IMPACT OF DIFFERENT INSECTICIDES ON PEST, NATURAL ENEMY AND NEUTRAL COMPLEX IN RICE ECOSYSTEM

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DECLARATION

I hereby declare that this thesis entitled "**Impact of different insecticides on pest, natural enemy and neutral complex in rice ecosystem**" 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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20-10-2004

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CERTIFICATE

Certified that this thesis entitled "**Impact of different insecticides on pest, natural enemy and neutral complex in rice ecosystem**" is a record of research work done independently by Ms. Smitha Gopan (2002-11-08) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Dedicated to
My Beloved Parents

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LIST OF ABBREVIATIONS

%	Per cent
@	At the rate of
^{0}C	Degree Celsius
a.i.	Active ingredient
Bt	*Bacillus thuringiensis*
CD	Critical difference
cm	Centimetre(s)
DAT	Days after transplanting
EC	Emulsifiable Concentrate
et al.	And others
Fig.	Figure
G	Granule
g	Gram
h	Hour
ha^{-1}	Per hectare
kg	Kilogram
l	Litre
m	Metre
m^2	Metre square
ml	Millilitre
ppm	Parts per million
RBD	Randomised Block Design
SL	Soluble Liquid
SP	Soluble Powder
spp.	Species
viz.	Namely
WG	Wettable Granule
WP	Wettable Powder

Introduction

1. INTRODUCTION

The United Nations General Assembly has declared 2004 as the International Year of Rice with the theme "rice is life" which emphasize the importance of rice in the world economy and human life. The International Year of Rice aims to focus attention on improved production to feed more than half the world's population, providing income for millions of rice producers, processors and traders. Yet rice farmers are among the poorest, often subject to risk and uncertainty and struggling for a livelihood. Development of sustainable rice based systems involving value addition to every part of the biomass can help to reduce hunger and poverty and contribute to environmental conservation and a better life for present and future generations.

As in the case of any other crop, pests have plagued rice ever since people began cultivation and reduced the yield of the crop. The introduction of high yielding varieties of rice, adoption of modern agronomic practices and large scale use of chemical inputs revolutionized production. The benefit achieved was not long lasting. The large scale use and misuse of toxic chemical pesticides created an array of problems such as pest outbreaks and other environmental and health problems (Conway and Pretty, 1991). The pest outbreaks were mainly due to pest resurgence or development of pesticide resistance to pests. Thus a condition arose when more and more pesticides had to be used to achieve less and less pest outbreaks. Ambitious development plans were proposed worldwide to overcome these problems for attaining sustainability to agriculture. One of such plans is to formulate strategies to sustain rice productivity through marginal adjustments in cultivation practices, respecting the ecological principles of diversity and by utilizing knowledge on traditional practices accumulated over centuries of experience by farmers. In view of the above, crop protection specialists are increasingly being asked to develop pest control methods with goals, which would contain the pests and at the same time provide a sustainable, productive, stable and equitable agriculture. To meet these aims, research must seek to integrate a range of complementary pest control methods. One among them is the use of selective insecticides, which are harmful to targeted species and safe to natural enemies and neutrals, for managing pests.

It is estimated that, on an average, one hectare of paddy field may have upto five to seven million parasitoids, predators and neutrals (Settle, 1994). Inspite of the high population of natural enemies, pest outbreaks are reported following pesticide application (Ooi, 1988). It is also reported that under optimum field conditions, rice crop with moderate level of natural enemies and without insecticides is found to tolerate a certain level of pest infestation without causing yield reduction (Nalinakumari *et al*., 2002).

The predator population develops in rice fields very early in the growing season by feeding on neutrals (detritivores and filter feeders). This suggests that rice fields are more stable and resilient to influxes of rice pests because of the development of predators early in the season, before pest population develops (Settle, 1994).

