth Stages

Leaf roller population was assessed by using sweep net collection during different growth stages of the crop *i.e.*, 30, 50 and 70 DAT, based on the larval as well as the adult count. The larval count was taken by observing the leaf fold closely. The damaged folded leaf was opened forcefully and the larval count was taken. After that it was kept as such without destroying. Counts were taken from three randomly selected locations in each farmer's field and mean population per field was worked out.

3.1.3 Studies on the Extent and Nature of Damage Caused by Rice Leaf Roller

The studies were conducted during the Mundakan season of 2002. The symptoms and damage caused by the rice leaf rollers were properly

Plate 1. Rearing Technique for Rice Leaf Roller

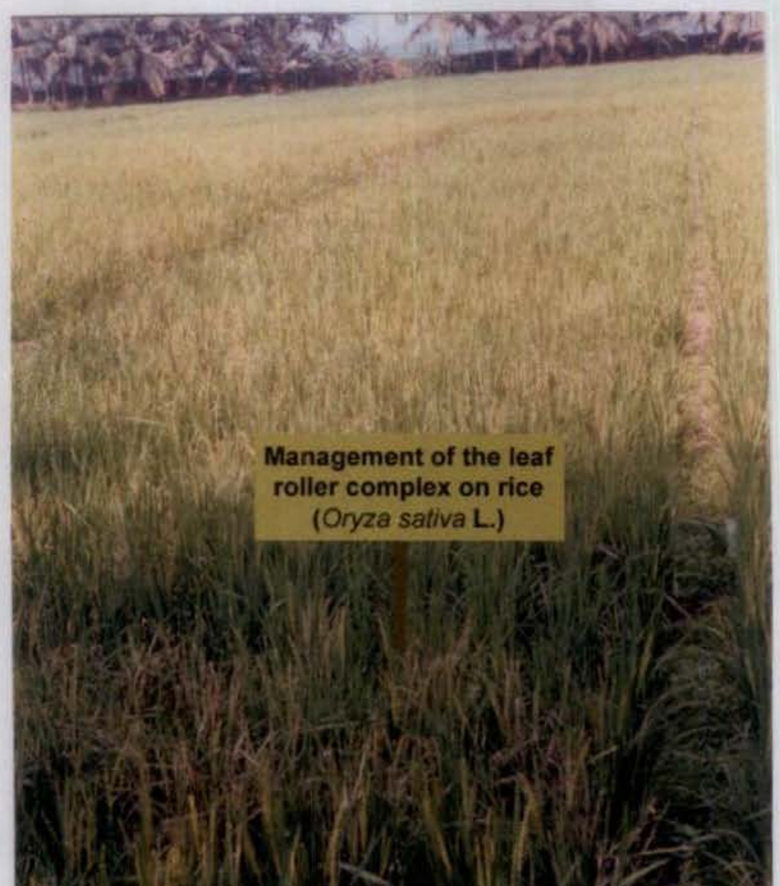


Plate 2. Experimental field

observed and documented. The presence of longitudinal and transparent whitish streaks on the damaged leaves indicated the presence of leaf roller attack. Combined damage due to different species of rice leaf roller was regularly monitored for one crop period at different growth stages of the crop *viz.*, 30, 50 and 70 DAT. The number of leaves damaged per m^2 from each plot due to leaf roller attack were counted and recorded at different growth stages of the crop.

The symptoms and damaged leaves were collected from the field and observed for its nature or type of folding.

3.2 SURVEY OF NATURAL ENEMIES AT DIFFERENT GROWTH STAGES OF RICE

The defenders or natural enemies were collected from the rice field by the method followed by Reissig *et al.* (1986). The specimens collected by using sweep net were transferred to polythene covers and brought to the laboratory for further examination. The natural enemies were collected from three randomly selected locations from each of the selected twenty farmers' field in Kalliyoor panchayat. The natural enemies present in each bag were separated and counted. This was treated as the natural enemy count of each location during the period of observation. The parasites and predators obtained in each sweep net were identified based on the key devised by Reissig *et al.* (1986). The population of these natural enemies were observed at different growth stages *viz.*, 30, 50 and 70 DAT.

3.3 EVALUATION OF BOTANICALS AND SYNTHETIC CHEMICALS FOR THE MANAGEMENT OF RICE LEAF ROLLER (RLR)

The investigations were carried out during 'Virippu' season to determine the efficacy of botanicals, newer synthetic insecticides and their combinations against the rice leaf roller. The experiment was conducted during the first crop season from August to November in the year 2002. The details of the materials used and the methods adopted for the study are presented below.

The experiment was conducted at the Instructional Farm attached to the College of Agriculture, Vellayani, located at 8.5° N latitude and 76.9° E longitude, at an altitude of 29 m above the mean sea level. The soil of the experimental site was sandy loam, belonging to the taxonomical order, oxisol. The area of the experimental site enjoys a humid tropical climate. The field experiment was conducted during the first crop season of 2002. The rice variety selected for the experiment was 'Jyothi', a short duration high yielding variety released from Regional Agricultural Research Station (RARS), Pattambi. The seeds for the experiment were obtained from RARS, Pattambi. Well decomposed and dried farmyard manure @ 5 t ha^{-1} was used for the experiment. Nitrogen, phosphorus and potassium were used @ 90 : 45 : 45 kg ha^{-1} for the experiment. The application was done as envisaged in the Package of Practices recommendations of the KAU (2002).

3.3.1 Design and Layout

Design	:	RBD
Treatments	:	10
Replications	:	3
Plot size	:	5 x 4 m^2
Spacing	:	10 x 15 cm
Total number of plots	:	30

Two rows of plants were left as border rows on all sides and the observations were taken from a marked 1 m^2 area from each plot.

The layout plan of the experiment is given below and general view of the experimental plot is given in Plate 2.

N

R_1		R_2		R_3	
T_2	T_7	T_3	T_{10}	T_3	T_5
T_5	T_3	T_6	T_8	T_2	T_6
T_8	T_1	T_5	T_1	T_9	T_4
T_6	T_{10}	T_7	T_9	T_7	T_{10}
T_4	T_9	T_4	T_2	T_1	T_8

3.3.2 Treatments

The treatments included in the experiments were.

T_1 → Neem seed oil (NSO) 3 %

T_2 → Azadirachtin 0.004 %

T_3 → Quinalphos 0.05 %

T_4 → Imidacloprid 0.005 %

T_5 → Neem seed oil 3 % + quinalphos 0.025 %

T_6 → Azadirachtin 0.004 % + quinalphos 0.025 %

T_7 → Neem seed oil 3 % + Imidacloprid 0.0025 %

T_8 → Azadirachtin 0.004 % + Imidacloprid 0.0025 %

T_9 → Mechanical control

T_{10} → Control

3.3.3 Imposition of Treatments

Insecticides were applied at two growth stages, the first spray was done at 30 DAT and second spray was applied at 60 DAT. While spraying a plastic sheet was tied (wind screen) between two plots to avoid drift of pesticide spray. The insecticides were applied as high volume spray using a knapsack sprayer. Plots in which water spray was given served as control. In the mechanical control plot, the leaf folds were opened with the help of a thorny twig.

3.3.4 Preparation of Spray Materials

3.3.4.1 Neem Seed Oil Emulsion (3 per cent)

Good quality neem seed oil was purchased from M/S Sundaresan Nair, Drugs Merchant, Chalai Bazar, Thiruvananthapuram.

Ninety ml of neem seed oil was taken in a bucket. 15 grams of ordinary washing soap was grated and lathered in 100 ml hot (50°C) water and the soap solution was added to the neem seed oil. 2.80 litres of water was added slowly and the solution was agitated thoroughly to obtain three litres of three per cent neem seed oil emulsion. This emulsion was applied as a high volume spray using a knapsack sprayer.

3.3.4.2 Azadirachtin 0.004 per cent

A commercial botanical pesticide, NeemAzal containing azadirachtin 1.0 per cent supplied by M/S EID Parry (I) Ltd., Chennai was used for the experiment. Azadirachtin 0.004 per cent was obtained by mixing 12 ml of NeemAzal in three litres of water.

3.3.4.3 Quinalphos 0.05 per cent

A commercial pesticide, Ekalux 25 per cent EC/AF, of M/S Sandoz India Ltd. was used for the experiment. Quinalphos 0.05 per cent was obtained by mixing six ml of the insecticide in three litres of water.

3.3.4.4 Imidacloprid 0.005 per cent

A commercial pesticide, confidor 200 SL of M/S Bayer(India) Limited was used for the experiment. Imidacloprid 0.005 per cent was prepared by dissolving 0.75 ml of the insecticide in three litres of water.

3.3.4.5 Neem Seed Oil Emulsion (3 per cent) + Quinalphos (0.025 per cent)

Ninety ml of good quality neem seed oil was dissolved in three litres of water to get three per cent neem seed oil emulsion. The procedure for the preparation of neem seed oil emulsion was the same as in 3.3.4.1. To this three ml of ekalux was added and thoroughly mixed.

3.3.4.6 Azadirachtin 0.004 per cent + Quinalphos (0.025 per cent)

Twelve ml of NeemAzal and three ml of ekalux (quinalphos) were taken in a bucket and 250 ml of water was added and then thoroughly mixed. This solution was made upto three litres and well agitated.

3.3.4.7 Neem Seed Oil Emulsion (3 per cent) + Imidacloprid 0.0025 per cent

Three litres of neem seed oil emulsion (3 per cent) was prepared as mentioned in 3.3.4.1. To this, 0.375 ml of confidor (imidacloprid) was added and then thoroughly mixed.

3.3.4.8 Azadirachtin (0.004 per cent) + Imidacloprid (0.0025 per cent)

Twelve ml of NeemAzal and 0.375 ml of confidor (imidacloprid) were taken in a bucket and 250 ml of water was added and then thoroughly mixed. This solution was made upto three litres and well agitated.

3.3.5 Observations of Percentage Damage and Population of Rice Leaf Roller and Natural Enemies

Observations on the percentage damage and the population of rice leaf roller and natural enemies were recorded at 24 hours, 48 hours and one week after spraying at 30 and 60 DAT. The population of larvae was recorded by counting the number of larvae/m^2 in each experiment plots.

3.3.6 Yield

The grains harvested from each net plot area were dried, cleaned, weighed and expressed in kg ha^{-1}. The straw was harvested separately from each net area and dried under sun and the weight was expressed in kg ha^{-1}.

3.3.7 Methodology Adopted for Recording Observations

Observations	**Methodology**
Combined leaf damage due to different species of leaf rollers	Percentage damage $\left[\dfrac{\text{Number of leaves damaged/m}^2}{\text{Total number of leaves/m}^2} \times 100\right]$
Nature of damage	Type of folding
Rice leaf roller population	Number of adults / sweep net
	Number of larvae/m^2
Natural enemy population	Number of different natural enemies per sweep net collection from each plot
Yield	Yield of grain and straw recorded from each experimental plot and expressed in kg ha^{-1}

3.3.8 Assessment of Results

Data generated from the survey were subjected to statistical analysis by applying paired 't' test. Data from field experiment were transformed and statistically analysed using Analysis of Variance (Panse and Sukhatme, 2000).

RESULTS

4. RESULTS

A survey to identify different species of rice leaf roller and its natural enemies was conducted at Kalliyoor panchayat of Thiruvananthapuram district during the Mundakan season of the year 2002.

4.1 OCCURRENCE AND DISTRIBUTION OF DIFFERENT SPECIES OF RICE LEAF ROLLER IN RICE ECOSYSTEM IN KALLIYOOR PANCHAYAT OF THIRUVANANTHAPURAM DISTRICT

The results of the survey conducted to study the occurrence and distribution of different species of rice leaf roller in rice ecosystem in Kalliyoor panchayat of Thiruvananthapuram district are presented in Table 1, 2 and 3.

The different species of rice leaf roller recorded in the survey were *Cnaphalocrocis medinalis* (Guenee) and *Marasmia patnalis* Bradley.

4.1.1 *C. medinalis*

The adult of *C. medinalis* is yellowish brown in colour. The forewing of adult moth have two black cross lines originating from the costal margin, of which one terminates near the base of the forewing while the other extends down to the hind wing. Also a brownish black patch is seen in costal margin in the middle of these two lines. The larvae of *C. medinalis* have a pair of brown coloured spot in the pronotum (Plate 3).

4.1.1.1 Larvae

The larval population of *C. medinalis* varied from 2.0 to 5.0 larvae/m^2 at 30 and 50 days after transplanting (DAT) respectively, whereas it ranged from 1.7 to 4.0 larvae/m^2 at 70 DAT. There was no significant variation in the larval population of *C. medinalis* observed at 30 DAT and 50 DAT, the

Table 1 Occurrence and distribution of different species of leaf roller and its damage in 20 farmers' rice field of Kalliyoor Panchayat, Thiruvananthapuram district

No.	Leaf roller larvae						Leaf roller Adults						Percentage leaf damage		
	Cnaphalocrocis medinalis			*Marasmia patnalis*			*C. medinalis*			*M. patnalis*					
	DAT			DAT			DAT			DAT			DAT		
	30	**50**	**70**	**30**	**50**	**70**	**30**	**50**	**70**	**30**	**50**	**70**	**30**	**50**	**70**
1	2.0	4.0	1.7	4.3	3.0	2.7	2.0	2.7	2.0	3.0	1.7	2.3	2.0	2.2	2.7
2	3.0	3.3	2.0	2.7	3.3	3.0	3.3	2.7	2.0	3.0	2.7	2.7	2.6	2.8	3.6
3	4.0	3.7	2.7	3.7	4.3	1.0	4.3	2.3	0.7	3.0	4.0	2.0	2.7	2.8	3.6
4	3.3	3.3	3.0	4.3	2.7	2.7	3.0	4.3	2.0	3.0	2.3	2.7	2.1	2.3	3.0
5	4.7	5.0	2.3	4.0	2.7	1.7	5.3	2.7	2.0	2.7	3.0	1.7	3.1	3.3	3.5
6	2.7	2.3	1.7	3.3	6.0	3.0	5.0	3.0	1.6	1.0	5.0	1.0	2.0	2.4	3.0
7	4.3	3.3	3.0	5.0	3.3	2.0	4.3	4.3	2.0	2.7	5.0	3.3	2.4	2.8	3.4
8	4.3	5.0	3.0	4.0	3.3	2.0	3.0	3.0	2.7	3.0	5.0	2.0	2.4	2.9	3.1
9	3.0	4.7	2.0	3.0	5.0	2.7	3.0	1.7	1.3	2.3	4.3	0.3	3.0	3.0	3.6
10	3.7	3.3	2.3	3.7	5.0	1.7	4.0	4.0	1.3	2.0	3.3	2.7	2.3	2.4	3.3
11	2.7	2.0	2.0	3.7	5.0	3.3	4.7	3.3	2.7	2.3	4.3	0.7	2.2	2.3	3.7
12	3.0	3.3	2.3	4.3	2.3	2.0	1.3	3.7	1.3	3.3	3.0	2.7	2.2	2.9	4.2
13	3.7	4.7	2.3	4.3	5.3	3.0	3.0	2.7	1.6	3.0	2.7	4.3	2.8	2.9	3.6
14	2.3	3.0	2.3	3.3	5.0	2.7	1.7	4.3	3.3	3.0	3.7	1.7	3.4	3.8	4.4
15	2.0	4.3	4.0	5.0	2.7	3.3	3.7	4.7	2.3	3.3	3.3	2.0	3.0	3.3	3.9
16	5.0	4.0	1.7	2.0	4.0	3.3	2.7	3.0	1.6	2.3	4.3	4.0	2.7	3.2	4.1
17	3.3	3.7	3.3	4.0	4.0	4.7	3.3	3.7	1.3	2.3	3.3	3.3	1.8	2.7	4.2
18	2.7	2.3	2.0	3.7	2.7	1.3	2.3	2.3	1.6	2.3	5.7	2.0	2.4	2.9	4.3
19	2.7	3.7	4.0	4.3	5.7	3.3	4.0	3.0	1.3	3.0	4.3	2.0	2.0	2.6	3.6
20	3.0	4.3	3.0	4.3	5.0	3.0	2.3	4.7	2.0	2.7	3.3	2.7	2.8	2.8	3.5

DAT - Days after transplanting

Table 2 Occurrence and distribution of different species of leaf roller and its percentage damage in Kalliyoor panchayat of Thiruvananthapuram district

Growth stages of the crop (DAT)	Mean percentage damage and mean number of different stages of rice leaf roller present in Kalliyoor panchayat of Thiruvananthapuram district				
	Mean number of larvae of rice leaf roller		Mean number of adults of rice leaf roller		Mean percentage of leaves damaged
	C. medinalis	*M. patnalis*	*C. medinalis*	*M. patnalis*	
30	3.267	3.833	3.317	2.633	2.489
50	3.667	4.000	3.300	3.733	2.696
t-value	1.4527	0.4553	0.5518	3.9438	3.4378
30	3.267	3.833	3.317	2.633	2.489
70	2.533	2.617	1.850	2.267	3.545
t-value	3.2545	3.8906	6.0662	1.6637	10.2194
50	3.667	4.000	3.300	3.733	2.696
70	2.533	2.617	1.850	2.267	3.545
t- value	4.0966	4.8824	6.8885	5.0812	10.3115

Table 3 Nature of leaf fold by rice leaf roller complex

No.	Nature of leaf fold											
	30 DAT				50 DAT				70 DAT			
	A	B	C	D	A	B	C	D	A	B	C	D
1	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
2	✓		✓	✓	✓	✓	✓		✓	✓	✓	
3	✓	✓	✓			✓	✓			✓	✓	✓
4	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
5	✓	✓		✓		✓	✓	✓	✓	✓	✓	✓
6	✓	✓	✓	✓	✓	✓	✓			✓	✓	
7	✓	✓			✓	✓	✓		✓	✓	✓	
8	✓	✓	✓		✓	✓	✓		✓	✓	✓	
9	✓	✓				✓	✓	✓	✓	✓	✓	✓
10	✓			✓	✓	✓	✓			✓	✓	✓
11		✓	✓	✓	✓	✓	✓			✓	✓	
12	✓	✓				✓	✓	✓	✓	✓	✓	
13	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	
14	✓	✓				✓	✓	✓		✓	✓	✓
15	✓	✓	✓			✓	✓	✓	✓	✓	✓	
16	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓
17	✓	✓			✓	✓	✓		✓	✓	✓	✓
18	✓		✓	✓	✓	✓	✓			✓	✓	
19	✓		✓		✓	✓	✓			✓	✓	
20		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓

A – Single leaf folded vertically backwards
B – Single leaf folded longitudinally
C Two leaves folded together
D – Multiple / composite leaf fold

C. medinalis **larva**

M. patnalis **larva**

Adult moth of *C. medinalis*

Adult moth of *M. patnalis*

Plate 3 Different species of rice leaf roller

population being 3.267 and 3.667 larvae/m^2 respectively. However the population at 30 and 70 DAT showed significant difference and the population was 2.533 at 70 DAT. A significant difference in larval population was also observed at 50 and 70 DAT. There was a gradual increase in the larval population from 30 to 50 DAT, then the population dropped at 70 DAT to a level which was even lower than the population at 30 DAT.

4.1.1.2 Adults

The mean population of *C. medinalis* adults collected at 30 DAT from 20 farmers field ranged from 1.3 to 5.3/10 sweeps and the same recorded during reproductive stages varied from 1.7 to 4.7 /10 sweeps (50 DAT) and 0.7 to 3.3 /10 sweeps (70 DAT) respectively. The highest mean population of adults of *C. medinalis* was noticed at 30 DAT in Kalliyoor panchayat. The mean population at 30 DAT was 3.317, which was statistically on par with population of *C. medinalis* at 50 DAT (3.300). Lowest mean population of *C. medinalis* was observed at 70 DAT (1.850) and differed significantly from 30 and 50 DAT.

4.1.2 *M. patnalis*

The adults of *M. patnalis* is straw coloured with three black cross lines on the forewing, of which two extends down to the hind wing. The larvae of *M. patnalis* have two pairs of brownish spot in the pronotum (Plate 3).