Cultivation of tolerant varieties together with conservation of natural enemies by avoiding insecticides application in vegetative phase and pocket application of selective insecticides in the reproductive stage of the crop, if flare up of pest population was noticed, were the steps recommended (KAU, 2002). Detailed investigation on the effect of insecticides reported as selective on pests, predators, parasitoids and neutrals is required to find out their bioefficacy to pests and safety to other arthropods in the rice ecosystem to utilise them for pocket application in integrated pest management (IPM). With these objectives in view, the present investigation was therefore undertaken:

1) To study the population status and species composition of arthropod community in the rice ecosystem

1) To evaluate the impact of insecticides on pests, natural enemies and neutrals in rice ecosystem

2) To identify and incorporate in IPM programmes insecticides which are effective in controlling the pests of rice without having much adverse effect on predators, parasitoids and neutrals.

Review of Literature

2. REVIEW OF LITERATURE

Arthropod community in rice ecosystem is not static and is always fluctuating. This is governed by the crop variety, cultivation practices and climatic factors of a particular area. The effect of different insecticides on the population of these organisms in rice ecosystem also fluctuates based on the species variation. The literature given below pertains to the population status of arthropod community in rice ecosystem and the effect of some of the commonly used insecticides on these organisms.

2.1 SPECIES COMPOSITION AND POPULATION STATUS VARIATION OF ARTHROPOD COMMUNITY IN THE RICE ECOSYSTEM

Many workers studied the composition and variation of arthropod community in the rice ecosystem and some of them are reviewed here under.

2.1.1 Pests

One of the earliest studies carried out by Nair (1978) reported *Scirpophaga incertulas* (Walker), *Leptocorisa acuta* (Thunberg), *Nilaparvata lugens* (Stal), *Orseolia oryzae* (Wood-Mason), *Cnaphalocrocis medinalis* (Guenee) and *Nymphula depunctalis* (Guenee) as major pests in the rice ecosystems of Kerala. Among these, it was observed that *S. incertulas, N. lugens* and *C. medinalis* affected all stages of the crop whereas *L. acuta*, *O. oryzae* and *N. depunctalis* were stage specific. According to him, *N. lugens* was a minor pest in Kerala till 1973 and from 1973 onwards it was a major pest in the Kuttanad and in the Kole areas of Kerala. *L. acuta* and *S. incertulas* were the major pests during the second crop season in Pattambi (KAU, 1992). Krishnakumar and Visalakshi (1996) reported the occurrence of *L. acuta* as one of the major pests of rice in Thiruvananthapuram district. Nalinakumari *et al*. (1996) recorded *N. lugens, C. medinalis, S. incertulas, O. oryzae,* *Nephotettix* sp. and *L. acuta* in the rice field of Kuttanad. *C. medinalis, S. incertulas, N. lugens, L. acuta, Nephotettix* sp. and *Oxya chinensis* (Thunberg) were present in different rice ecosystems of Thiruvananthapuram district whereas *N. depunctalis* was observed only in the fields of Nedumangad taluk (Ajayakumar, 2000). Outbreak of *C. medinalis* was noticed during 1998 in Thanjavur, Nagapattinam and Thiruvarur districts of Tamil Nadu (Balasubramani *et al*., 2000). *Porthesia xanthorhoea* (Kollar) were found in large numbers in Regional Agricultural Research Station, Pattambi (Nadarajan, 2000). *Oxya velox* (Fabricius) was identified as a serious pest of rice in Aligarh (Rizvi *et al*., 2001). Nandakumar *et al*. (2002) observed *C. medinalis*, *O. oryzae, Nephotettix* sp., *Dicladispa armigera* (Olivier), *S. incertulas, N. depunctalis* and *L. acuta* as important pests in rice ecosystem of Kollam district. Accoridng to Premila (2003) *Nephotettix* sp., *Sogatella furcifera* (Horvath) and *N. lugens* dominated when compared to *C. medinalis, Parapoynx stagnalis* (Zeller) and *D. armigera* in the Kuttanad ecosystem, double cropped fields of Thiruvananthapuram district and Pokkali areas. It was further observed that population of *N. lugens* was comparatively low in Kuttanad.