4.1.2.1 Larvae

In the case of *M. patnalis*, the larval population varied from 2.0 to 5.0 larvae/m^2 at 30 DAT. The population ranged from a minimum of 2.3 to a maximum of 6.0 and 1.0 to 4.7 larvae/m^2 at 50 and 70 DAT respectively. The mean population of *M. patnalis* observed at 30, 50 and 70 DAT were 3.833, 4.000 and 2.617 larvae/m^2 respectively. A similar trend was observed as in the case of *C. medinalis*. There was a gradual increase in the population of larvae from 30 DAT to 50 DAT. Then the population dropped at 70 DAT to a level which was even lower than the population at 30 DAT. There was no significant difference in the larval population of *M. patnalis* at 30 and 50 DAT. However the population differed significantly between 50 and 70 DAT and 30 and 70 DAT.

4.1.2.2 Adult

Comparatively high population of *M. patnalis* was observed from the farmers field which ranged from 1.0 to 3.3, 1.7 to 5.7 and 0.3 to 4.3 per 10 sweeps at 30, 50 and 70 DAT respectively. There was significant difference in the population of *M. patnalis* observed at different growth stages. The population of adults of *M. patnalis* dropped after reaching a peak at 50 DAT. The highest mean population of *M. patnalis* was recorded at 50 DAT (3.733) followed by 30 DAT (2.633) and lowest during 70 DAT (2.267).

4.1.3 Leaf Damage

4.1.3.1 Nature of Damage

Early instar larvae on hatching congregated on the youngest leaf and began to feed. They migrated to older leaves from the second larval stage onwards and made folds of various lengths and fed within them. Leaf folding was accomplished by connecting the margins of leaf blades with a series of threads which the caterpillar secreted. The larvae remained within the leaf fold, feeding by scraping the leaf surface (Plate 4 & 5). Different types of fold noticed in the field were:

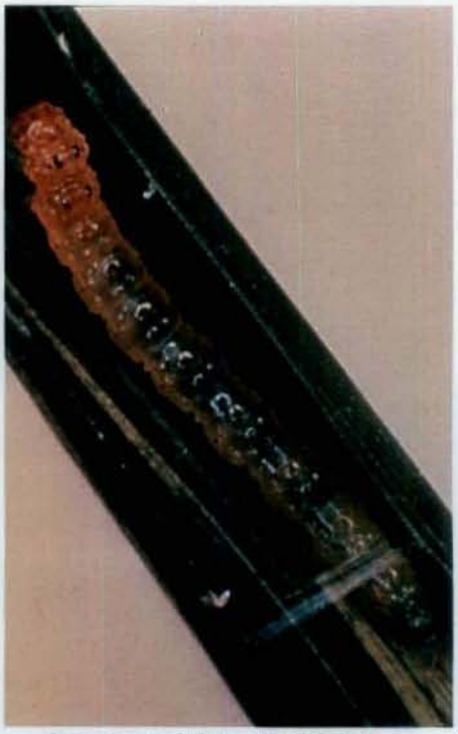
1) Single leaf folded longitudinally

In this type, the leaf folding was accomplished by connecting the two margins of a leaf blade longitudinally with a series of threads, which the caterpillar secreted.

2) Single leaf folded vertically backwards

Here the leaf was folded back first, then the margins were woven by using the threads secreted by the larvae.

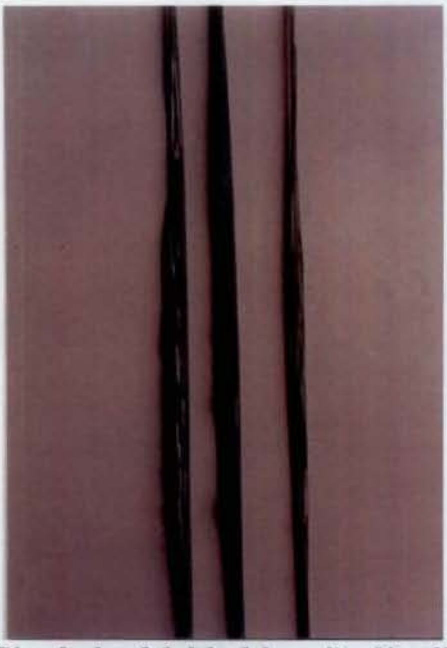
Damage of leaf roller



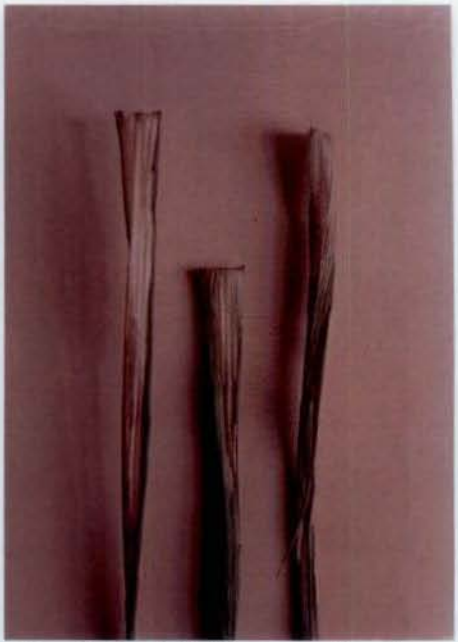
Larva within the fold

Field damage

Plate 4. Nature of damage

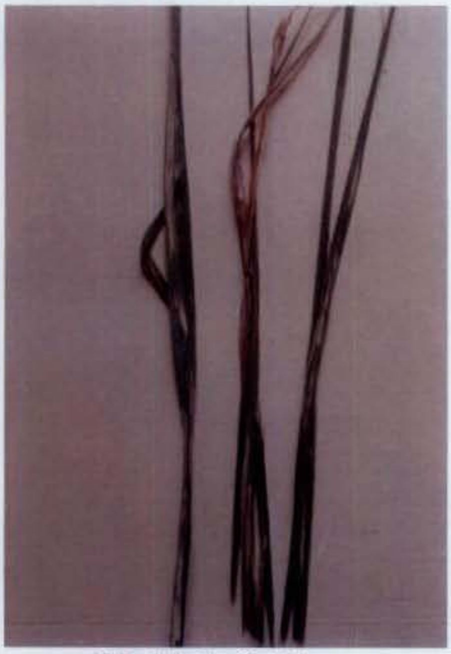


Single leaf folded longitudinally



Single leaf folded vertically backwards

Two leaves folded together



Multiple folding

Plate 5. Type of leaf folds

3) Two leaves folded together

In this type, two leaves were folded together longitudinally by the silken threads secreted by the larvae.

4) Multiple / composite folding

Here more than one leaf was folded together longitudinally using silken threads secreted by the larvae.

During the vegetative stage, majority of the leaf folds seen in the field were single leaf folded vertically backwards and single leaf fold longitudinally. But in the early and late reproductive stage, majority of the leaf folds were single leaf folded longitudinally and two leaves folded together.

4.1.3.2 Percentage of Leaves Damaged

The symptom manifested by the combined attack of the two species of rice leaf roller was recorded and represented as percentage of leaf damaged. As indicated in Table 1, the damage due to rice leaf roller varied with a minimum percentage damage of 1.8 to a maximum of 3.40 at 30 DAT among the 20 farmers' field observed. The percentage leaf damage showed an increasing trend which ranged from 2.2 to 3.8 and 2.7 to 4.4 per cent at 50 and 70 DAT respectively. The percentage of leaves damaged at different growth stages of rice crop showed significant variation at 30 and 50, 30 and 70 and 50 and 70 DAT. The population ranged from 2.489 at 30 DAT to 3.545 at 70 DAT. There was a gradual increase in the percentage of leaves damaged from 30 DAT to 70 DAT.

4.2 OCCURRENCE AND DISTRIBUTION OF DIFFERENT NATURAL ENEMIES IN RICE ECOSYSTEM IN KALLIYOOR PANCHAYAT OF THIRUVANANTHAPURAM DISTRICT

The different natural enemies seen the rice ecosystem in Kalliyoor panchayat of Thiruvananthapuram district at different growth stages were shown in Table 4 (Plate 6).

Table 4 Natural enemies present in the rice ecosystem in Kalliyoor panchayat

Common name	Scientific name	Family	Order
a. Parasites	*Goniozus triangulifer* Kieffer	Bethylidae	Hymenoptera
	Xanthopimpla flavolineata Cameron	Ichneumonidae	"
	Cotesia sp.	Braconidae	"
b. Predators			
1. Spiders			
i) Long jawed spider	*Tetragnatha maxillosa* Thorell	Tetragnathidae	Araneae
ii) Wolf spider	*Lycosa pseudoannulata* (Boesenberg and Strand)	Lycosidae	"
iii) Lynx spider	*Oxyopes javanus* Thorell	Oxyopidae	"
2. Damselfly	*Agriocnemis* spp.	Coenagrionidae	Odonata
3.Predatory beetles			
Lady bird beetle	*Micraspis crocea* (Mulsant)	Coccinellidae	Coleoptera
Rove beetle	*Paederus fuscipes* Curtis	Staphylinidae	"
Ground beetle	*Ophionia nigrofasciata* Schmidt-Goebel	Carabidae	"
4.Predatory bugs			
Mirid bug	*Cyrtorhinus lividipennis* Reuter	Miridae	Hemiptera
Assassin bug	*Polytoxus fuscovitattus* (Stal)	Reduviidae	"
5. Grass hopper	*Conocephalus* sp.	Tettigonidae	Orthoptera

Goniozus **sp**

Cotesia **sp**

Paederus fuscipes

***Micraspis* sp**

***Tetragnatha* sp**

***Tetragnatha* sp**

Plate 6. Natural enemies of Rice Leaf Roller

The results of the survey conducted to study the distribution of different natural enemies in the rice ecosystem in Kalliyoor panchayat of Thiruvananthapuram district are presented in Table 5 and 6.

4.2.1 *G. triangulifer*

The population of *G. triangulifer* varied from 1.0 to 3.7 per 10 sweeps at 30 DAT. At 50 and 70 DAT the population ranged from 1.7 to 5.7 and 3.0 to 6.3 per 10 sweeps respectively among the observation fields. The population of *G. triangulifer*, a parasite of rice leaf roller, showed an increasing trend from 30 DAT to 70 DAT. From 30 DAT to 50 DAT, there was a significant increase in the population. Eventhough a gradual increase in population was observed from 50 DAT to 70 DAT, stastically there was no significant variation in population among the growth stages. The population were 2.417, 3.317 and 3.800 per 10 sweeps respectively on 30, 50 and 70 DAT respectively.

4.2.2 *X. flavolineata*

The population of *X. flavolineata* varied from 0.0 to 3.0, 0.7 to 2.0 and 0.7 to 2.0 per 10 sweeps at 30, 50 and 70 DAT respectively among the 20 farmers' field. There was a significant increase in the population of *X. flavolineata* from 30 DAT to 50 DAT. However the population almost remained the same from 50 to 70 DAT. There was a significant difference in the population at 30 and 70 DAT. The highest mean population was observed at 70 DAT (1.333) followed by 50 DAT (1.267) and 30 DAT (0.883).

4.2.3 *Cotesia* sp.

The population of *Cotesia* sp. varied from 0.0 to 2.2, 0.0 to 1.7 and 0.3 to 2.3 per 10 sweeps at 30, 50 and 70 DAT respectively among the observation fields. Observations at different growth stages of the crop *viz.*, at 30 DAT and 50 DAT indicated that there was no significant increase in the population of *Cotesia* sp. However from 50 to 70 DAT, a significant difference in the population of *Cotesia* sp. was observed. The mean population of *Cotesia* adults recorded was 0.550, 0.700 and 1.200 per 10 sweeps at 30, 50 and 70 DAT respectively.

Table 5 Occurrence and distribution of natural enemies in the rice ecosystem in 20 farmers' rice fields of Kalliyoor Panchayat of Thiruvananthapuram district

No.	Natural enemies observed at different growth stages																							
	Goniozus triangulifer			*Xanthopimpla flavolineata*			*Cotesia* sp			*Agriocnemis* spp.			Spiders			Predatory beetles			Predatory bugs			*Conocephalus* sp.		
	DAT			DAT			DAT			DAT			DAT			DAT			DAT			DAT		
	30	**50**	**70**	**30**	**50**	**70**	**30**	**50**	**70**	**30**	**50**	**70**	**30**	**50**	**70**	**30**	**50**	**70**	**30**	**50**	**70**	**30**	**50**	**70**
1	3.0	3.3	6.3	0.0	1.3	2.0	0.7	1.0	2.0	1.3	2.0	3.3	1.0	2.0	5.0	3.7	3.7	7.7	3.0	3.3	8.7	1.0	1.3	3.0
2	3.3	3.7	5.3	1.3	1.7	1.3	1.0	1.7	1.7	1.7	1.7	3.0	1.7	4.3	4.3	3.3	5.0	7.7	1.3	4.3	8.7	1.0	1.7	3.0
3	2.0	2.0	3.3	2.0	0.7	1.3	0.7	0.3	1.0	1.0	1.3	2.3	2.0	2.0	2.7	3.7	4.7	5.3	1.3	3.0	7.0	1.0	2.3	2.0
4	2.3	5.7	3.0	3.0	1.7	1.3	0.3	1.0	0.3	2.0	2.0	1.7	1.7	3.3	1.7	5.0	4.0	3.0	2.0	4.0	4.0	2.0	1.7	2.3
5	1.7	3.0	4.0	1.0	1.3	1.3	0.7	0.7	0.7	3.0	1.3	2.0	1.3	2.3	3.0	3.3	4.3	6.0	0.7	2.7	5.3	0.7	1.7	2.7
6	3.0	3.0	4.0	1.0	1.7	1.3	0.3	0.3	0.7	1.0	2.3	2.3	1.3	2.7	2.7	4.0	4.3	5.7	0.0	4.3	5.0	0.3	1.3	3.0
7	2.0	2.7	4.3	1.3	1.0	1.0	0.0	1.0	0.7	2.0	2.3	2.0	1.0	3.3	2.3	3.3	5.3	5.3	0.3	4.0	5.3	1.3	2.3	2.0
8	2.0	4.7	4.0	2.0	1.7	1.3	0.3	1.3	1.0	2.0	2.7	2.3	1.3	3.7	3.3	3.7	5.0	6.7	0.7	3.0	5.7	1.7	1.7	3.3
9	2.0	3.3	4.0	2.0	1.0	1.3	0.7	0.7	1.3	3.0	1.7	2.3	2.0	3.0	3.7	3.3	3.0	5.3	1.0	3.7	5.0	1.0	2.7	3.3
10	2.3	3.0	3.3	1.0	1.0	1.3	0.3	0.3	1.0	1.0	2.3	4.0	1.3	3.3	3.3	3.0	5.3	5.3	1.3	4.3	5.3	1.7	1.7	2.3
11	3.0	1.7	3.3	2.0	0.7	1.0	0.7	0.7	1.0	2.0	2.3	1.7	2.0	2.3	2.7	4.3	4.0	6.3	1.7	4.7	6.0	1.7	1.0	2.3
12	1.0	2.0	3.3	1.0	1.3	1.7	0.3	0.3	1.3	2.0	2.3	3.0	1.0	3.7	3.0	2.3	5.7	6.7	1.0	5.7	6.0	1.0	3.3	2.7
13	2.7	3.0	3.7	0.7	1.3	1.3	0.3	0.3	1.0	2.0	2.3	2.3	2.0	2.3	3.3	4.3	5.3	3.7	0.7	4.7	3.3	1.3	2.0	1.7
14	2.0	2.7	4.0	1.3	2.0	2.0	0.7	0.7	1.0	3.0	1.7	2.0	1.7	1.7	5.0	3.7	4.7	6.0	0.7	5.3	4.7	1.3	1.7	2.0
15	2.7	3.7	3.3	0.7	2.0	1.0	0.3	0.7	1.3	3.0	2.3	2.3	1.3	2.7	4.0	4.3	5.0	6.0	0.0	4.7	6.3	1.7	2.7	1.0
16	2.3	3.3	3.3	0.7	1.3	1.3	1.7	1.0	1.0	1.0	2.3	1.3	1.7	3.3	3.0	3.3	4.3	6.0	0.7	4.3	5.0	1.7	2.0	2.3
17	3.7	3.0	3.3	1.0	1.3	0.7	0.7	0.0	1.7	2.0	1.7	1.7	2.0	2.7	3.3	3.7	5.0	5.3	0.7	3.7	4.7	1.7	2.3	2.3
18	1.7	3.0	3.3	2.0	1.3	1.3	2.2	0.3	2.3	2.0	1.3	2.0	2.0	2.7	3.7	3.7	5.0	5.7	1.0	3.7	5.7	2.0	1.7	3.3
19	2.7	5.0	4.0	1.0	2.0	2.0	0.3	0.7	1.3	3.0	2.3	2.0	2.3	2.7	3.3	3.7	5.7	5.7	0.0	6.0	4.7	2.0	3.0	2.7
20	3.0	3.3	3.3	1.0	1.3	1.3	0.3	1.0	1.7	1.0	2.7	2.3	1.7	3.0	3.0	5.0	5.7	5.0	0.7	4.7	5.7	2.0	2.7	2.0

DAT - Days after transplanting

Table 6 Occurrence and distribution of natural enemies in Kalliyoor panchayat of Thiruvananthapuram district

Growth stage DAT	Mean number of natural enemies present in Kalliyoor panchayat of Thiruvananthapuram district							
	G. triangulifer	*X. flavolineata*	*Cotesia* sp	*Agriocnemis* spp.	Spiders	Predatory beetles	Predatory bugs	*Conocephalus* sp.
30	2.417	0.883	0.550	1.350	1.617	3.750	0.933	1.350
50	3.317	1.267	0.700	2.050	2.850	4.750	4.200	2.033
t-value	3.5826	3.3561	1.2418	6.5364	6.7918	4.5904	13.4851	4.8951
30	2.417	0.883	0.550	1.350	1.617	3.750	0.933	1.350
70	3.800	1.333	1.200	2.200	3.317	5.667	5.600	2.517
t-value	6.8074	3.6151	4.7731	6.2417	9.0613	6.5776	18.9214	5.7382
50	3.317	1.267	0.700	2.050	2.850	4.750	4.200	2.033
70	3.800	1.333	1.200	2.200	3.317	5.667	5.600	2.517
t-value	1.9705	0.6140	3.4351	1.1555	2.4265	3.2794	4.2934	2.3719

4.2.4 *Agriocnemis* spp.

The population of *Agriocnemis* spp. varied from 1.0 to 3.0, 1.3 to 2.7 and 1.3 to 4.0 per 10 sweeps at 30, 50 and 70 DAT respectively among the farmer's field. The highest mean population of *Agriocnemis* spp., the predator of rice leaf roller, was observed at 70 DAT, the population being 2.200, followed by 2.050 at 50 DAT and lowest population of 1.350 per 10 sweeps at 30 DAT. There was a significant difference in the population of *Agriocnemis* spp. from 30 DAT to 50 DAT, but the population at 50 and 70 DAT did not differ significantly.

4.2.5 Spiders

The population of spiders in different farmer's field ranged from 1.0 to 2.3, 1.7 to 4.3 and 1.7 to 5.0 per 10 sweeps at 30, 50 and 70 DAT respectively. Spider population was noticed at all the growth stages of the crop. The lowest mean population was recorded at 30 DAT (1.617). There was a significant increase in the population of spiders from 30 DAT to 50 DAT and then to 70 DAT. The mean populations at 50 DAT and 70 DAT were 2.850 and 3.317 per 10 sweeps respectively.

4.2.6 Predatory Beetles

The population of predatory beetles at different growth stages (30, 50 and 70 DAT) ranged from 2.3 to 5.0, 3.0 to 5.7 and 3.0 to 7.7 per 10 sweeps respectively among the 20 farmer's field. Lowest mean population of predatory beetles (3.750) was observed at 30 DAT. There was a significant difference among the population of predatory beetles noticed at 30, 50 and 70 DAT. The populations of predatory beetles at 50 and 70 DAT differed significantly and the populations were 4.750 and 5.670 per 10 sweeps respectively.

4.2.7 Predatory Bugs

The mean population of predatory bugs ranged from 0.0 to 3.0, 2.7 to 6.0 and 3.3 to 8.7 per 10 sweeps at 30, 50 and 70 DAT respectively among the different fields. There was a significant increase in the population of predatory bugs, from 30 DAT to 70 DAT. The increase was significant in all the growth stages. The lowest population mean was observed at 30 DAT (0.933). The population recorded at 50 and 70 DAT were 4.200 and 5.600 per 10 sweeps respectively.

4.2.8 *Conocephalus* sp.