Variation in the occurrence of major pests of rice in central Kerala over 30 years was analysed by Nadarajan (1996). The major pests recorded were *O. oryzae, S. incertulas* and *C. medinalis.* He observed that infestation levels of *O. oryzae* varied from 10 per cent to 20 per cent and that of *S. incertulas* varied from eight to 14 per cent. The *C. medinalis* infestation was below five per cent during the period from 1965 to 1974 and its infestation level reached upto 40 per cent during 1990-’95 periods.

Seasonal abundance of the pests of rice was reviewed by many workers. *Spodoptera mauritia* Boisd. was more common on the Punja crop during October to December (Ananthanarayanan and Ayyar, 1937; Cherian and Ananthanarayanan, 1937). *S. incertulas* population was high during August – September and February – March in Kuttanad tracts and during October to January in Pattambi area (Abraham *et al*., 1972). They found that *N. lugens* infestation was more severe in summer crop (October - November to January – February) and not severe in autumn season.

Haplothrips ganglbaueri (Schmutz) was more abundant during the first fortnight of December (Abraham and Nair, 1975). Maximum infestation of *O. oryzae* occurred in rice planted during June and low infestation was noticed in rice planted in the first fortnight of July (Thomas *et al*., 1975). In Kuttanad, *N. lugens* was present in the field throughout the year with major population peak during January to March and minor peak during August to September (Nair *et al*., 1980). Subramanian (1990) found that rice planted during January, August and September had more *C. medinalis* damage than rice planted during other periods. According to Salim *et al*. (1991) *C. medinalis* infestation in late planted crop was higher than that in early crop. Sontakke *et al*. (1994) reported that population of *S. furcifera* on rice was highest during the Rabi than the Kharif season. *Gryllotalpa africana* (P. de. Beauv.) appeared on the first crop during March – April (Nair,1995). Nadarajan (1996) reported that *O. oryzae* and *C. medinalis* infestation was more during Kharif than in Rabi season and the infestation of *S. incertulas* was more during Rabi season. He had also observed that minor pests like *Leptispa pygmaea* Baly and *Baliothrips biformis* (Bagnall) became more severe in the nurseries both in Kharif and Rabi season. Peak population of *O. oryzae* was observed in December – January sown crop when compared to October – November sown crop (KAU, 2001).

Wide variations in the pest status were observed in different growth stages of the crop. Singh and Singh (1987) reported four species of bugs *Dolycoris indicus* Westwood, *Menida histrio* Fabricius, *Scotinophara coarctata* Fabricius and *Cletus signatus* Walker during the milky stage of rice. Leafhopper population was above the economic threshold during the tillering stage and gradually declined to zero by the flowering stage (Prakash *et al*., 1988). Panicle initiation stage was the most preferred stage for the buildup of the *N. lugens* population and the seedling stage was the least preferred (Nair, 1999). Nalinakumari and Remamony (1999) found that pests were present throughout the cropping season but in a fluctuating trend. According to Ajayakumar (2000) population of *C. medinalis*, *Nephotettix* sp. and *N. depunctalis* were highest at vegetative phase whereas *N. lugens* and *L. acuta* population were highest at the reproductive stage of the crop. The incidence of *C. medinalis* occurred from 28 to 70 DAT (Faliero *et al*., 2000; Nandakumar *et al*., 2002; Lekha, 2003).