The mean population of *Conocephalus* sp. varied from 0.3 to 2.0, 1.0 to 3.3 and 1.0 to 3.3 per 10 sweeps at 30, 50 and 70 DAT respectively among different farmers' field. Mean population of *Conocephalus* sp. recorded from Kalliyoor panchayat ranged from 1.350 at 30 DAT to 2.510 at 70 DAT. The population was 2.033 at 50 DAT. There was a significant difference in the population of *Conocephalus* sp. at 30 DAT and 70 DAT.

4.3 EFFICACY OF DIFFERENT BOTANICALS AND SYNTHETIC INSECTICIDES ON RICE LEAF ROLLER

A field experiment was conducted to evaluate the efficacy of different botanicals, synthetic insecticides and botanicals + half dose of synthetic insecticides against rice leaf roller.

4.3.1 Effect of Botanicals and Synthetic Insecticides on the Population of Leaf Roller Larvae

The population of rice leaf roller larvae at different intervals (24 hours, 72 hours and one week) after treatment at different growth stages of rice *viz.*, 30 DAT and 60 DAT are presented in Table 7.

4.3.1.1 Population of Rice Leaf Roller Larvae at 30 DAT

24 hours after treatment, significant reduction in the number of leaf roller larvae was observed in plots treated with neem seed oil (NSO) three per cent + imidacloprid 0.0025 per cent (4.972) compared to control (11.948). However this was on par with all other treatments *viz.*, quinalphos 0.05 per cent, NSO three per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, azadirachtin

Table 7 Effect of botanicals and synthetic insecticides on the population of leaf roller larvae at different growth stages of the crop

Treatments	Number of larvae (per m^2) observed at different intervals after spraying (days)					
	30 DAT			60 DAT		
	24 HAS	72 HAS	1 WAS	24 HAS	72 HAS	1 WAS
Neem seed oil (NSO) 3 %	9.939 $(3.307)^{b}$	8.292 $(3.048)^{efg}$	13.307 (3.782)	7.981 $(2.997)^{efg}$	7.327 $(2.886)^{cd}$	7.642 (2.940)[illegible]
Azadirachtin 0.004 %	8.251 $(3.042)^{b}$	7.288 $(2.879)^{def}$	12.598 $(3.688)^{fg}$	6.979 $(2.825)^{ef}$	6.301 $(2.702)^{c}$	7.620 $(2.936)^{d}$
Quinalphos 0.05 %	6.576 $(2.753)^{ab}$	4.133 $(2.266)^{abcde}$	7.288 $(2.879)^{abcd}$	4.972 $(2.444)^{bcd}$	3.277 $(2.068)^{b}$	3.860 $(2.205)^{bc}$
Imidacloprid 0.005 %	7.925 $(2.988)^{ab}$	3.966 $(2.229)^{abcd}$	6.500 $(2.739)^{ab}$	5.903 $(2.627)^{cde}$	2.046 $(1.745)^{ab}$	3.576 $(2.139)^{bc}$
NSO 3 % + Quinalphos 0.025%	6.659 $(2.768)^{b}$	2.046 $(1.744)^{ab}$	8.983 $(3.160)^{bcde}$	4.323 $(2.307)^{abc}$	2.592 $(1.895)^{ab}$	4.262 $(2.294)^{c}$
Azadirachtin 0.004% + Quinalphos 0.025%	7.925 $(2.988)^{ab}$	3.576 $(2.139)^{abcd}$	9.661 $(3.265)^{cdef}$	3.966 $(2.229)^{ab}$	1.943 $(1.715)^{ab}$	2.317 (1.821)[illegible]
NSO 3% + Imidacloprid 0.0025 %	4.972 $(2.444)^{a}$	1.403 $(1.550)^{a}$	5.605 $(2.570)^{a}$	2.958 $(1.989)^{a}$	1.214 $(1.488)^{a}$	2.219 $(1.794)^{a}$
Azadirachtin 0.004% + imidacloprid 0.0025 %	7.925 $(2.988)^{ab}$	2.300 $(1.817)^{abc}$	7.240 $(2.871)^{abc}$	3.966 $(2.229)^{ab}$	3.321 $(2.079)^{b}$	3.654 $(2.157)^{bc}$
Mechanical control	8.567 $(3.093)^{ab}$	8.661 $(3.108)^{fgh}$	11.635 $(3.555)^{ef}$	8.983 $(3.160)^{fg}$	9.328 $(3.214)^{cd}$	9.661 $(3.265)^{d}$
Control	11.948 $(3.598)^{b}$	13.640 $(3.826)^{gh}$	18.313 (4.395)	9.311 $(3.211)^{g}$	9.985 $(3.314)^{d}$	10.329 $(3.366)^{d}$
CD (0.05)	0.9333	0.7864	0.5006	0.3797	0.5739	0.4886
F	3.0[illegible]1*	7.540**	11.256**	11.255**	11.739**	12.547**

Figures in parenthesis are $\sqrt{X+1}$ transformed values. DAT – Days after transplanting. HAS – Hours after spraying. WAS – Week after spraying
*Significant at 5 per cent level. **Significant at 1 per cent level

0.004 per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent, mechanical control and NSO three per cent. Quinalphos 0.05 per cent was on par with all other treatments including botanicals *viz.*, NSO three per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent, mechanical control, NSO three per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, and control containing the population of leaf roller larvae. The mean population being 6.659, 7.925, 7.925, 8.251, 8.567, 9.939 and 11.948 respectively.

Seventy two hours after application of insecticides, significantly lower population of larvae was observed in plots treated with NSO three per cent + imidacloprid 0.0025 per cent (1.403). This treatment was on par with NSO three per cent + quinalphos 0.025 per cent (2.046), azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (2.299), azadirachtin 0.004 per cent + quinalphos 0.025 per cent (3.576), imidacloprid 0.005 per cent (3.966) and quinalphos 0.05 per cent (4.133). The number of larvae was comparatively higher in NSO three per cent, azadirachtin 0.004 per cent and mechanical control treatments. However, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent and quinalphos 0.05 were on par with azadirachtin 0.004 per cent (7.288). The treatment quinalphos 0.05 per cent was on par with botanicals, NSO three per cent and azadirachtin 0.004 per cent with a mean population of 8.292 and 7.288 respectively. However NSO three per cent and azadirachtin 0.004 per cent were on par with mechanical control which in turn on par with control. NSO three per cent was also found to be on par with quinalphos 0.05 per cent and azadirachtin 0.004 per cent.

At seven days after insecticide sprays, significant reduction in total population of larvae was recorded in plots with NSO three per cent + imidacloprid 0.0025 per cent (5.605) which was on par with imidacloprid 0.005 per cent (6.500), azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (7.240) and quinalphos 0.05 per cent (7.288). However azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and quinalphos 0.05 per cent were on par with NSO three per cent + quinalphos 0.025 per cent and azadirachtin 0.004 per cent + quinalphos 0.025 per cent with a larval population of 8.983 and 9.661 respectively. NSO three per cent (13.307) differed significantly from mechanical control (11.635) which was found to be on par with azadirachtin 0.004 per cent (12.598) and azadirachtin 0.004 per cent + quinalphos 0.025 per cent (9.661). With regard to the population of leaf roller larvae the treatments including botanicals and synthetic insecticides differed significantly from control (18.313) and found to be superior.

4.3.1.2 Population of Rice Leaf Roller Larvae at 60 DAT

Twenty four hours after application, significantly lower population was noticed in plots receiving NSO three per cent + imidacloprid 0.0025 per cent (2.958), which was on par with azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent and NSO three per cent + quinalphos 0.025 per cent. The population being 3.966, 3.966 and 4.323 respectively. However, NSO three per cent + imidacloprid 0.0025 per cent was significantly superior to quinalphos 0.05 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent, NSO three per cent, mechanical control and control, the population ranged from 3.966 to 9.311. Quinalphos 0.05 per cent (4.972) was found to be on par with azadirachtin 0.004 per cent + quinalphos 0.025 per cent (3.966), azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (3.966) and NSO three per cent + quinalphos 0.025 per cent (4.323). Azadirachtin 0.004 per cent (6.979), NSO three per cent (7.981) and mechanical control (8.983) were found to be on par. However imidacloprid 0.005 per cent was on par with NSO three per cent and azadirachtin 0.004 per cent. Also NSO three per cent and mechanical control were on par with control.

Seventy two hours after application, lower population of larvae was observed in plots receiving NSO three per cent + imidacloprid 0.0025 per cent (1.214) and was on par with azadirachtin 0.004 per cent + quinalphos 0.025 per cent (1.943), imidacloprid 0.005 per cent (2.046) and NSO three per cent + quinalphos 0.025 per cent (2.592). However the treatments quinalphos 0.05 per cent (3.277) and azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (3.321) were on par with NSO three per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent and azadirachtin0.004 per cent + quinalphos 0.025 per cent. The botanical treatments *viz*., NSO three per cent (7.327) and azadirachtin 0.004 per cent (6.301) differed significantly from insecticidal treatments alone and in combination with botanicals and was on par with mechanical control (9.328). Also NSO three per cent and mechanical control were found to be on par with control (9.985). With the exception of NSO three per cent, azadirachtin 0.004 per cent and mechanical control, all the insecticidal treatments resulted in reduction in the larval population.

One week after the application of treatments, NSO three per cent + imidacloprid 0.0025 per cent (2.219) was found to be superior in reducing the larval population and was found to be on par with azadirachtin 0.004 per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and quinalphos 0.05 per cent with larval population of 2.317, 3.576, 3.654 and 3.860 respectively. However the treatment NSO three per cent + quinalphos 0.025 per cent was on par with quinalphos 0.05 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, imidacloprid 0.005 per cent and azadirachtin 0.004 per cent + quinalphos 0.025 per cent. Also the treatment including botanicals (NSO three per cent and azadirachtin 0.004 per cent) and mechanical control were on par with control (10.329) and differed significantly from insecticidal treatments *viz*., NSO three per cent + quinalphos 0.025 per cent, quinalphos 0.05 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent and NSO three per cent + imidacloprid 0.0025 per cent. The larval population in azadirachtin 0.004 per cent, NSO three per cent, and mechanical control were 7.620. 7.642 and 9.661 respectively. The mean population of larvae ranged from 2.219 to 10.329 among the treatments.

4.3.2 Effect of Botanicals and Synthetic Insecticides on the Population of Leaf Roller Adults

The population of rice leaf roller adult at different intervals (24 hours, 72 hours and one week) after treatment at different growth stages of rice *viz.*, 30 DAT and 60 DAT are presented in Table 8.

4.3.2.1 Population of Rice Leaf Roller Adults at 30 DAT

Twenty four hours after application, a trend similar to the effect of treatments on the larval population was observed in the case of adults. The range of adult population varied from 1.165 in NSO three per cent + imidacloprid 0.0025 per cent to 5.658 in control plots. NSO three per cent + imidacloprid 0.0025 per cent was superior in reducing the adult population and was on par with NSO three per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, quinalphos 0.05 per cent and azadirachtin 0.004 per cent + quinalphos 0.025 per cent with an adult count of 1.644, 1.644, 1.943, 1.943 and 2.317 respectively. NSO three per cent (4.323) was on par with azadirachtin 0.004 per cent (2.958) and mechanical control (4.323). However NSO three per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, quinalphos 0.05 per cent and azadirachtin 0.004 per cent + quinalphos 0.025 per cent were on par with azadirachtin 0.004 per cent. Highest adult population was recorded in the control plots which differed significantly from the insecticidal treatment.

Table 8. Effect of botanicals and synthetic insecticides on the population of leaf roller adults at different growth stages of the crop

Treatments	Number of adults (/10 sweeps) observed at different intervals after spraying					
	30 DAT			60 DAT		
	24 HAS	72 HAS	1 WAS	24 HAS	72 HAS	1 WAS
NSO 3 %	4.323 (2.307)cd	3.654 $(2.157)^{bcd}$	4.972 $(2.444)^{cd}$	5.976 $(2.641)^{cd}$	6.281 $(2.698)^{cd}$	5.658 $(2.580)^{ab}$
Azadirachtin 0.004 %	2.958 $(1.989)^{bc}$	3.321 $(2.079)^{bcd}$	4.657 $(2.378)^{bcd}$	6.326 $(2.707)^{cd}$	7.305 $(2.882)^{d}$	4.972 $(2.444)^{a}$
Quinalphos 0.05 %	1.943 $(1.715)^{ab}$	3.000 $(2.000)^{abcd}$	3.654 $(2.157)^{abc}$	4.323 $(2.307)^{abc}$	3.966 $(2.229)^{abc}$	4.972 $(2.444)^{a}$
Imidacloprid 0.005 %	1.644 $(1.626)^{ab}$	2.000 $(1.732)^{a}$	2.958 $(1.989)^{ab}$	5.273 $(2.505)^{bc}$	3.321 $(2.079)^{ab}$	5.325 $(2.515)^{ab}$
NSO 3 % + Quinalphos 0.025%	1.644 $(1.626)^{ab}$	2.000 $(1.732)^{a}$	3.654 $(2.157)^{abc}$	3.966 $(2.229)^{ab}$	4.000 $(2.236)^{abc}$	3.966 $(2.229)^{a}$
Azadirachtin 0.004% + Quinalphos 0.025%	2.317 $(1.821)^{ab}$	2.651 $(1.911)^{ab}$	3.321 $(2.079)^{ab}$	4.657 $(2.378)^{abc}$	5.563 $(2.562)^{bcd}$	5.563 $(2.562)^{ab}$
NSO 3% + Imidacloprid 0.0025 %	1.165 $(1.471)^{a}$	1.778 $(1.667)^{a}$	2.651 $(1.911)^{a}$	2.958 $(1.989)^{a}$	3.654 $(2.157)^{ab}$	3.966 $(2.229)^{a}$
Azadirachtin 0.004% + imidacloprid 0.0025 %	1.943 $(1.715)^{ab}$	2.958 $(1.989)^{abcd}$	3.246 $(2.061)^{abc}$	3.622 $(2.150)^{ab}$	3.966 $(2.229)^{abc}$	4.323 $(2.307)^{a}$
Mechanical control	4.323 $(2.307)^{cd}$	4.323 $(2.307)^{cd}$	5.976 $(2.641)^{d}$	7.642 $(2.940)^{d}$	6.500 $(2.739)^{cd}$	7.233 $(2.869)^{bc}$
Control	5.658 $(2.580)^{d}$	4.657 $(2.378)^{d}$	6.281 $(2.698)^{d}$	8.251 $(3.042)^{d}$	8.292 $(3.048)^{e}$	9.328 $(3.214)^{c}$
CD (0.05)	0.4119	0.3884	0.3698	0.4080	0.4804	0.3569
F	6.983**	3.454*	4.831**	6.228**	4.491**	6.407**

Figures in parenthesis are $\sqrt{x+1}$ transformed values, DAT - Days after transplanting, HAS - Hours after spraying, WAS - Week after spraying
*Significant at 5 per cent level **Significant at 1 per cent level

Seventy two hours after application, among the insecticidal treatments, NSO three per cent + imidacloprid 0.0025 per cent (1.778) was superior in reducing the adult population, which was on par with other insecticidal treatments alone and in combination with botanicals *viz.*, imidacloprid 0.005 per cent, NSO three per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and quinalphos 0.05 per cent with a mean population of 2.000, 2.000, 2.651, 2.958 and 3.00 respectively. However azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and quinalphos 0.05 per cent were on par with azadirachtin 0.004 per cent, NSO three per cent and mechanical control. A similar trend was observed 72 hours after spraying with a maximum population of adults in control plots (4.657). However this was on par with NSO three per cent, azadirachtin 0.004 per cent and mechanical control. The populations being 3.654, 3.321 and 4.323 respectively. Quinalphos 0.05 per cent was also on par with the above treatments.

One week after application, plots receiving NSO three per cent + imidacloprid 0.0025 per cent showed lowest adult population of 2.651 which was on par with imidacloprid 0.005 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, NSO three per cent + quinalphos 0.025 and quinalphos 0.05 per cent, the population being 2.958, 3.246, 3.321, 3.654 and 3.654 respectively. Also NSO three per cent + quinalphos 0.025 per cent and quinalphos 0.05 per cent were found to be on par with NSO three per cent and azadirachtin 0.004 per cent, the population being 4.972 and 4.657 respectively. Highest population of adults was seen in control plots (6.281) which was on par with mechanical control, NSO three per cent and azadirachtin 0.004 per cent, the population being 5.976, 4.972 and 4.657 respectively.

4.3.2.2 Population of Rice Leaf Roller Adults at 60 DAT

The lowest population of adults was observed in NSO three per cent + imidacloprid 0.0025 per cent (2.958) which was on par with azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, NSO three per cent + quinalphos 0.025 per cent, quinalphos 0.05 per cent and azadirachtin 0.004 per cent + quinalphos 0.025 per cent, the population being 3.622, 3.966, 4.323 and 4.657 respectively. Imidacloprid 0.005 per cent (5.273) differed significantly from NSO three per cent + imidacloprid 0.0025 per cent with a lower population of adults and all other treatments including insecticides alone and in combination with botanicals were on par with NSO three per cent + imidacloprid 0.0025 per cent. All the treatments including insecticides alone and in combination with botanicals differed significantly from control with 8.251 adult population which was the highest. NSO three per cent, azadirachtin 0.004 per cent and mechanical control (population being 5.976, 6.326 and 7.642 respectively) were on par with control. However azadirachtin 0.004 per cent and NSO three per cent were found to be on par with imidacloprid 0.005 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent and quinalphos 0.05 per cent in reducing the adult population.

Seventy two hours after spraying, lowest population of adults was seen in imidacloprid 0.005 per cent with an adult count of 3.321. This was followed by NSO three per cent + imidacloprid 0.0025 per cent, quinalphos 0.05 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and NSO three per cent + quinalphos 0.025 per cent. The population being 3.654, 3.966, 3.966 and 4.000 respectively and were on par. The above treatments were found to be on par with azadirachtin 0.004 per cent + quinalphos 0.025 per cent (5.563) except NSO three per cent + imidacloprid 0.0025 per cent. However quinalphos 0.05 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, NSO three per cent + quinalphos 0.025 per cent and azadirachtin 0.004 per cent +

quinalphos 0.025 per cent were on par with NSO three per cent. The population of adults in treatments, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, NSO three per cent, azadirachtin 0.004 per cent, mechanical control and control was significantly higher compared to the other treatments including insecticides *viz.*, imidacloprid 0.005 per cent, NSO three per cent + imidacloprid 0.0025 per cent, quinalphos 0.05 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and NSO three per cent + quinalphos 0.025 per cent. Treatments including botanicals alone and mechanical control were on par with control (8.292).

One week after application of insecticides, it was found that all treatments including insecticides and botanicals were on par and the adult population varied from 3.966 as in NSO three per cent + imidacloprid 0.0025 per cent to 9.328 in control.

4.3.3 Effect of Botanicals and Synthetic Insecticides on the Percentage of Leaf Damage by Leaf Roller

The symptom manifested by the combined attack of the two species of rice leaf roller was recorded and represented as percentage of leaf damaged. The percentage of leaves damaged by leaf roller at different intervals (24 hour, 72 hour and 1 week) after each treatment spray at different growth stages of rice *viz.*, 30 DAT and 60 DAT are presented in Table 9.