The role of climatic factors on the occurrence of major pests was reported by many workers. According to Abraham *et al*. (1972) climatic factors play an important role in the occurrence of pests in rice ecosystem and found that *S. incertulas* infestation was negatively correlated with rainfall, minimum temperature and relative humidity. Thomas *et al*. (1975) reported a strong positive correlation between percentage of silver shoots caused by the *O. oryzae* and rainfall and a strong negative correlation with maximum temperature. *D. armigera* and *Brevennia rehi* (Lindinger) were severe and wide spread under drought conditions (Nair, 1978). As regards the influence of temperature, relative humidity and rainfall on the incidence of *N. lugens*, Nair *et al*. (1980) reported that a temperature of around 29°C and relative humidity of 60 to 90 per cent were most favourable for the development and survival of the nymphs of *N. lugens*. Further, it was found that rainfall in association with relative humidity and maximum temperature played a decisive role in regulating the population of *N. lugens*. According to Krishnakumar and Visalakshi (1996) maximum number of *L. acuta* was observed when the rainfall was high while maximum and minimum temperature as well as relative humidity did not show significant effect on the *L. acuta* population. *S. incertulas*, *C. medinalis*, *Nephotettix* sp. and *L. acuta* showed a negative correlation with minimum temperature, evening relative humidity and rainfall whereas *C. medinalis*, *N. depunctalis, Nephotettix* sp. and *L. acuta* showed a positive correlation with sunshine hours (Bhatnagar and Saxena, 1999).

2.1.2 Predators

Pawar (1975) reported *Cyrtorhinus lividipennis* Reuter as a predator of eggs and nymphs of *N. lugens* and *Nephotettix* sp. in Himachal Pradesh. Bhardwaj and Pawar (1987) found that *Agriocnemis pygmaea* (Rambur), *Paederus fuscipes* (Curtis) and *C. lividipennis* were the most abundant predators of pests in monsoon rice in Chhattisgarh. Reghunath *et al*. (1990) reported several natural enemies *viz*., *Micraspes crocea* (Mulsant), *Menochilus sexmaculatus* (Fab.), *Harmonia octomaculata* (Fab.), *Ophionea nigrofasciata* (Schmidt and Goebel), *Agriocnemis* sp., *C. lividipennis*, *Polytoxus fuscovittatus* (Stal), *Tetragnatha maxillosa* Thorell, *Lycosa pseudoannulata* (Boesenberg and Strand), *Oxyopes javanus* Thorell, *Oxyopes lineatipes* (C.L. Koch) and *Atypena formosana* (Oi) in the Punja paddy ecosystem of southern Kerala. Nalinakumari *et al*. (1996) reported *Micraspis* sp., *C. lividipennis*, *O. nigrofasciata, P. fuscovittatus, Agriocnemis* sp. and *Microvelia douglasi atrolineata* Bergroth in large numbers along with spiders in rice ecosystem of Kuttanad. According to Ambikadevi (1998) predators *viz*., *Ophionea* sp., *Micraspis* sp., *M. sexmaculatus, C. lividipennis, Conocephalus longipennis* (de Hann), *Polytoxus* sp., *Agriocnemis* sp., *Lycosa* sp., *Oxyopes* sp., *T. maxillosa* and *Atypena* sp. were present in the same tract. Nandakumar and Pramod (1998) observed *O. nigrofasciata, M. douglasi atrolineata, Micraspis sp., Agriocnemis* sp., *L. pseudoannulata, Oxyopes* sp., *T. maxillosa, Phidippus* sp., *Atypena* sp. and *Araneus* sp. as major predators in the rice ecosystem of Kollam district. Ajayakumar (2000) reported *Agriocnemis* sp., *Crocothemis* sp., *C. lividipennis*, *L. pseudoannulata* and *T. maxillosa* in rice ecosystem of Thiruvananthapuram district. *Tetragnatha* sp. and *Oxyopes* sp were dominant predators in irrigated rice field of Punjab (Kaur *et al*., 2001). Lekha (2003) reported *Agriocnemis* sp., *M. crocea, P. fuscipes, O. nigrofasciata, C. lividipennis, P. fuscovittatus, Conocephalus* sp., *T. maxillosa*, *L. pseudoannulata* and *O. javanus* from the rice fields of Thiruvananthapuram district. Premila *et al*. (2003) observed high population of predators *viz*., *C. lividipennis*, *Micraspis discolor* (Fabricius), *O. nigrofasciata, P. fuscovittatus, Eucyrtus* sp., *Conocephalus* sp., *T. maxillosa* and *L. pseudoannulata* in Pokkali areas as compared to Kuttanad ecosystem and double cropped fields of Thiruvananthapuram district.