4.3.3.1 Percentage Leaf Damage Observed at 30 DAT

Twenty four hours after spraying, the percentage leaf damage varied from 2.110 to 5.113 in various treatments. Significantly lower percentage of leaf damage was observed in plots receiving NSO three per cent + imidacloprid 0.0025 per cent (2.110). This was found to be on par with NSO three per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, imidacloprid 0.005 per cent, quinalphos 0.05 per cent and azadirachtin 0.004 per cent + quinalphos 0.025 per cent. The values being 2.483, 2.489, 2.552, 2.637 and 2.722

Table 9. Effect of botanicals and synthetic insecticides on the percentage of leaf damage by leaf roller

Treatments	Percentage of leaf damaged					
	30 DAT			60 DAT		
	24 HAS	72 HAS	1 WAS	24 HAS	72 HAS	1 WAS
NSO 3 %	3.997 (2.235)[d]	4.180 (2.276)[cd]	4.633 (2.373)[cde]	4.669 (2.381)	4.815 (2.412)	5.427 (2.535)
Azadirachtin 0.004 %	3.484 (2.118)[c]	3.798 (2.190)[c]	4.225 (2.286)[abcde]	4.386 (2.321)	4.657 (2.378)	5.096 (2.469)
Quinalphos 0.05 %	2.637 (1.907)[abc]	2.637 (1.907)[ab]	3.602 (2.145)[abc]	3.974 (2.230)	4.092 (2.257)	5.786 (2.605)
Imidacloprid 0.005 %	2.552 (1.885)[bc]	2.585 (1.894)[ab]	2.869 (1.967)[a]	4.830 (2.415)	4.623 (2.371)	4.648 (2.377)
NSO 3 % + Quinalphos 0.025%	2.483 (1.866)[ab]	2.509 (1.873)[ab]	3.779 (2.186)[abcd]	4.463 (2.337)	4.463 (2.337)	4.456 (2.336)
Azadirachtin 0.004% + Quinalphos 0.025%	2.722 (1.929)[abc]	2.722 (1.929)[ab]	3.163 (2.040)[ab]	4.802 (2.409)	5.003 (2.450)	5.364 (2.523)
NSO 3% + Imidacloprid 0.0025 %	2.110 (1.764)[a]	2.110 (1.764)[a]	2.650 (1.911)[a]	3.636 (2.153)	3.722 (2.173)	3.787 (2.188)
Azadirachtin 0.004% + imidacloprid 0.0025 %	2.489 (1.868)[ab]	2.489 (1.868)[ab]	3.393 (2.096)[ab]	4.334 (2.310)	4.452 (2.335)	4.807 (2.410)
Mechanical control	4.328 (2.308)[d]	4.566 (2.359)[cd]	4.797 (2.408)[de]	5.765 (2.601)	5.957 (2.638)	6.043 (2.654)
Control	5.113 (2.473)[d]	5.279 (2.506)[d]	5.388 (2.527)[e]	7.353 (2.890)	7.478 (2.912)	8.117 (3.020)
CD (0.05)	0.2354	0.2424	0.2956	NS	NS	NS
F	8.730**	9.670**	4.090**		-	-

Figures in parenthesis are $\sqrt{x+1}$ transformed values. DAT – Days after transplanting. HAS – Hours after spraying. WAS – Week after spraying
** Significant at 1 per cent level. NS – Non significant

respectively. All the above treatments was significantly superior to control (5.113). The treatments *viz.*, azadirachtin 0.004 per cent (3.484), NSO three per cent (3.997) and mechanical control (4.328) were found to be on par. Among these treatments, NSO three per cent and mechanical control were found to be on par with control. But azadirachtin 0.004 per cent showed significantly lower leaf damage than control and it was found to be on par with imidacloprid 0.005 per cent, quinalphos 0.05 per cent and azadirachtin 0.004 per cent + quinalphos 0.025 per cent.

The treatments containing synthetic insecticide alone and in combination with botanicals reduced the damage of rice leaf roller significantly compared to control (5.279 per cent) at 72 hours after spraying. The mean percentage damage of leaves ranged from 2.110 to 4.566 among the treatments. The least infestation was noted in NSO three per cent + imidacloprid 0.0025 per cent treated plots (2.110 per cent). However this treatment was statistically on par with Azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (2.489 per cent), NSO three per cent + quinalphos 0.025 per cent (2.509 per cent), imidacloprid 0.005 per cent (2.585 per cent), quinalphos 0.05 per cent alone (2.637 per cent) and azadirachtin 0.004 per cent + quinalphos 0.025 per cent (2.722 per cent). Azadirachtin 0.004 per cent (3.798 per cent) was on par with NSO three per cent (4.180 per cent) which was in turn on par with mechanical control (4.566 per cent). Among these treatments, NSO three per cent and mechanical control was on par with control.

Observations recorded one week after the application of treatments indicated that treatments including synthetic insecticides alone and in combination with botanicals were significantly superior to control. Lower infestation was observed in NSO three per cent + imidacloprid 0.0025 per cent (2.650) which was on par with imidacloprid 0.005 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, quinalphos 0.05 per cent and NSO three per cent + quinalphos 0.025 per cent with percentage damages of 2.869, 3.163, 3.393, 3.602 and 3.779 respectively. NSO three per cent alone (4.633 per cent) was on par with azadirachtin 0.004 per cent (4.225), NSO three per cent + quinalphos 0.025 per cent (3.779) and quinalphos 0.05 per cent (3.602). Mechanical control (4.797) was found to be on par with NSO three per cent, azadirachtin 0.004 per cent and NSO three per cent + quinalphos 0.025 per cent. The infestation was higher (5.388 per cent) in control plot and which was on par with NSO three per cent, azadirachtin 0.004 per cent and mechanical control.

4.3.3.2 Percentage Leaf Damage Observed at 60 DAT

At 60 DAT, the leaves damaged by leaf roller 24 hours after spraying did not show any significant variation among the treatments. The percentage damage of leaves ranged from 3.636 in NSO three per cent + imidacloprid 0.0025 per cent to 7.353 in control.

A similar trend was noticed at 72 hours after spraying. No significant difference was observed among the treatments and control. The leaf damage ranged from 3.722 per cent in NSO three per cent + imidacloprid 0.0025 per cent to 7.478 in control.

One week after application of spray, the effect of different treatments did not show any significant variation among the treatments and the percentage damage ranged from 3.787 in NSO three per cent + imidacloprid 0.0025 per cent to 8.117 per cent in control.

4.4 EFFICACY OF DIFFERENT BOTANICALS AND SYNTHETIC INSECTICIDES ON NATURAL ENEMIES IN RICE ECOSYSTEM

4.4.1 Effect of Botanicals and Synthetic Insecticides on *G. triangulifer* at Different Growth Stages of Rice Crop

The population of the parasite of rice leaf roller, *G. triangulifer* observed at 30 and 60 DAT after the application of different treatments were shown in Table 10.

Table 10 Effect of botanicals and synthetic insecticides on *G. triangulifer* at different growth stages of the crop

Treatments	Number of *G. triangulifer* (per 10 sweeps) observed at different intervals after spraying					
	30 DAT			60 DAT		
	24 HAS	72 HAS	1 WAS	24 HAS	72 HAS	1 WAS
NSO 3 %	3.520 (2.126)	3.277 (2.068)	4.907 (2.431)	6.095 (2.664)^{cd}	6.979 (2.825)^{b}	7.660 (2.943)^{c}
Azadirachtin 0.004 %	3.080 (2.020)	2.958 (1.989)	5.809 (2.610)	5.495 (2.549)^{bcd}	6.614 (2.759)^{b}	6.639 (2.764)^{c}
Quinalphos 0.05 %	0.994 (1.411)	1.644 (1.626)	2.966 (2.229)	2.997 (1.817)^{ab}	3.622 (2.150)^{a}	4.594 (2.365)^{ab}
Imidacloprid 0.005 %	1.488 (1.577)	1.628 (1.621)	4.481 (2.341)	2.958 (1.989)^{abc}	4.657 (2.374)^{a}	4.972 (2.444)^{ab}
NSO 3 % + Quinalphos 0.025%	0.910 (1.382)	1.488 (1.577)	3.246 (2.061)	2.046 (1.745)^{a}	2.958 (1.989)	3.966 (2.229)^{a}
Azadirachtin 0.004% + Quinalphos 0.025%	1.311 (1.520)	0.910 (1.382)	2.958 (1.989)	2.958 (1.989)^{abc}	3.576 (2.139)^{a}	3.520 (2.126)^{a}
NSO 3% + Imidacloprid 0.0025 %	1.214 (1.488)	2.317 (1.821)	4.262 (2.294)	3.654 (2.151)^{abc}	4.262 (2.294)^{a}	4.907 (2.431)^{ab}
Azadirachtin 0.004% + imidacloprid 0.0025 %	2.317 (1.821)	1.743 (1.656)	4.323 (2.307)	3.966 (2.229)^{abc}	3.966 (2.229)^{a}	4.657 (2.378)^{ab}
Mechanical control	2.958 (1.989)	3.966 (2.229)	4.972 (2.444)	7.925 (2.988)^{d}	8.309 (3.051)^{b}	8.661 (3.108)^{c}
Control	4.657 (2.378)	4.323 (2.307)	6.281 (2.689)	8.292 (3.048)^{d}	8.983 (3.160)^{b}	8.983 (3.160)^{c}
CD (0.05)	NS	NS	NS	0.7488	0.4317	0.4045
F	-	-	-	3.469*	8.191**	7.407**

Figures in parenthesis are $\sqrt{X+1}$ transformed values. DAT – Days after transplanting, HAS – Hours after spraying, WAS – Week after spraying

*Significant at 5 per cent level, **Significant at 1 per cent level, NS – Non significant

4.4.1.1 Population of G. triangulifer at 30 DAT

Twenty four hours after application there was no significant difference among the treatments. The adult population of *G. triangulifer* ranged from 0.910 in NSO three per cent + quinalphos 0.025 per cent to 4.657 in control.

There was no significant difference observed among the treatment 72 hours after application, the population ranged from 0.910 in azadirachtin 0.004 per cent + quinalphos 0.025 per cent to 4.323 in control.

A similar trend was seen in one week after application, the values ranged from 2.958 in azadirachtin 0.004 per cent + quinalphos 0.025 per cent to 6.281 in control.

At 30 DAT none of the treatments adversely affected the population of *G. triangulifer* in all the three observations made.

4.4.1.2 Population of G. triangulifer at 60 DAT

The population of *G. triangulifer* recorded 24 hours after spraying showed that NSO three per cent + quinalphos 0.025 per cent significantly reduced the population (2.046). Quinalphos 0.05 per cent (2.997), imidacloprid 0.005 per cent (2.958), azadirachtin 0.004 per cent + quinalphos 0.025 per cent (2.958), NSO three per cent + imidacloprid 0.0025 per cent (3.654), azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (3.966) were found to be on par with azadirachtin 0.004 per cent. Also NSO three per cent was on par with imidacloprid 0.005 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, NSO three per cent + imidacloprid 0.0025 per cent and azadirachtin 0.004 per cent + imidacloprid 0.0.05 per cent. However. the treatments azadirachtin 0.004 per cent. NSO three per cent, and mechanical control with population of 5.495, 6.095 and 7.925 respectively were on par with control (8.292).

Seventy two hours after spraying, imidacloprid 0.005 per cent (4.657) was found to be on par with azadirachtin 0.004 per cent (6.614).

The treatments receiving botanicals *viz.*, NSO three per cent, azadirachtin 0.004 per cent and mechanical control were on par with control (8.983) and the population being 6.614, 6.979 and 8. 983 respectively. The insecticide treatments alone and in combination with botanicals *viz.*, NSO three per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, quinalphos 0.05 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, NSO three per cent + imidacloprid 0.0025 per cent and imidacloprid 0.005 per cent significantly reduced the population of *G. triangulifer* (ranged from 2.958 to 4.657) over control (8.983).

One week after spraying, quinalphos 0.05 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, NSO three per cent + imidacloprid 0.0025 per cent and imidacloprid 0.005 per cent were found to be on par with azadirachtin 0.004 per cent. The treatments azadirachtin 0.004 per cent (6.639), NSO three per cent (7.660) and mechanical control (8.661) was found to be on par with control (8.983). The treatment azadirachtin 0.004 per cent + quinalphos 0.025 per cent (3.520) affect the population of *G. triangulifer* adversely and which was found to be on par with NSO three per cent + quinalphos 0.025 per cent (3.966), quinalphos 0.05 per cent (4.594), azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (4.657), NSO three per cent + imidacloprid 0.0025 per cent (4.907) and imidacloprid 0.005 per cent (4.972).

4.4.2 Effect of Botanicals and Synthetic Insecticides on *X. flavolineata* at Different Growth Stages of Rice Crop

The number of adults of *X. flavolineata*, a parasite of leaf roller. observed during various growth stages of the plant at different intervals, after spraying are depicted in Table 11.

4.4.2.1 Population of X. flavolineata at 30 DAT

Twenty four hours after spraying, significant reduction in *X. flavolineata* population was recorded in treatments receiving insecticides

Table 11 Effect of botanicals and synthetic insecticides on *X. flavolineata* at different growth stages of the crop

Treatments	Number of *X. flavolineata* (per 10 sweeps) observed at different intervals after spraying					
	30 DAT			60 DAT		
	24 HAS	72 HAS	1 WAS	24 HAS	72 HAS	1 WAS
NSO 3 %	1.850 (1.688)^{cd}	1.644 (1.626)^{cd}	3.576 (2.139)	2.958 (1.959)^{abc}	3.966 (2.229)	4.629 (2.373)
Azadirachtin 0.004 %	1.311 (1.520)^{bcd}	1.311 (1.520)^{bc}	3.080 (2.020)	2.850 (1.962)^{bcde}	3.622 (2.150)	4.262 (2.294)
Quinalphos 0.05 %	0.295 (1.138)^{abc}	0.629 (1.276)^{ab}	1.644 (1.626)	2.219 (1.794)^{bcde}	2.610 (1.900)	2.886 (1.971)
Imidacloprid 0.005 %	0.000 (1.000)^{a}	0.000 (1.000)^{a}	2.547 (1.883)	0.910 (1.382)^{a}	1.943 (1.715)	2.317 (1.821)
NSO 3 % + Quinalphos 0.025%	0.295 (1.138)^{ab}	0.629 (1.276)^{ab}	1.644 (1.626)	2.000 (1.732)^{abcd}	2.610 (1.900)	3.576 (2.139)
Azadirachtin 0.004% + Quinalphos 0.025%	1.000 (1.414)^{abcd}	0.910 (1.382)^{b}	1.943 (1.715)	1.943 (1.715)^{abc}	2.958 (1.989)	3.576 (2.139)
NSO 3% + Imidacloprid 0.0025 %	0.629 (1.276)^{abc}	1.311 (1.520)^{bc}	2.958 (1.989)	1.311 (1.520)^{ab}	3.576 (2.139)	4.179 (2.276)
Azadirachtin 0.004% + imidacloprid 0.0025 %	0.629 (1.276)^{abc}	0.629 (1.276)^{ab}	1.943 (1.715)	0.295 (1.138)	2.728 (1.931)	2.966 (1.992)
Mechanical control	1.943 (1.715)^{d}	2.317 (1.821)^{cd}	3.907 (2.215)	3.860 (2.205)^{cde}	4.657 (2.378)	5.000 (2.450)
Control	2.958 (1.989)^{e}	2.651 (1.911)^{d}	3.654 (2.157)	4.629 (2.373)	4.972 (2.444)	5.658 (2.580)
CD (0.05)	0.4217	0.3820	NS	0.6230	NS	NS
F	4.798**	4.621**	-	3.690**	-	-

Figures in parenthesis are $\sqrt{X+1}$ transformed values. DAT – Days after transplanting, HAS – Hours after spraying, WAS – Week after spraying
*Significant at 5 per cent level, **Significant at 1 per cent level, NS – Non significant

viz., imidacloprid 0.005 per cent, NSO three per cent + quinalphos 0.025 per cent, quinalphos 0.05 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, NSO three per cent + imidacloprid 0.0025 per cent and azadirachtin 0.004 per cent + quinalphos 0.025 per cent and these treatments were on par, the population being 0.00, 0.295, 0.295, 0.629, 0.629 and 1.00 respectively. The treatments NSO three per cent + quinalphos 0.025 per cent, quinalphos 0.05 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, NSO three per cent + imidacloprid 0.0025 per cent and azadirachtin 0.004 per cent + quinalphos 0.025 per cent were on par with azadirachtin 0.004 per cent. However quinalphos 0.05 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, NSO three per cent + imidacloprid 0.0025 per cent and azadirachtin 0.004 per cent + quinalphos 0.025 per cent were found to be on par with azadirachtin 0.004 per cent and NSO three per cent. The treatments azadirachtin 0.004 per cent + quinalphos 0.025 per cent (1.00), azadirachtin 0.004 per cent (1.311), NSO three per cent (1.850) and mechanical control (1.943) were on par.

Seventy two hours after application, the treatments NSO three per cent + imidacloprid 0.0025 per cent (1.311), azadirachtin 0.004 per cent (1.311) and NSO three per cent (1.644) were on par with mechanical control (2.317) which inturn on par with control (2.651). A significant reduction in the population was recorded in all treatments except mechanical control and NSO three per cent when compared with control. The population ranged from 0.00 to 2.651. The treatments imidacloprid 0.005 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, quinalphos 0.05 per cent and NSO three per cent + quinalphos 0.025 per cent were on par and differed significantly from control.

One week after application of treatments, no significant difference was observed among the treatments. All the treatments including botanicals and synthetic insecticides alone and in combination were on par with control. The population of *X. flavolineata* adults ranged from 1.644 to 3.907 among the treatments.

4.4.2.2 Population of X. flavolineata at 60 DAT

Twenty four hours after spraying, NSO three per cent + imidacloprid 0.0025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, NSO three per cent + quinalphos 0.025 per cent and quinalphos 0.05 per cent were on par with azadirachtin 0.004 per cent and NSO three per cent (2.850 and 2.958). Population of *X. flavolineata* adults in the plots receiving botanicals *viz.*, NSO three per cent and azadirachtin 0.004 per cent and mechanical control were on par with control (4.629) and were not adversely affected. A significant reduction in the population of *X. flavolineata* adults was observed in plots receiving azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (0.295) which was on par with imidacloprid 0.005 per cent (0.910), NSO three per cent + imidacloprid 0.0025 per cent (1.311), azadirachtin 0.004 per cent + quinalphos 0.025 per cent (1.943) and NSO three per cent + quinalphos 0.025 per cent (2.000) and were found to be on par.

There was no significant difference among the treatments 72 hours after application and the values ranged from 1.943 in imidacloprid 0.005 per cent to 4.972 in control.

A similar trend was observed at one week after spraying *i.e.*, no significant difference observed among the treatments. The population ranged from 2.317 in imidacloprid 0.005 per cent to 5.658 in control. All the treatments were found to be safe to *X. flavolineata* at three days and seven days after spraying.

4.4.3 Effect of Botanicals and Synthetic Insecticides on *Cotesia* sp. at Different Growth Stages of the Crop

The population of the parasite *Cotesia* sp. recorded at 30 and 60 DAT in the field trial are presented in Table 12.

Table 12 Effect of botanicals and synthetic insecticides on *Cotesia* sp. at different growth stages of the crop

Treatments	Number of *Cotesia* sp. (per 10 sweeps) observed at different intervals after spraying					
	30 DAT			60 DAT		
	24 HAS	72 HAS	1 WAS	24 HAS	72 HAS	1 WAS
NSO 3 %	1.943 $(1.715)^{c}$	1.943 (1.715)	1.644 (1.626)	3.860 $(2.205)^{bc}$	4.972 $(2.444)^{e}$	4.972 $(2.444)^{d}$
Azadirachtin 0.004 %	1.311 $(1.520)^{c}$	0.910 (1.382)	2.479 (1.865)	3.576 $(2.139)^{bc}$	3.966 $(2.229)^{cde}$	4.32[illegible] $(2.307)^{cd}$
Quinalphos 0.05 %	0.629 $(1.276)^{ab}$	0.295 (1.138)	1.644 (1.626)	1.644 $(1.626)^{ab}$	2.651 $(1.911)^{abc}$	3.000 $(2.000)^{cd}$
Imidacloprid 0.005 %	0.295 $(1.138)^{ab}$	1.644 (1.626)	1.943 (1.715)	2.610 $(1.900)^{abc}$	2.886 $(1.971)^{abcd}$	3.321 $(2.079)^{bcd}$
NSO 3 % + Quinalphos 0.025%	0.000 $(1.000)^{a}$	0.910 (1.382)	1.644 (1.626)	0.778 $(1.333)^{a}$	2.000 $(1.732)^{a}$	1.943 $(1.715)^{ab}$
Azadirachtin 0.004% + Quinalphos 0.025%	0.295 $(1.318)^{ab}$	0.629 (1.276)	1.943 (1.715)	0.778 $(1.333)^{a}$	1.644 $(1.626)^{a}$	2.651 $(1.911)^{bc}$
NSO 3% + Imidacloprid 0.0025 %	0.000 $(1.000)^{a}$	1.644 (1.626)	2.479 (1.865)	2.886 $(1.911)^{bc}$	2.219 $(1.794)^{a}$	1.943 $(1.715)^{ab}$
Azadirachtin 0.004% + imidacloprid 0.0025 %	0.629 $(1.276)^{ab}$	0.910 (1.382)	2.727 (1.931)	2.000 $(1.732)^{bc}$	2.610 $(1.900)^{ab}$	2.046 $(1.745)^{a}$
Mechanical control	1.311 $(1.520)^{c}$	2.000 (1.732)	3.246 (2.061)	3.966 $(2.229)^{c}$	4.262 $(2.294)^{de}$	4.179 $(2.276)^{cd}$
Control	2.219 $(1.794)^{c}$	2.886 (1.971)	3.576 (2.139)	4.323 $(2.307)^{c}$	4.972 $(2.444)^{e}$	4.972 $(2.444)^{d}$
CD (0.05)	0.3822	NS	NS	0.6209	0.3563	0.5258
F	4.[illegible]22**	-	-	2.975*	6.129**	[illegible]

Figures in parenthesis are $\sqrt{x+1}$ transformed values. DAT – Days after transplanting. HAS – Hours after spraying. WAS – Week after spraying
*Significant at 5 per cent level. ** Significant at 1 per cent level. NS – Non significant

4.4.3.1 Population of Cotesia sp. at 30 DAT

The population of *Cotesia* sp. recorded 24 hours after spraying showed that insecticide treatments alone and in combination with botanicals significantly reduced the population. NSO three per cent + imidacloprid 0.0025 per cent (0.000) and NSO three per cent + quinalphos 0.025 per cent (0.000) and were on par with azadirachtin 0.004 per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and quinalphos 0.05 per cent, the population being 0.295, 0.295, 0.629 and 0.629 respectively. However, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent + imidacloprid 0.005 percent and quinalphos 0.05 per cent was found to be on par with mechanical control (1.311) and azadirachtin 0.004 per cent (1.311). Botanical treatments *viz.*, NSO three per cent and azadirachtin 0.004 per cent and mechanical control, the population being 1.943, 1.311 and 1.311 respectively were on par with control.

Seventy two hours after spraying, no significant difference was observed among the treatments. The population of *Cotesia* sp. ranged between 0.295 in quinalphos 0.05 per cent to 2.886 in control.

One week after the application of insecticides, none of the treatments were found detrimental to the population of *Cotesia* sp. The observations recorded did not show significant reduction in any of the treatments, the population ranged from 1.644 to 3.576 among the treatments.

4.4.3.2 Population of Cotesia sp. at 60 DAT

The observations recorded 24 hours after spraying showed that quinalphos 0.05 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and imidacloprid 0.005 per cent were found to be on par with NSO three per cent + imidacloprid 0.0025 per cent (2.886), azadirachtin 0.004 per cent(3.576) and NSO three per cent (3.860). All the treatments except azadirachtin 0.004 per cent + quinalphos 0.025 per cent, NSO three per cent + quinalphos 0.025 per cent and quinalphos 0.05 per cent were on par with control (4.323). However, NSO three per cent + quinalphos 0.025 per cent (0.778) and azadirachtin 0.004 per cent + quinalphos 0.025 per cent (0.778) significantly reduced the population of *Cotesia* sp. and were found to be on par with quinalphos 0.05 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and imidacloprid 0.005 per cent, the population being 1.644, 2.000 and 2.610.

Seventy two hours after spraying, significantly higher population was recorded in treatments with NSO three per cent, azadirachtin 0.004 percent and mechanical control, the population being 4.972, 3.966 and 4.262 respectively which were on par with control (4.972). Lowest population was observed in azadirachtin 0.004 per cent + quinalphos 0.025 per cent (1.644) which was on par with NSO three per cent + quinalphos 0.025 per cent. NSO three per cent + imidacloprid 0.0025 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, quinalphos 0.05 per cent and imidacloprid 0.005 per cent, the population ranged between 2.00 and 2.886. However azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, quinalphos 0.05 per cent and imidacloprid 0.005 per cent were found to be on par with azadirachtin 0.004 per cent.

One week after application of treatments, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, quinalphos 0.05 per cent and imidacloprid 0.005 per cent were on par with mechanical control (4.179) and azadirachtin 0.004 per cent (4.323). However quinalphos 0.05 per cent, imidacloprid 0.005 per cent, mechanical control, azadirachtin 0.004 per cent and NSO three per cent were found to be on par with control (4.972). Significantly lower population was noticed in plots receiving azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (2.046), which was found to be on par with NSO three per cent + imidacloprid 0.0025 per cent. NSO three per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, quinalphos 0.05 per cent and imidacloprid 0.005 per cent, the population being 1.943, 1.943, 2.651, 3.000 and 3.321 respectively.

4.4.4 Effect of Botanicals and Synthetic Insecticides on *Agriocnemis* spp. at Different Growth Stages of the Crop

A sizable population of *Agriocnemis* spp., a predator of rice leaf roller was recorded at 30 and 60 DAT. The populations recorded 24 hours, 72 hours and one week after spraying are given in Table 13.

4.4.4.1 Population of Agriocnemis spp. at 30 DAT

Twenty four hours after application of treatments, NSO three per cent + imidacloprid 0.0025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent, NSO three per cent + quinalphos 0.025 per cent and azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent were on par with azadirachtin 0.004 per cent. The treatment with botanicals *viz*., azadirachtin 0.004 per cent, NSO three per cent and mechanical control (1.943, 2.958 and 2.958) were not detrimental to the population of *Agriocnemis* spp., which was on par with control (3.246). However, significant reduction in the population of *Agriocnemis* spp. adults was recorded in treatments receiving insecticides alone and in combination with botanicals, the population ranged from 0.295 to 1.00. The treatments *viz*., quinalphos 0.05 per cent, NSO three per cent + imidacloprid 0.0025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent, NSO three per cent + quinalphos 0.025 per cent and azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent were on par and the population being 0.295, 0.629, 0.629, 0.629, 0.910 and 1.0 respectively and differed significantly from control (3.246).

Table 13. Effect of botanicals and synthetic insecticides on *Agriocnemis* spp. at different growth stages of the crop

Treatments	Number of *Agriocnemis* spp. (per 10 sweeps) observed at different intervals after spraying					
	30 DAT			60 DAT		
	24 HAS	72 HAS	1 WAS	24 HAS	72 HAS	1 WAS
NSO 3 %	2.958 (1.989)^{c}	2.610 (1.900)^{de}	6.685 (2.773)	6.614 (2.759)^{c}	8.983 (3.160)^{f}	9.328 (3.214)^{c}
Azadirachtin 0.004 %	1.943 (1.715)^{bc}	2.317 (1.821)^{de}	6.198 (2.683)	5.933 (2.633)^{bc}	8.251 (3.042)^{f}	8.625 (3.102)^{c}
Quinalphos 0.05 %	0.295 (1.138)^{a}	0.629 (1.276)^{ab}	4.179 (2.276)	2.046 (1.745)^{a}	3.966 (2.229)^{a}	3.907 (2.215)^{ab}
Imidacloprid 0.005 %	0.629 (1.276)^{ab}	1.311 (1.520)^{abcd}	5.048 (2.459)	3.246 (2.061)^{ab}	3.576 (2.139)^{c}	3.520 (2.126)^{ab}
NSO 3 % + Quinalphos 0.025 %	0.910 (1.382)^{ab}	1.311 (1.520)^{abcd}	4.109 (2.602)	2.000 (1.732)^{a}	2.317 (1.821)^{a}	2.651 (1.911)^{a}
Azadirachtin 0.004 % + Quinalphos 0.025 %	0.629 (1.276)^{ab}	0.910 (1.382)^{abd}	4.036 (2.244)	2.547 (1.883)^{a}	2.958 (1.989)^{a}	3.277 (2.068)^{ab}
NSO 3 % + Imidacloprid 0.0025 %	0.629 (1.276)^{ab}	2.000 (1.732)^{bce}	4.896 (2.428)	2.219 (1.794)^{a}	3.654 (2.157)^{a}	4.323 (2.307)^{ab}
Azadirachtin 0.004 % + imidacloprid 0.0025 %	1.000 (1.414)^{ab}	1.000 (1.414)^{abc}	4.731 (2.394)	1.943 (1.715)^{a}	3.966 (2.229)^{c}	4.657 (2.378)^{b}
Mechanical control	2.958 (1.989)^{c}	3.576 (2.139)^{ef}	6.862 (2.804)	7.554 (2.925)^{c}	8.983 (3.160)^{c}	9.311 (3.211)^{c}
Control	3.246 (2.061)^{c}	4.972 (2.444)^{f}	7.626 (2.936)	8.292 (3.048)^{c}	9.661 (3.265)	9.985 (3.314)^{c}
CD (0.05)	0.4616	0.4072	NS	0.6709	0.4119	0.4372
F	5.136**	6.890**	-	5.844**	16.545**	14.245**

Figures in parentheses are $\sqrt{x+1}$ transformed values, DAT - Days after transplanting, HAS - Hours after spraying, WAS - Week after sprayin
**Significant at 1 per cent level, NS - Non significant

Seventy two hours after the application of insecticides, the effect of botanicals (NSO three per cent and azadirachtin 0.004 per cent) and mechanical control were not harmful to *Agriocnemis* spp., the populations being 2.610, 2.317 and 3.576 respectively and these were on par with control (4.972). Significant reduction in the population of *Agriocnemis* spp. was noticed in quinalphos 0.05 per cent (0.629) and this was on par with azadirachtin 0.004 per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, NSO three per cent + quinalphos 0.025 per cent and imidacloprid 0.005 per cent, the population being 0.910, 1.00, 1.311 and 1.311 respectively.

One week after spraying, the effects of botanicals and synthetic insecticides were not detrimental to *Agriocnemis* spp. All the treatments involving botanicals and synthetic insecticides were found to be on par with control and no significant difference was noticed among the treatments. The population of *Agriocnemis* spp. ranged from 4.036 in azadirachtin 0.004 per cent + quinalphos 0.025 per cent to 7.620 in NSO three per cent.

4.4.4.2 Population of Agriocnemis spp. at 60 DAT

Twenty four hours after application the botanicals (NSO three per cent and azadirachtin 0.004 per cent) and mechanical control did not exert an adverse effect on *Agriocnemis* spp. and were on par with control (8.292). There was significant reduction in the population of *Agriocnemis* spp. in azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (1.943) which was on par with NSO three per cent + quinalphos 0.025 per cent, quinalphos 0.05 per cent, NSO three per cent + imidacloprid 0.0025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent and imidacloprid 0.005 per cent, the population being 2.000, 2.046, 2.219, 2.547 and 3.246 respectively. However, imidacloprid 0.005 per cent was found to be on par with azadirachtin 0.004 per cent.

Seventy two hours after the insecticide spray, a significantly higher population of *Agriocnemis* spp. was observed in treatment with botanicals (azadirachtin 0.004 per cent and NSO three per cent) and mechanical control and the population being 8.251, 8.983 and 8.983 respectively. In plots receiving botanical treatments, the predator population was not affected and they were on par with control. However, significant reduction was recorded only in treatments receiving synthetic insecticide alone and in combination with botanicals. All the treatments including chemicals were on par and the population ranged from 2.317 to 3.966 among the treatments and these treatments *viz*., NSO three per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent, NSO three per cent + imidacloprid 0.0025 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and quinalphos 0.05 per cent differed significantly from other treatments.

The same trend was observed one week after spraying. Azadirachtin 0.004 per cent, mechanical control and NSO three per cent recorded a significantly higher population of the predator. The population being 8.625, 9.311 and 9.328 respectively and these were on par with control (9.985). However, a significant decrease in the population of *Agriocnemis* spp. was observed in plots receiving insecticides compared to the botanical (NSO three per cent and azadirachtin 0.004 per cent) and control. The population of *Agriocnemis* spp. was very low in treatments receiving NSO three per cent + quinalphos 0.025 per cent (2.651) and was on par with other insecticidal treatment alone and in combination with botanicals *viz*., azadirachtin 0.004 per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent, quinalphos 0.05 per cent, NSO three per cent + imidacloprid 0.0025 per cent and azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, the population being 3.277, 3.520, 3.907, 4.323 and 4.657 respectively.

4.4.5 Effect of Botanicals and Synthetic Insecticides on Spider Population at Different Growth Stages of the Crop

Spiders were observed through out the cropping season. The spiders observed were *L. pseudoannulata*, *T. maxillosa* and *O. javanus*.

The total population of different species of spiders recorded 24 hours, 72 hours and one week after spraying at 30 and 60 DAT are presented in Table 14.

4.4.5.1 Population of Spiders at 30 DAT

The population of spiders recorded 24 hours after spraying showed that the botanicals did not adversely affect the spider population. The total spider fauna in NSO three per cent (3.576), azadirachtin 0.004 per cent (3.520) and mechanical control (3.860) treatment plots were on par with control (3.966). Insecticide treatment alone and in combination with botanicals significantly reduced the population of spiders, the population being lowest in azadirachtin 0.004 per cent + quinalphos 0.025 per cent (0.295). This was on par with NSO three per cent + imidacloprid 0.0025 per cent, NSO three per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent, quinalphos 0.05 per cent and azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, the population being 0.910, 0.910, 0.910, 0.910 and 1.214 respectively.

Seventy two hours after spraying, a similar trend was observed in the spider population. However NSO three per cent + quinalphos 0.025 per cent (1.165), azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (1.214), imidacloprid 0.005 per cent (1.590) and NSO three per cent + imidacloprid 0.0025 per cent (1.644) were on par with azadirachtin 0.004 per cent (2.651). Treatments involving botanicals (NSO three per cent (3.000) and azadirachtin 0.004 per cent (2.651)) and mechanical control (3.860) recorded higher levels of spider population and were on par with control (5.204). The insecticidal treatments *viz.*, azadirachtin 0.004 per

Table 14 Effect of botanicals and synthetic insecticides on spider population at different growth stages of the crop

Treatments	Number of spiders (per 10 sweeps) observed at different intervals after spraying					
	30 DAT			60 DAT		
	24 HAS	72 HAS	1 WAS	24 HAS	72 HAS	1 WAS
NSO 3 %	3.576 (2.139)^{b}	3.000 (2.000)^{de}	9.463 (3.235)	9.629 (3.260)	10.573 (3.402)^{cd}	10.329 (3.366)^{e}
Azadirachtin 0.004 %	3.520 (2.126)^{b}	2.651 (1.911)^{cde}	8.792 (3.129)	10.300 (3.362)^{c}	11.611 (3.551)^{d}	11.635 (3.555)^{f}
Quinalphos 0.05 %	0.910 (1.382)^{a}	0.548 (1.244)^{ab}	5.426 (2.535)	6.281 (2.698)^{abc}	7.587 (2.930)^{ab}	7.288 (2.879)^{abc}
Imidacloprid 0.005 %	0.910 (1.382)^{a}	1.590 (1.610)^{abcd}	7.412 (2.900)	8.309 (3.051)^{cd}	3.985 (3.314)^{bcd}	9.328 (3.214)^{de}
NSO 3 % + Quinalphos 0.025%	0.910 (1.382)^{a}	1.165 (1.471)^{abc}	5.338 (2.518)	5.325 (2.515)^{a}	6.326 (2.707)^{a}	6.000 (2.646)^{a}
Azadirachtin 0.004% + Quinalphos 0.025%	0.295 (1.138)^{a}	0.548 (1.244)^{a}	5.426 (2.535)	5.605 (2.570)^{ab}	7.305 (2.882)^{ab}	6.979 (2.825)^{ab}
NSO 3% + Imidacloprid 0.0025 %	0.910 (1.382)^{a}	1.644 (1.626)^{abcd}	7.352 (2.890)	7.981 (2.997)^{bcd}	9.328 (3.214)^{bcd}	8.983 (3.160)^{cde}
Azadirachtin 0.004% + imidacloprid 0.0025 %	1.214 (1.488)^{a}	1.214 (1.488)^{abc}	7.161 (2.857)	6.576 (2.753)^{abc}	8.251 (3.042)^{abc}	7.941 (2.990)^{bcd}
Mechanical control	3.860 (2.205)^{b}	3.622 (2.150)^{de}	9.831 (3.291)	11.635 (3.555)	11.948 (3.598)^{d}	11.635 (3.555)^{f}
Control	3.966 (2.229)^{b}	5.204 (2.491)	11.960 (3.600)	11.990 (3.600)^{c}	12.277 (3.644)^{d}	11.948 (3.598)^{f}
CD (0.05)	0.5926	0.6073	NS	0.4384	0.4476	0.3288
F	4.668**	3.945**	-	7.286**	4.735**	9.350**

Figures in parenthesis are $\sqrt{x+1}$ transformed values, DAT – Days after transplanting, HAS – Hours after spraying, WAS – Week after spraying
** Significant at 1 per cent level, NS – Non significant

cent + quinalphos 0.025 per cent, quinalphos 0.05 per cent, NSO three per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, imidacloprid 0.005 per cent and NSO three per cent + imidacloprid 0.0025 per cent were found to be on par and differed significantly from control (5.204). The population being 0.548, 0.548, 1.165, 1.214, 1.590 and 1.644 respectively.

One week after spraying, all the treatments involving botanicals and synthetic insecticides alone and in combination were found to be on par. The number of spiders recorded in different treatments did not show any significant variation, the population ranged from 5.338 in NSO three per cent + quinalphos 0.025 per cent to 11.960 in control.

4.4.5.2 Population of Spiders at 60 DAT

The observations recorded 24 hours after spraying NSO three per cent + imidacloprid 0.0025 per cent and imidacloprid 0.005 per cent were found to be on par with NSO three per cent and azadirachtin 0.004 per cent. Significantly higher population was recorded in NSO three per cent (9.629) which was on par with azadirachtin 0.004 per cent, mechanical control and unsprayed control with a population of 10.300, 11.635 and 11.990 respectively. However, significant reduction in the population of spiders in NSO three per cent + quinalphos 0.025 per cent (5.325) which was on par with azadirachtin 0.004 per cent + quinalphos 0.025 per cent, quinalphos 0.05 per cent and azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, the populations being 5.605, 6.281 and 6.576 respectively. Among these, quinalphos 0.05 per cent and azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent were on par with NSO three per cent + imidacloprid 0.0025 per cent and imidacloprid 0.005 per cent.

Seventy two hours after spraying, significantly higher population was recorded in azadirachtin 0.004 per cent (11.611) followed by NSO three per cent and mechanical control, the population being 10.573 and 11.948 respectively. These treatments were on par with control (12.277).

Whereas insecticide treatment alone and in combination with botanicals significantly reduced the population of spiders, the population being 6.326 in NSO three per cent + quinalphos 0.025 per cent, 7.305 in azadirachtin 0.004 per cent + quinalphos 0.025 per cent, 7.587 in quinalphos 0.05 per cent and 8.251 in azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent. The population of spiders in plots receiving insecticides alone and in combination with botanicals were significantly lower compared to control.

One week after the application of treatments, significantly higher population was observed in azadirachtin 0.004 per cent (11.635) which was on par with mechanical control (11.635) and control (11.948). A significant reduction in the spider fauna was observed in NSO three per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent and quinalphos 0.05 per cent, the population being 6.00, 6.979 and 7.288 respectively and these were significantly on par. Azadirachtin 0.004 per cent + quinalphos 0.025 per cent (6.979) and quinalphos 0.05 per cent (7.288) were on par with azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (7.941). However, NSO 3 per cent (10.329) was on par with imidacloprid 0.005 per cent (9.328) and NSO 3 per cent + imidacloprid 0.0025 per cent (8.983).

4.4.6 Effect of Botanicals and Synthetic Insecticides on the Population of Predatory Beetles at Different Growth Stages of the Crop

The predatory beetles observed in the experiment field were *O. nigrofasciata*, *P. fuscipes* and *M. crocea*. The population of predatory beetles recorded 30 and 60 DAT are presented in Table 15.

4.4.6.1 Population of Predatory Beetles at 30 DAT

There was no significant difference in the population of predatory beetles among the treatments in all the three observations made. The population varied from 0.629 to 4.629, 1.488 to 5.605 and 7.128 to 12.988

Table 15 Effect of botanicals and synthetic insecticides on predatory beetles at different growth stages of the crop

Treatments	Number of predatory beetles (per 10 sweeps) observed at different intervals after spraying					
	30 DAT			60 DAT		
	24 HAS	72 HAS	1 WAS	24 HAS	72 HAS	1 WAS
NSO 3 %	3.080 (12.020)	3.860 (2.205)	12.136 (3.624)	12.598 (3.688)	13.317 (3.784)	13.989 (3.872)
Azadirachtin 0.004 %	2.958 (1.989)	2.651 (1.911)	10.960 (3.458)	13.989 (3.872)	14.330 (3.915)	15.000 (4.000)
Quinalphos 0.05 %	0.629 (1.276)	1.488 (1.577)	7.128 (2.851)	7.516 (2.918)	8.657 (3.108)	9.458 (3.234)
Imidacloprid 0.005 %	1.214 (1.488)	1.743 (1.656)	9.176 (3.190)	9.139 (3.184)	10.028 (3.321)	11.201 (3.493)
NSO 3 % + Quinalphos 0.025%	1.644 (1.626)	1.778 (1.667)	8.110 (3.018)	6.325 (2.707)	8.039 (3.007)	8.792 (3.129)
Azadirachtin 0.004% + Quinalphos 0.025%	1.743 (1.656)	2.315 (1.821)	7.413 (2.900)	5.643 (2.577)	7.382 (2.895)	8.592 (3.097)
NSO 3% + Imidacloprid 0.0025 %	1.214 (1.488)	2.610 (1.900)	7.956 (2.993)	9.402 (3.225)	10.715 (3.423)	11.489 (3.534)
Azadirachtin 0.004% + imidacloprid 0.0025 %	2.547 (1.883)	2.958 (1.989)	8.551 (3.090)	8.304 (3.050)	9.067 (3.173)	9.831 (3.291)
Mechanical control	4.545 (2.355)	5.000 (2.450)	12.988 (3.740)	14.622 (3.952)	14.970 (3.996)	15.990 (4.122)
Control	4.629 (2.373)	5.605 (2.570)	12.892 (3.727)	14.990 (3.999)	15.330 (4.041)	16.654 (4.202)
CD (0.05)	NS	NS	NS	NS	NS	NS
F	-	-	-	-	-	-

Figures in parenthesis are $\sqrt{X+1}$ transformed values, DAT Days after transplanting, HAS Hours after spraying, WAS Week after spraying.
NS - Non significant

at 24 hours, 72 hours and one week after spraying respectively. At 30 DAT the treatments *viz.*, botanicals, synthetic insecticides and botanicals + half dose of synthetic insecticides did not affected the population of predatory beetles adversely. All the treatments were found to be on par with control.

4.4.6.2 Population of Predatory Beetles at 60 DAT

A similar trend as seen in the case of 30 DAT was observed in all the three observations made at 60 DAT. The population of predatory beetles varied from 5.643 to 14.990, 7.328 to 15.330 and 8.592 to 16.654 at 24 hours, 72 hours and one week after spraying respectively.

4.4.7 Effect of Botanicals and Synthetic Insecticides on the Population of Predatory Bugs at Different Growth Stages of the Crop

The population of predatory bugs recorded 30 and 60 DAT after application of botanicals and synthetic insecticides are presented in Table 16.

4.4.7.1 Population of Predatory Bugs at 30 DAT

Twenty four hours after spraying, highest population of predatory bugs was obtained in control (5.325) and was found to be on par with NSO three per cent, mechanical control and azadirachtin 0.004 per cent with a population of 4.594, 4.323 and 3.654 respectively. Lowest population of predatory bugs was recorded in the treatment azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and was on par with NSO three per cent + imidacloprid 0.0025 per cent, quinalphos 0.05 per cent and NSO three per cent + quinalphos 0.025 per cent, population being 0.548, 0.548 and 0.629 respectively. However NSO three per cent + quinalphos 0.025 per cent was on par with azadirachtin 0.004 per cent + quinalphos 0.025 per cent and imidacloprid 0.005 per cent (1.943 and 1.943 respectively). The population of predatory bugs in plots receiving imidacloprid 0.005 per cent did not showed any variation from azadirachtin 0.004 per cent (3.654).

Table 16 Effect of botanicals and synthetic insecticides on predatory bugs at different growth stages of the crop

Treatments	Number of predatory bugs (per 10 sweeps) observed at different intervals after spraying					
	30 DAT			60 DAT		
	24 HAS	72 HAS	1 WAS	24 HAS	72 HAS	1 WAS
NSO 3 %	[illegible].594 (2.365)^{d}	3.907 (2.215)	9.748 (3.279)^{cde}	10.648 (3.413)^{de}	11.987 (3.604)^{e}	5.296 (2.509)
Azadirachtin 0.004 %	[illegible].651 (2.157)^{cd}	2.958 (1.989)	8.759 (3.124)^{bcde}	9.985 (3.314)^{cd}	9.985 (3.314)^{cd}	10.329 (3.366)
Quinalphos 0.05 %	0.548 (1.244)^{a}	1.488 (1.577)	5.903 (2.627)^{ab}	5.976 (2.641)^{ab}	6.301 (2.702)^{a}	6.659 (2.768)
Imidacloprid 0.005 %	1.943 (1.715)^{bc}	1.743 (1.656)	8.304 (3.050)^{bcde}	8.983 (3.160)^{c}	9.661 (3.265)^{bcd}	10.000 (3.317)
NSO 3 % + Quinalphos 0.025%	0.629 (1.276)^{ab}	1.488 (1.577)	7.233 (2.869)^{bcd}	5.635 (2.576)^{a}	6.301 (2.702)^{a}	6.979 (2.825)
Azadirachtin 0.004% + Quinalphos 0.025%	1.943 (1.715)^{b}	1.165 (1.471)	6.468 (2.733)^{bc}	5.476 (2.545)^{a}	5.774 (2.603)^{a}	7.642 (2.940)
NSO 3% + Imidacloprid 0.0025 %	0.548 (1.244)^{a}	1.778 (1.667)	8.066 (3.011)^{bcde}	6.979 (2.825)^{b}	7.660 (2.943)^{abc}	7.981 (2.997)
Azadirachtin 0.004% + imidacloprid 0.0025 %	0.000 (1.000)^{a}	1.214 (1.488)	3.321 (2.079)^{a}	6.226 (2.688)^{ab}	7.305 (2.882)^{ab}	6.941 (2.818)
Mechanical control	4.323 (2.307)^{c}	4.657 (2.378)	10.999 (3.464)^{de}	11.987 (3.604)^{e}	12.329 (3.651)^{de}	12.663 (3.696)
Control	5.325 (2.515)^{d}	5.563 (2.562)	11.948 (3.598)^{e}	13.955 (3.867)	15.310 (4.039)^{e}	15.654 (4.081)
CD (0.05)	0.4910	NS	0.6026	0.2466	0.4212	0.3039
F	11.154**	-	4.706**	10.091**	11.597**	22.060**

Figures in parenthesis are $\sqrt{x+1}$ transformed values, DAT - Days after transplanting, HAS - Hours after spraying, WAS - Week after spraying

**Significant at 1 per cent level, NS - Non significant

Seventy two hours after application none of the treatments varied significantly from control. The values ranged from 1.165 to 5.563.

One week after spraying, all the treatments involving synthetic insecticide alone and in combination with botanicals significantly reduced the population of predatory bugs. Highest population of predatory bugs was obtained in control plot (11.948) and was found to be on par with mechanical control, NSO three per cent, azadirachtin 0.004 per cent, imidacloprid 0.005 per cent and NSO three per cent + imidacloprid 0.0025 per cent with regard to population of predatory bugs, the population being 10.999, 9.748, 8.759, 8.304 and 8.066 respectively. Treatments *viz.*, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (3.321) recorded the lowest population of predatory bugs and was on par with quinalphos 0.05 per cent (5.903). However quinalphos 0.05 per cent was found to be on par with azadirachtin 0.004 per cent + quinalphos 0.025 per cent, NSO three per cent + quinalphos 0.025 per cent, NSO three per cent + imidacloprid 0.0025 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent and NSO three per cent, the population being 6.468, 7.233, 8.066, 8.304, 8.759 and 9.748 respectively.

4.4.7.2 Population of Predatory Bugs at 60 DAT

Twenty four hours after the application, all the treatments differed significantly from control. Higher population of predatory bugs was observed in treatments involving botanicals, NSO three per cent and azadirachtin 0.004 per cent which were found to be on par. However. NSO three per cent was in turn on par with mechanical control. Significant reduction in the population of predatory bugs was recorded in plots receiving azadirachtin 0.004 per cent + quinalphos 0.025 per cent. (5.476) and was on par with NSO three per cent + quinalphos 0.025 per cent, quinalphos 0.05 per cent and azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, the population being 5.635, 5.976 and 6.226 respectively. However quinalphos 0.05 per cent and azadirachtin 0.004

per cent + imidacloprid 0.0025 per cent were found to be on par with NSO three per cent + imidacloprid 0.0025 per cent (6.979). Imidacloprid 0.005 per cent was found to be on par with azadirachtin 0.004 per cent which in turn on par with NSO three per cent.

Seventy two hours after spraying, the treatments including imidacloprid 0.005 per cent (9.661), azadirachtin 0.004 per cent (9.985) and NSO three per cent (11.987) were on par with mechanical control (12.329). Highest population of predatory bugs was obtained in control treatments (15.310) and was on par with mechanical control. Lowest population was obtained in azadirachtin 0.004 per cent + quinalphos 0.025 per cent (5.774) and was on par with quinalphos 0.05 per cent, NSO three per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and NSO three per cent + imidacloprid 0.0025 per cent, the population being 6.301, 6.301, 7.305 and 7.660 respectively. However azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and NSO three per cent + imidacloprid 0.0025 per cent were on par with imidacloprid 0.005 per cent which in turn on par with azadirachtin 0.004 per cent.

One week after spraying of treatments, there was significant reduction in the population of predatory bugs in treatments receiving insecticide alone and in combination with botanicals, the population ranged from 5.296 to 7.981 and this differed significantly from azadirachtin 0.004 per cent (10.329) as well as from control (15.654). Highest population was observed in control (15.654) and it differed significantly from all other treatments.

4.4.8 Effect of Botanicals and Synthetic Insecticides on the Population of *Conocephalus* sp at Different Growth Stages of the Crop

Population of *Conocephalus* sp observed during various growth stages of the crop at different intervals after spraying is depicted in Table 17.

Table 17 Effect of botanicals and synthetic insecticides on *Conocephalus* sp. at different growth stages of the crop

Treatments	Number of *Conocephalus* sp. (per 10 sweeps) observed at different intervals after spraying					
	30 DAT			60 DAT		
	24 HAS	72 HAS	1 WAS	24 HAS	72 HAS	1 WAS
NSO 3 %	2.958 (1.989)^{c}	2.958 (1.989)^{cd}	6.862 (2.804)	5.658 (2.580)^{bcd}	6.979 (2.825)cd	8.309 (3.051)^{cd}
Azadirachtin 0.004 %	2.000 (1.732)^{bc}	2.000 (1.732)^{cd}	6.639 (2.764)	5.976 (2.641)^{cd}	7.981 (2.997)^{d}	8.983 (3.160)^{d}
Quinalphos 0.05 %	0.000 (1.000)^{a}	0.629 (1.276)^{ab}	4.395 (2.323)	4.000 (2.236)^{abc}	5.658 (2.580)^{bc}	6.226 (2.688)^{bc}
Imidacloprid 0.005 %	0.910 (1.382)^{ab}	1.943 (1.715)^{cd}	5.933 (2.633)	3.654 (2.157)^{ab}	5.000 (2.450)^{ab}	5.658 (2.580)^{ab}
NSO 3 % + Quinalphos 0.025 %	0.629 (1.276)^{a}	0.910 (1.382)^{bc}	5.296 (2.509)	2.046 (1.745)^{a}	4.288 (2.300)^{ab}	4.657 (2.378)^{ab}
Azadirachtin 0.004% + Quinalphos 0.025%	0.000 (1.000)^{a}	0.000 (1.000)^{a}	4.395 (2.323)	2.958 (1.989)^{a}	4.657 (2.378)^{ab}	4.972 (2.444)^{ab}
NSO 3% + Imidacloprid 0.0025 %	0.629 (1.276)^{a}	1.311 (1.520)^{bc}	5.843 (2.616)	2.958 (1.989)^{a}	3.966 (2.229)^{ab}	5.843 (2.616)^{abc}
Azadirachtin 0.004% + imidacloprid 0.0025 %	0.548 (1.244)^{a}	1.644 (1.626)^{cd}	5.048 (2.459)	2.317 (1.821)^{a}	3.576 (2.139) a	3.966 (2.229)^{ad}
Mechanical control	2.958 (1.989)^{c}	2.958 (1.989)^{d}	6.468 (2.733)	6.614 (2.759)^{d}	7.620 (2.936)^{cd}	8.309 (3.051)^{cd}
Control	3.576 (2.139)^{c}	3.966 (2.229)^{e}	6.837 (2.799)	7.642 (2.940)^{e}	8.963 (3.160)^{d}	9.328 (3.214)
CD (0.05)	0.4480	0.3963	NS	0.4715	0.3699	0.4516
F	7.921**	[illegible].667**	-	6.917**	8.222**	5.376**

Figures in parenthesis are $\sqrt{x+1}$ transformed values. DAT – Days after transplanting, HAS – Hours after spraying, WAS – Week after spraying
**Significant at 1 per cent level, NS – Non significant

4.4.8.1 Population of Conocephalus sp. at 30 DAT

Highest population level was observed in control (3.576) and was on par with azadirachtin 0.004 per cent, mechanical control and NSO three per cent the population being 2.000, 2.958 and 2.958 respectively. Lowest population of the predator *Conocephalus* sp. was obtained in azadirachtin 0.004 per cent + quinalphos 0.025 per cent (0.00) and quinalphos 0.05 per cent (0.00) and they were on par with azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, NSO three per cent + imidacloprid 0.0025 per cent, NSO three per cent + quinalphos 0.025 per cent and imidacloprid 0.005 per cent, the population being 0.548, 0.629, 0.629 and 0.910 respectively. However imidacloprid 0.005 per cent was on par with azadirachtin 0.004 per cent (2.00).

Seventy two hours after the application of treatments, NSO three per cent was on par with control wherein a highest population of 3.966 was observed. A significant reduction in the population of the predator *Conocephalus* sp was noticed in azadirachtin 0.004 per cent + quinalphos 0.025 per cent (0.00) and this was on par with quinalphos 0.05 per cent (0.629) and NSO three per cent + quinalphos 0.025 per cent (0.910). However quinalphos 0.05 per cent and NSO three per cent + quinalphos 0.025 per cent was on par with NSO three per cent + imidacloprid 0.0025 per cent and azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent with a population of 1.311 and 1.644. The insecticide treatments *viz.*, azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent and imidacloprid 0.005 per cent (1.943) were found to be on par with azadirachtin 0.004 per cent, NSO three per cent and mechanical control, population being 2.000, 2.958 and 2.958 respectively.

One week after treatment application, no significant difference in the population of predator, *Conocephalus* sp. was observed among the treatments. The population ranged from 4.395 to 6.862 among the treatments.

4.4.8.2 Population of Conocephalus sp. at 60 DAT

Twenty four hours after spraying, highest population was noticed in control (7.642) and it was on par with mechanical control, azadirachtin 0.004 per cent and NSO three per cent, with a population of 6.614, 5.976 and 5.658 respectively. A significant reduction in the population of predator, *Conocephalus* sp. was noticed in NSO three per cent + quinalphos 0.025 per cent (2.046) and was found to be on par with azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent, NSO three per cent + imidacloprid 0.0025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent and quinalphos 0.05 per cent, the population being 2.317, 2.958, 2.958, 3.654 and 4.00 respectively among the treatments. However imidacloprid 0.005 per cent and quinalphos 0.05 per cent were found to be on par with NSO three per cent.

Seventy two hours after application, plots receiving NSO three per cent (6.979), azadirachtin 0.004 per cent (7.981) and mechanical control (7.620) were on par with control (8.963) and recorded highest population of the predator. Lowest population of predator was observed in azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (3.576) and was on par with NSO three per cent + imidacloprid 0.0025 per cent, NSO three per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent and imidacloprid 0.005 per cent the population being 3.966, 4.288, 4.657 and 5.000 respectively. However NSO three per cent + imidacloprid 0.0025 per cent, NSO three per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent and imidacloprid 0.005 per cent were on par with quinalphos 0.05 per cent

A similar trend as seen in 72 hours after treatment was observed at one week after spraying. Highest population of predators was observed in NSO three per cent (9.328) and was on par with azadirachtin 0.004 per cent, NSO three per cent and mechanical control, the population being

8.983, 8.309 and 8.309. Significant reduction in the population was seen in azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent (3.966) and was on par with NSO three per cent + quinalphos 0.025 per cent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent and NSO three per cent + imidacloprid 0.0025 per cent, the population being 4.657, 4.972, 5.658 and 5.843 respectively. However, NSO three per cent + quinalphos 0.025 percent, azadirachtin 0.004 per cent + quinalphos 0.025 per cent, imidacloprid 0.005 per cent and NSO three per cent + imidacloprid 0.0025 per cent were on par with quinalphos 0.05 per cent which in turn on par with mechanical control and NSO three per cent. NSO three per cent + imidacloprid 0.0025 per cent, quinalphos 0.05 per cent and mechanical control were found to be on par with NSO three per cent.

4.4.9 Effect of Botanicals and Synthetic Insecticides on Yield of Grain and Straw (kg ha^{-1})

The results of the effect of botanicals and synthetic insecticides on yield of rice are presented in Table 18.

The average yield of grain per hectare ranged from 1691.60 kg ha^{-1} in control to 2545.00 kg in plots treated with NSO 3 per cent + imidacloprid 0.0025 per cent, which was followed by plots treated with quinalphos 0.05 per cent (2400.00), imidacloprid 0.005 per cent (2348.30), NSO three per cent + quinalphos 0.025 per cent (2285.00), azadirachtin 0.04 per cent + quinalphos 0.025 per cent (2220.00) and mechanical control (2161.60) and they were found to be on par. The yield in control, azadirachtin 0.004 per cent, NSO three per cent and azadirachtin 0.004 per cent + imidacloprid 0.0025 per cent were on par with an average of 1691.6, 1801.6, 1963.3 and 2028.3 kg ha^{-1} respectively. The yield in these treatment plots was significantly lower compared to the other treatments.

The straw yield did not show any significant variation among the treatments and the average yield varied from 3434.20 to 4198.30 kg ha^{-1}.

Table 18 Effect of botanicals and synthetic insecticides on yield of grain and straw

Treatments	Grain (kg ha^{-1})	Straw (kg ha^{-1})
NSO 3 %	1963.3[b]	3434.2
Azadirachtin 0.004 %	1801.6[b]	3614.2
Quinalphos 0.05 %	2400.0[a]	3996.7
Imidacloprid 0.005 %	2348.3[a]	4198.3
NSO 3 % Quinalphos 0.025%	2285.0[a]	3861.7
Azadirachtin 0.004% + Quinalphos 0.025%	2220.0[a]	4165.0
NSO 3% + Imidacloprid 0.0025 %	2545.0[a]	4034.0
Azadirachtin 0.004% + imidacloprid 0.0025 %	2028.0[b]	3938.0
Mechanical control	2161.6[a]	3838.0
Control	1691.6[b]	3723.0
CD (0.05) :	441.72**	NS

**Significant at 1 per cent level, NS Non significant

DISCUSSION

5. DISCUSSION

Since the mid-sixties, rice leaf rollers have increased in abundance and in many Asian countries they are considered as important pests (Reissig *et al.*, 1986 and Khan *et al.*, 1988). The shift from minor to major pests has been attributed to the adoption of new rice growing practices that accompanied the introduction of high yielding varieties. The incidence of the pest has been widespread in rice fields of Kerala, whose folding and scraping activity drastically reduces the photosynthetic capacity of the rice plants. The farmers respond usually by applying insecticides, even at very low infestation levels, which probably create an environment free of natural enemies, favouring multiplication of pests. Information on the occurrence of the leaf roller, its species composition, their natural enemies and damage caused is a necessary requisite for developing an effective management strategy.

5.1 OCCURRENCE AND DISTRIBUTION OF DIFFERENT SPECIES OF RICE LEAF ROLLER IN RICE ECOSYSTEM IN KALLIYOOR PANCHAYAT OF THIRUVANANTHAPURAM DISTRICT

A detailed survey was undertaken in twenty farmers' fields in Kalliyoor panchayat of Thiruvananthapuram district to assess the occurrence, distribution and magnitude of different species of leaf roller and their natural enemies at different growth stages of rice crop.

Two species of leaf roller *viz.*, *Cnaphalocrocis medinalis* (Guenee) and *Marasmia patnalis* Bradley were recorded during the survey. As early as 1863 Leader had reported two genera of rice leaf roller, *Cnaphalocrocis* and *Marasmia*. Barrion *et al.* (1987) recorded eight species of rice leaf roller from Philippines whereas Rajendran and Gopalan (1987) reported three species *viz.*, *C. medinalis*, *M. patnalis* and *Marasmia ruralis* (Walker) from the rice fields of Tamil Nadu. According to Nadarajan and

Skaria (1988), the predominant species of rice leaf roller reported from Pattambi were *C. medinalis, M. patnalis* and *Brachmia atrotraea* (Meyrick).

The distribution of two species of rice leaf roller larvae showed the same trend. The larval population of *C. medinalis* and *M. patnalis* was high during vegetative and early reproductive stage and the population significantly reduced during the late reproductive stage (70 DAT) (Fig. 1). Many workers (Kaul and Singh, 1999; Manisegaran and Letchoumanane, 2001 and Ramasubramanian *et al.*, 2001) explained the random larval distribution pattern of *C. medinalis* throughout the growth stages of the crop. The present study also coincides with the above findings.

However the distribution of the two species of rice leaf roller varied widely among the various growth stages of the crop. The plants at vegetative stage were found to harbour the highest mean population of *C. medinalis* adults. The population gradually declined and reached the lowest at 70 days after transplanting (DAT). In the case of *M. patnalis*, the population of adults was lowest during the vegetative stage, increased to a peak at 50 DAT, then the population declined during the late reproductive stage (Fig. 2). The same trend was observed by Barrion *et al.* (1991) in the distribution of *C. medinalis* and *M. patnalis*. Faliero *et al.* (2000) have reported that the incidence of rice leaf roller first occurred from 28 DAT and continued upto 70 DAT. The present study also has revealed the continuous distribution of two species of leaf roller adults throughout the growth period of the crop.

Even though the distribution pattern observed for larvae and adults were different, the total population of rice leaf roller showed a gradual increase from vegetative to early reproductive stage and then the population declined (Fig.3).

Observations on the nature of damage revealed that the larvae injured the rice plants by scraping the young leaf surface and then

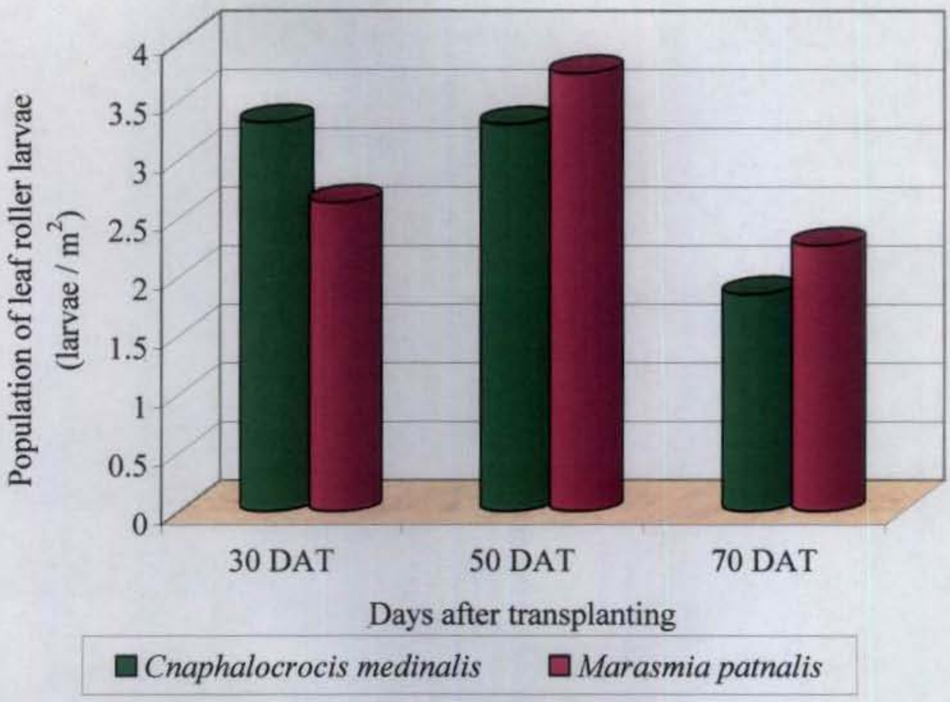


Fig. 1 Distribution of rice leaf roller larvae at different growth stages of the crop

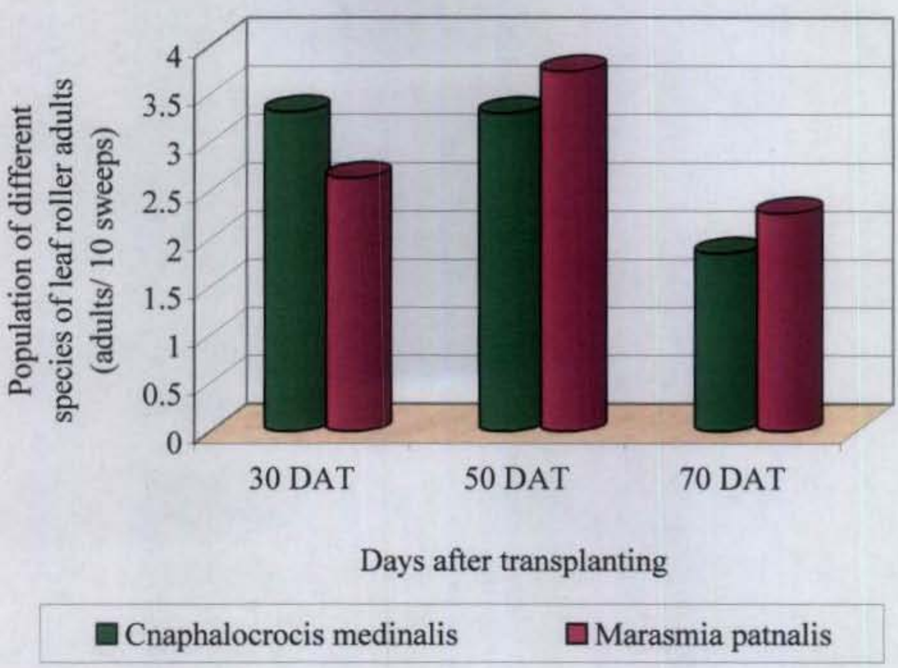


Fig. 2 Distribution of rice leaf roller adults at different growth stages of the crop

migrated to other leaves. A single larva folded the leaves and scraped the green mesophyll tissue inside the leaf folds. Four different types of folds were observed in the field. They were 1) single leaf folded longitudinally, 2) single leaf folded vertically backwards, 3) two leaf folded together and 4) multiple folding. Similar type of observations were made by Rajamma and Das (1969) and KAU (2002). The present study revealed that there was variation in the distribution of different types of folds in the field at different growth stages of the crop. Single leaf folded longitudinally and single leaf folded vertically backwards were more during vegetative stage whereas single leaf folded longitudinally and two leaf folded together were more prevalent during the reproductive stage.

In this study, the symptoms manifested by the combined attack of the two species of leaf roller were recorded and represented as percentage of leaf damage, which at different growth stages of the crop showed a highly fluctuating trend. The infestation level showed a cumulative increase from vegetative to late reproductive stage.(Fig.4) Highest leaf damage observed during the late reproductive stage was in consonance with the observations made by Kraker (1996). Murugesan and Chelliah (1983) reported that the leaf roller infestation was high at maximum tillering or flag leaf stage. According to Goud *et al.* (2001) the stages of the crop most vulnerable to leaf roller damage were 45 and 60 DAT. The same observations has been recorded in the present study.

5.2 OCCURRENCE AND DISTRIBUTION OF DIFFERENT NATURAL ENEMIES IN RICE ECOSYSTEM IN KALLIYOOR PANCHAYAT OF THIRUVANANTHAPURAM DISTRICT

The survey conducted in different farmers' field revealed the presence of larval parasites *viz.*, *Goniozus triangulifer* Kiefer, *Xanthopimpla flavolineata* Cameron and *Cotesia* sp. The predators observed were *Agriocnemis* spp., *Tetragnatha maxillosa* Thorell, *Lycosa pseudoannulata* (Boesenberg and Strand), *Oxyopes javanus* Thorell, *Micraspis crocea*

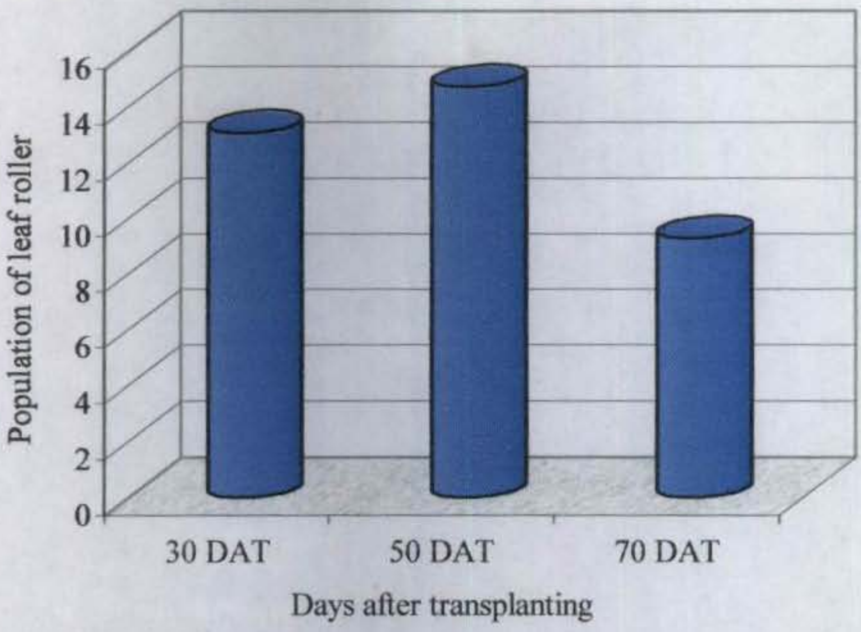


Fig. 3 Total population of rice leaf roller (larvae + adults) at different growth stages of the crop

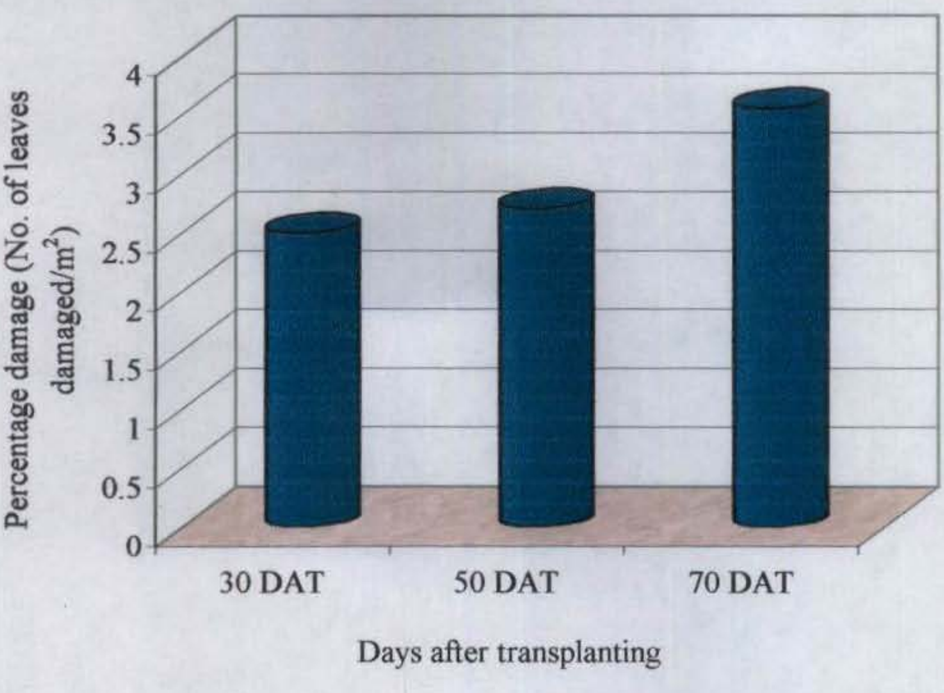


Fig. 4 Extent of damage caused by leaf roller at different growth stages of the crop

(Mulsant), *Paederus fuscipes* Curtis, *Ophionea nigrofasciata* Schmidt-Goebel, *Cyrtorhinus lividipennis* Reuter, *Polytoxus fuscovitattus* (Stal.) and *Conocephalus* sp.

These natural enemies had been reported earlier from different rice ecosystems of Kerala (Reghunath *et al.*, 1990; Nalinakumari *et al.*, 1996; Ambikadevi, 1998a and 1998b; Nandakumar and Pramod, 1998; Premila and Nalinakumari, 2002).

Results presented in 4.2 showed the distribution of the three parasites present in the rice ecosystem. For the two parasites, *G. triangulifer* and *X. flavolineata* the highest population were recorded during the reproductive stage of the crop which coincided with the peak incidence of the leaf roller in the field, whereas significantly lower population of these parasites was observed in the vegetative phase. In the case of *Cotesia* sp., the population remained steady without any significant increase during the vegetative stage and early reproductive stage, while increase in population was noticed during late reproductive stage. Thus it was evident that these parasites were present throughout the growth period of the crop and the increase in population of the parasite coincided with that of the pest. According to Hidaka *et al.* (1998) and Heong *et al.* (1991), the parasites started development only after the pests established in the rice field.

The predatory fauna present in the rice field showed a continuous distribution through out the growth period of the crop. A similar trend as observed in the case of parasites was noticed in the case of predators also. There was a significant increase in the predatory fauna from vegetative to reproductive stage. The population was maximum during the late reproductive stage. According to Heong *et al.* (1991) and Williamsettle (1994), the predator population was maximum during the vegetative phase as they depended on filter feeders and detritivores in the rice ecosystem before the pest established. The present study was undertaken in a reclaimed field where rice was planted for the first time. This could have been the reason for initial decrease in the predatory population and as the pest established, the population of the predators increased and reached the maximum at the late reproductive stage. Distribution of parasites and predators in the rice ecosystem showed an increasing trend from vegetative to reproductive stage (Fig.5).

5.3 EVALUATION OF BOTANICALS AND SYNTHETIC INSECTICIDES ON RICE LEAF ROLLER

Though a wide range of insecticides have been used for the control of rice leaf roller in different parts of India, the results obtained are highly variable and inconclusive. It appears that repeated application of insecticides will not ensure positive results against leaf roller. This may be due to the characteristic distribution of the pest in patches in the field and due to the larval habit of remaining concealed in leaf folds. Another important factor is the destruction of the natural enemies. Under such a situation, use of synthetic insecticides which cause minimum disturbances to the ecosystem, is likely to be more advantageous for the management of leaf roller. Hence detailed studies on the efficacy of botanicals and safer synthetic insecticides for the management of this pest were undertaken. To accomplish effective control of a pest using insecticides, the life stages of the pest prevalent in the field have to be taken into consideration since the relative susceptibility of different stages of the pest may vary. The larvae and moths are responsible for the damage and are vulnerable to insecticidal pressure in the field. Hence an evaluation of the botanicals [neem seed oil (NSO) 3 per cent and azadirachtin 0.004 per cent], synthetic insecticides (quinalphos 0.05 per cent and imidacloprid 0.005 per cent) and botanicals + half dose of the synthetic insecticides against these two stages has been made.

The results of the present study (4.3.1) showed that among the botanicals, synthetic insecticides and botanicals + half dose of synthetic insecticides evaluated in the field, synthetic insecticides alone and botanicals + half dose of synthetic insecticides were effective in

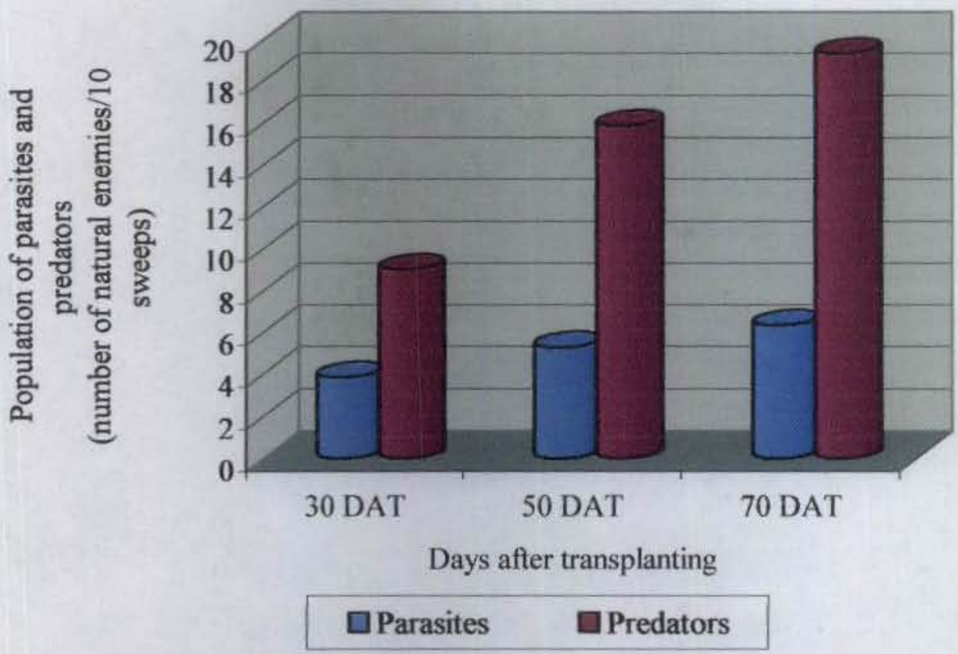


Fig. 5 Distribution of parasites and predators in rice ecosystem at different growth stages of the crop

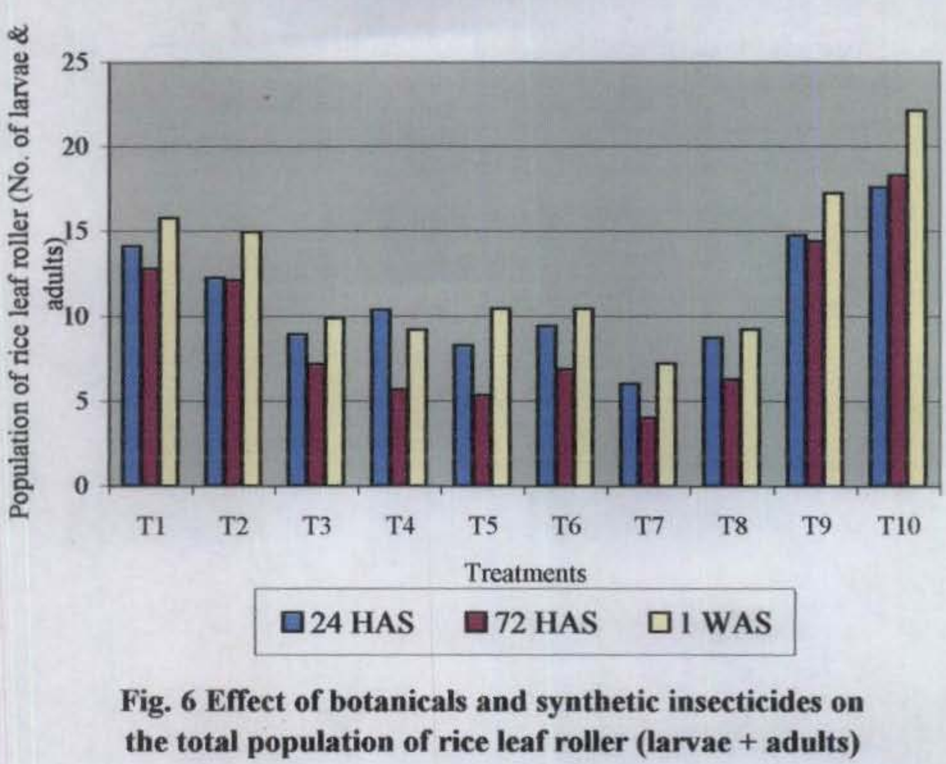


Fig. 6 Effect of botanicals and synthetic insecticides on the total population of rice leaf roller (larvae + adults)

suppressing the larval population of rice leaf roller. The population of leaf roller larvae observed in the plot sprayed with either of the botanicals + half dose of either of the synthetic insecticides and synthetic insecticides alone were significantly lower than that in untreated control. Effective control of the pest, obtained with botanicals + half dose of synthetic insecticides and synthetic insecticides alone confirmed with the earlier findings of Lim (1991); Sontakke (1993); Hai (1996); Babu *et al.* (2000) and Verma and Gupta (2001). Other treatments like neem seed oil, azadirachtin and mechanical control were ineffective in suppressing the larval population. The ineffectiveness of neem oil three per cent was against the observations made by Reguraman and Rajasekaran (1996) and Krishnaiah and Kalode (1990). Whereas the ineffectiveness of azadirachtin observed in the study was in consonance with the observations made by Naganagouda *et al.* (1997) and Baitha *et al.* (2000).

With regard to the adult population of rice leaf roller, a similar trend of mortality as seen in the case of larval population was observed. The adult population of leaf roller was significantly lower in the plots receiving botanicals + half dose of synthetic insecticides as well as synthetic insecticides alone compared to untreated control. This result was in confirmity with the findings of Mer *et al.* (2001) and Verma and Gupta (2001). Similarly the treatments with botanicals alone and mechanical control were found to be ineffective in checking the adults of rice leaf roller. While considering the total population of rice leaf roller, NSO three per cent + imidacloprid 0.0025 per cent was effective in suppressing the leaf roller population (Fig. 6)

The infestation levels of leaf roller at 30 DAT showed that the botanicals + half dose of synthetic insecticides and synthetic insecticides alone were effective in reducing the leaf damage in all the three observations made. The efficacy of quinalphos alone and in combination with neem oil was well documented by Sontakke (1993). Similarly, Hai

(1996) reported that imidacloprid alone was highly effective in managing the leaf roller damage. The present finding also agreed with this view. However the botanicals and mechanical control were ineffective in reducing the leaf damage. At 60 DAT, none of the treatments had positive effect in reducing the leaf roller damage. Over all leaf damage at 30 and 60 DAT showed that the maximum reduction in the infestation levels was noticed in treatments with NSO three per cent + imidacloprid 0.0025 per cent (Fig 7).

5.4 EFFICACY OF DIFFERENT BOTANICALS AND SYNTHETIC INSECTICIDES ON NATURAL ENEMIES IN RICE ECOSYSTEM

The results presented in 4.4 showed the effect of various botanicals, synthetic insecticides and botanicals + half dose of synthetic insecticides on natural enemies in the rice field.

The botanicals synthetic insecticides and botanicals + half dose of synthetic insecticides were found to be safe to *G. triangulifer* in all the three observations made at 30 DAT and none of the treatments affected the population adversely. However at 60 DAT, while the botanicals and mechanical control were found to be safe to the natural enemy, the synthetic insecticides alone and in combination with botanicals suppressed the population of *G. triangulifer* in all the three observations.

In the case of *X. flavolineata*, there was suppression in the population one day and three days after spraying with synthetic insecticides alone and in combination with botanicals, there was no adverse effect observed at seven days after spraying since the persistent toxicity was less. Similarly at 60 DAT, the population suppression was noticed only at one day after spraying with synthetic insecticide alone and botanical + half dose of synthetic insecticides. The persistent toxicity was still less compared to that observed at 30 DAT. The botanicals were found to be safe to *X. flavolineata* in all the three observations made both at 30 and 60 DAT.

A similar trend as seen in the case of *X. flavolineata* was observed for *Cotesia* sp. also. Even though there was an initial suppression of the population of *Cotesia* sp. at one day after spraying, there was a recolonisation of the natural enemy at three days and seven days after spraying. Since the persistent toxicity was very less for all the synthetic insecticides tried, none of the treatments affected the parasite population adversely. Even at one day after spraying, botanicals proved to be safe to the natural enemies. At 60 DAT, the same trend was noticed with botanicals. However synthetic insecticides alone and botanicals + half dose of synthetic insecticides affected the parasite population adversely.

The present study again confirmed the safety of botanicals to the parasites present in the rice ecosystem. This view supported the findings of Saxena *et al.* (1981b), Schmutterer *et al.* (1983) and TNAU (1992). The effect of various insecticidal treatments on the parasite population present at different growth stages of the plant also varied very much. In the present study, synthetic insecticides were found to be safe to the parasite population at 30 DAT even though there was an initial suppression. This result was in accordance with the findings of Panda and Mishra (1998) and Katole and Patil (2000). During the later growth stages (60 DAT), these insecticides adversely affected the population of *G. triangulifer* and *Cotesia* sp. Adverse effect of synthetic insecticides to the parasites was earlier reported by Patel *et al.* (1997).

The results presented in 4.4.4 gave a clear picture regarding the safety of botanicals to the predator, *Agriocnemis* spp. According to the present study, the botanicals like neem seed oil and azadirachtin were found to be safe to *Agriocnemis* spp. at 30 and 60 DAT in all the three observations made. At 30 DAT, synthetic insecticides alone and in combination with botanicals adversely affected the predator population at one day and three days after spraying. However at seven day after spraying no adverse effect was observed. Insecticides at 60 DAT gave an entirely different picture. In all the observations, synthetic insecticides alone and their combination with botanicals were toxic to the *Agriocnemis* spp. The reduction in *Agriocnemis* spp. recorded in these treatments varied. This variation could be due to the presence of different species of *Agriocnemis* and their relative susceptibility to these insecticides.

According to Saxena *et al.* (1981b), Lakshmi *et al.* (1998) and Dash *et al.* (2001), botanicals were found to be safe to the natural enemies. Some of the workers like Sontakke (1993) and Ajayakumar (2000) reported the toxicity of synthetic insecticides to *Agriocnemis* spp. The present study was in consonance with the above findings.

The results presented in 4.4.5 showed the effect of various botanicals and synthetic insecticides on the spider population in rice field. The spiders recorded in the study were *T. maxillosa*, *L. pseudoannulata* and *O. javanus*. The spiders were present in the experimental plot throughout the growth period of the crop. Various workers reported the safety of different botanicals on spiders in rice ecosystem (Saxena *et al.*, 1981b; Wu, 1986; Ajayakumar, 2000 and Dash *et al.*, 2001). The result of the present study supported the above mentioned findings. The treatments with botanicals did not affect the spider population even at one day after spraying. The highest population of spiders was recorded in untreated control, which was statistically on par with botanicals and mechanical control treatments. The adverse effect of synthetic insecticides lasted only for three days at 30 DAT. After that recolonization occurred, since the persistent toxicity was less. But at 60 DAT, adverse effect lasted for seven days. This variation in the effect of insecticides may be due to the species diversity in spider population. Some species may be highly susceptible to insecticides and probably these species dominated at 60 DAT. In all the observations made at 30 and 60 DAT, botanicals were found to be safe to the spiders. The adverse effect of synthetic insecticides noticed in the present study was against the findings of Xin and Xi (1995), Katole and Patil (2000) and Satheesan *et al.* (2002).

The results presented in 4.4.5 gave an idea about the impact of botanicals and synthetic insecticides on the predatory beetles. The major predatory beetles observed in the field were *O. nigrofasciata*, *P. fuscipes* and *M. crocea*. Among these predatory beetles, *O. nigrofasciata* was an effective and specific predator of rice leaf roller. The observations made at 30 and 60 DAT clearly showed that there was no adverse effect of botanicals as well as synthetic insecticides on predatory beetles upto seven days after application of treatments (Fig. 8). This view was supported by the findings of Saxena *et al.* (1981b), Patel and Yadav (1993), Patel *et al.*, 1997), Panda and Mishra (1998) and Katole and Patil (2000).

The predatory bugs observed in the field were *C. lividipennis* and *P. fuscovitattus*. Unlike the case of predatory beetles, adverse effect of synthetic insecticides was noticed in all the three observations made at 30 and 60 DAT. However, botanicals were found to be safe to the predatory bug fauna. According to Saxena *et al.* (1984) neem oil was toxic to *C. lividipennis*. However, the present result agreed with Mohan *et al.* (1991) who opined that eventhough there was initial suppression in the population of *C. lividipennis*, recolonization occurred later. The toxicity of synthetic insecticides to the predator was against the findings of Satheesan *et al.* (2002).

The result presented in 4.4.7 gave a clear indication that the treatments containing synthetic insecticides were harmful to *Conocephalus* sp. The effect of various treatments on the predator present at different growth stages also varied very much. The botanicals were safe to the predator at both growth stages in all the three observations made, since the population was statistically same with that of untreated control. At 30 DAT, the effect of synthetic insecticides lasted for three days. After that recolonization occurred since the persistent toxicity was less. But at

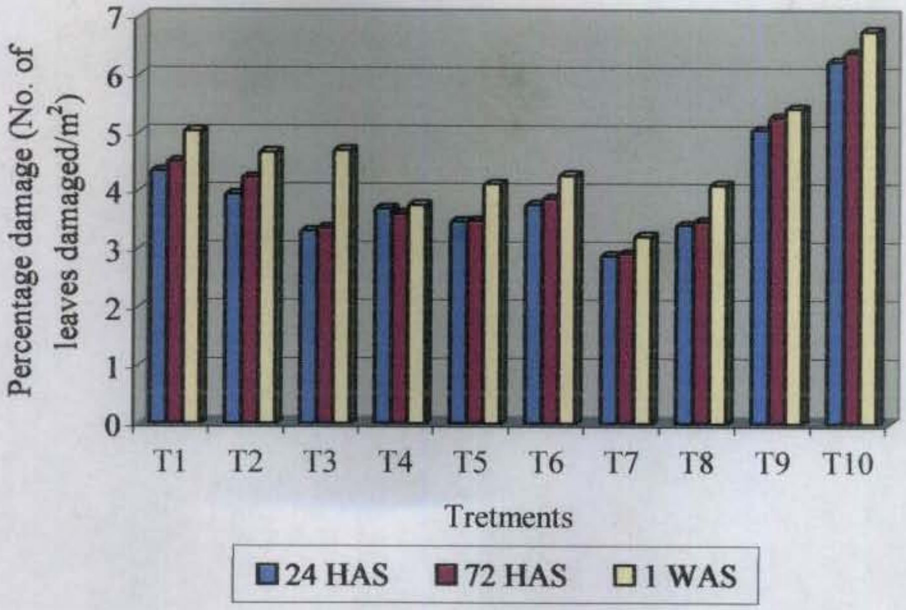


Fig. 7 Effect of botanicals and synthetic insecticides on the leaf damage by rice leaf roller

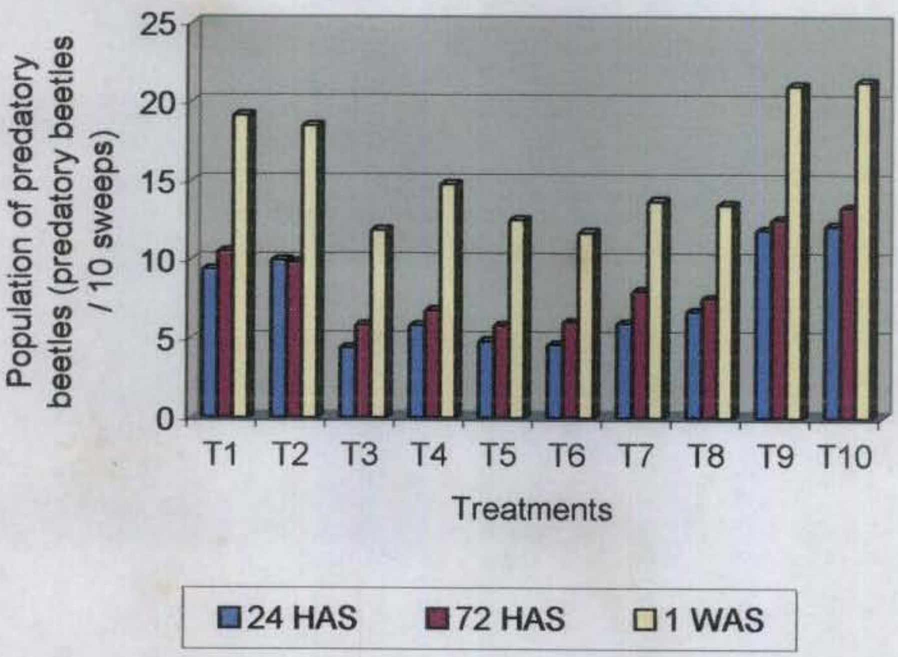


Fig. 8 Effect of botanicals and synthetic insecticides on predatory beetles

60 DAT, the persistent toxicity was comparatively high and the adverse effect of synthetic insecticides was noticed upto seven days after spraying. The safety of botanicals recorded in the present study was in confirmity with the findings of Lakshmi *et al.* (1998) and Dash *et al.* (2001).

The result presented in 4.4.9 showed that significantly higher yield was obtained in plots treated with synthetic insecticides alone and botanicals + half dose of synthetic insecticides as compared to control. The yield in the plots receiving botanicals were statistically on par with untreated control. Lowest yield was recorded in untreated control. According to Palis *et al.* (1988) rice yield was seriously affected by leaf roller defoliation.

The present study clearly indicated that rice leaf roller was a serious pest of rice throughout the cropping period. The leaf roller complex consisted of two species *viz.*, *C. medinalis* and *M. patnalis*. The natural enemies were recorded throughout the growth stages of the crop especially during the peak activity of the pest.

From the present investigation, it was very evident that the safer synthetic insecticides *viz.*, imidacloprid, quinalphos and botanicals + half dose of these synthetic insecticides were found to be equally effective in reducing the pest population as well as damage. With regard to the parasites. the persistent toxicity was less for synthetic insecticides. Though there was an initial suppression, recolonization occurred later. Among the parasites recorded, *G. triangulifer* was a specific parasite of rice leaf roller and were found to be unaffected by synthetic insecticides during the vegetative stage. Eventhough these synthetic insecticides were toxic to some of the natural enemies, predatory beetle fauna was an exception. These predatory beetles were effective predators of rice leaf roller. Since these synthetic insecticides effectively suppressed the pest population and were relatively safe to the specific natural enemies, we can resort to the use of these synthetic insecticides. The synthetic insecticides alone and botanicals + half dose of the synthetic insecticides were found to be equally effective in suppressing the pest population. Hence by the application of botanicals (NSO three per cent or azadirachtin 0.004 per cent) + half dose synthetic insecticides (quinalphos 0.025 per cent or imidacloprid 0.0025 per cent), the insecticide load can be reduced thereby ensuring environment safety.

SUMMARY

6. SUMMARY

Rice leaf roller is a major pest occurring in almost all rice growing areas of our country including Kerala. Information regarding the pest species, nature and extent of damage and their natural enemies are very essential to derive an ecofriendly management strategy. The composition of different species of rice leaf roller was assessed through a survey conducted in Kalliyoor panchayat of Thiruvananthapuram district. Detailed information of the population of different species of leaf rollers, extent of damage and the natural enemies in the rice ecosystem were documented at different growth stages of the crop. The efficacy of two botanicals (neem seed oil and azadirachtin), two synthetic insecticides (quinalphos and imidacloprid) and either of the botanicals + half dose either of the synthetic insecticides were evaluated against rice leaf roller and natural enemies under field conditions.

The major findings of the study are summarized below:-

1. The different species of rice leaf roller observed during the study were *Cnaphalocrocis medinalis* (Guenee) and *Marasmia patnalis* (Bradley).

2. Regarding the distribution of leaf roller species, the highest population of *C. medinalis* adults was observed during the vegetative stage, whereas maximum population of *M. patnalis* was observed during the early reproductive stage.

3. The larval population of *C. medinalis* and *M. patnalis* showed a gradual increase from vegetative to early reproductive stage and then the population declined.

4. The leaf damage was maximum during the late reproductive stage of the crop and the damage showed a steady increase from 30 to 70 DAT.

5. Four different types of folds observed in the field were single leaf folded longitudinally, single leaf folded vertically backwards, two leaves folded together and multiple folding.
6. Natural enemies observed during the survey were *Goniozus triangulifer* Kieffer, *Xanthopimpla flavolineata* Cameron and *Cotesia* sp., *Agriocnemis* spp., *Tetragnatha maxillosa* Thorell, *Lycosa pseudoannulata* (Boesenberg and Strand), *Oxyopes javanus* Thorell, *Micraspis crocea* (Mulsant), *Paederus fuscipes* Curtis, *Ophionea nigrofasciata* Schmidt-Goebel, *Cyrtorhinus lividipennis* Reuter. *Polytoxus fuscovitattus* (Stal.) and *Conocephalus* sp.
7. With regard to the distribution of natural enemies of rice leaf roller. the highest population of parasites and predators were recorded during the late reproductive stage.
8. Among the botanicals, synthetic insecticides and botanicals + half dose of synthetic insecticides evaluated against rice leaf roller. synthetic insecticides alone and botanicals + half dose of synthetic insecticides were equally effective and superior to all the other treatments in controlling rice leaf roller larvae, adults as well as reduction in leaf damage.
9. *G. triangulifer*, a specific larval parasite of rice leaf roller, was unaffected by the botanicals, synthetic insecticides and their combinations at 30 DAT
10. In the case of *X. flavolineata* and *Cotesia* sp, there was an initial suppression in the population when treated with synthetic insecticides alone and botanicals + half dose of synthetic insecticides, but later recolonization occurred.
11. The population of predatory beetles was not adversely affected by botanicals. synthetic insecticides and botanicals + half dose of synthetic insecticides at different growth stages of the crop.

12. The population of *Agriocnemis* spp, spiders, predatory bugs and *Conocephalus* sp. were adversely affected by synthetic insecticides included treatments at different growth stages of the crop.

13. The highest grain yield was recorded in plots treated with synthetic insecticides alone and botanicals + half dose of synthetic insecticides and were found to be statistically on par. Lowest grain yield was recorded in plots receiving botanicals and mechanical control and were statistically on par with control.

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*Original not seen

MANAGEMENT OF THE LEAF ROLLER COMPLEX ON RICE, *Oryza sativa* L.

LEKHA. M.

Abstract of the
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ABSTRACT

The magnitude and intensity of leaf roller complex and natural enemies at different growth stages of the rice crop were assessed in a survey conducted during Mundakan season of 2002, adopting random sampling technique in Kalliyoor panchayat of Thiruvananthapuram district.

The survey revealed the occurrence of two different species of leaf roller *viz.*, *Cnaphalocrocis medinalis* (Guenee) and *Marasmia patnalis* (Bradley). The distribution pattern of these two species in the rice ecosystem varied. *C. medinalis* had a population peak during the vegetative stage and showed a gradual decline as the crop growth progressed, whereas, *M. patnalis* had a population peak during the early reproductive stage compared to vegetative and late reproductive stage.

The natural enemies recorded from the rice ecosystem include three parasites and ten predators. The distribution of natural enemies in the rice ecosystem revealed that the population of parasites and predators showed a gradual increase from vegetative to reproductive phase.

From the field experiment, it was evident that the synthetic insecticides alone and botanicals + half dose synthetic insecticides were efficient in suppressing the population of rice leaf roller. The treatments with botanicals alone did not show any significant reduction in the population of leaf roller compared to control.

G. triangulifer, a specific larval parasite of rice leaf roller, was unaffected by the botanicals, synthetic insecticides and their combinations at 30 DAT. In the case of *X. flavolineata* and *Cotesia* sp., only an initial suppression was noticed in insecticide included treatments. Later it was found to be safe. All these treatments were found to be relatively safe to predatory beetles. But *Agriocnemis* sp., spiders, predatory bugs and

Conocephalus sp. was adversely affected by the insecticide included treatments. Botanicals were safe to all the natural enemies observed but they were ineffective against rice leaf roller. The yield obtained was also the highest in synthetic insecticides alone and botanicals + half dose of synthetic insecticide treatments and were on par.

Overall assessment of the results obtained revealed that synthetic insecticides alone and botanicals + half dose of synthetic insecticides were equally effective in controlling rice leaf roller and safe to its specific parasites and predators. For other natural enemies, it showed a varying trend. In some cases there was an initial suppression and then recolonization occurred. From this result, it was clear that botanicals + half dose synthetic insecticides were as equally effective as full dose of synthetic insecticides in suppressing the pest and in protecting natural enemies. Hence we can substitute the full dose of synthetic insecticides with combination of botanicals (either NSO three per cent or azadirachtin 0.004 per cent) and half dose of synthetic insecticides (either quinalphos 0.0025 per cent or imidacloprid 0.0025 per cent) for an ecofriendly management of rice leaf roller.