Ajayakumar (2000) reported varied population of *L. pseudoannulata*, *T. maxillosa*, *M. crocea, O. nigrofasiata*, *C. lividipennis* and *Agriocnemis* sp. at different growth stages of the crop in Thiruvananthapuram district. According to Nalinakumari and Hebsybai (2002) population of beneficials was high at the early stages of the crop and showed a declining trend after the vegetative phase. Highest population of *Conocephalus* sp., *Agriocnemis* sp., spiders, predatory beetles and predatory bugs were observed at the reproductive phase of the crop (Lekha, 2003).

2.1.3 Parasitoids

According to Reghunath *et al*. (1990) parasitoids found on punja crop in southern Kerala were mainly *Tetrastichus schoenobii* Ferriere, *Telenomus rowani* (Gahan) and *Cotesia angustibasis* (Gahan). Nalinakumari *et al*. (1996) recorded *Xanthopimpla* sp., *Haplogonatopus* sp., *Telenomus* sp. and *Cotesia* sp. as the major parasitoids in Kuttanad. Mohanraj and Veenakumari (1997) reported *Trichogramma japonicum* Ash. in rice fields in Andaman Islands. The presence of high parasitism of *T. japonicum*, *T. schoenobii*, *Tetrastichus versicolor* Ranawere, *T. rowani*, *Telenomus* nr. t*riptus* Nixon, *Trichomalopsis apantelocefenae* Crawford, *Platygaster oryzae* Cameron, *Haplogonatopus* sp., *Pseudogonatopus* spp., *Macrocentrus* sp. and *Cotesia* sp.was reported by Ambikadevi (1998). Nandakumar and Pramod (1998) identified five parasitoids *viz*., *Stenobracon* sp., *Xanthopimpla* sp., *Charops brachypterum* (Cameron); *Cotesia* sp. and *Opius* sp. in Kollam district. Ajayakumar (2000) noted sizeable population of *Cotesia flavipes* Cameron and *T. schoenobii* in Thiruvananthapuram district. Among the 96 species of natural enemies identified, 77 species were hymenopteran parasitoids. High level parasitisation of *Telenomus* sp., *Tetrastichus* sp. and *Trichogramma* sp. on *S. incertulas* eggs and *Cotesia* sp., *Apanteles* sp., *Brachymeria excarinata* Gahan, *Carzochilus philippinensis* Ashmead, *Goniozus* sp., *Macrocentrus philippinensis* Ashmead and *Xanthopimpla* spp. on *C. medinalis* larvae and pupae (KAU, 2001). Lekha (2003) reported *Goniozus triangulifer* Kieffer, *Xanthopimpla flavolineata* Cameron and *Cotesia* sp. from Thiruvananthapuram district.

Ajayakumar (2000) recorded varied population of *C. flavipes* and *T. schoenobii* at different growth stages of rice in Thiruvananthapuram district. Lekha (2003) reported a gradual increase in population of *Cotesia* sp., *G. triangulifer* and *X. flavolineata* from vegetative to reproductive phase.

2.1.4 Neutrals

Studies on plant – natural enemy interaction in a natural rice ecosystem in Thiruvananthapuram district, indicated that very large population of general predators existed on detritivores and filter feeders even before the herbivores appeared and kept the pest under check up to the vegetative phase (Nalinakumari and Hebsybai, 2002). Low population of neutrals was found in rice ecosystem of Kuttanad, double cropped ecosystem of Thiruvananthapuram district and Pokkali area whereas comparatively high population was recorded in non-rice habitat in the adjoining area (Premila, 2003).

2.2 EFFECT OF DIFFERENT INSECTICIDES ON ARTHROPOD COMMUNITY IN RICE ECOSYSTEM

The influence of different insecticides on pests, predators, parasitoids and neutrals in rice ecosystem is reviewed here under.

2.2.1 Pests

2.2.1.1 Acephate

Acephate was effective against larvae of *C. medinalis* (Das and Nair, 1975). For the management of *C. medinalis*, acephate at 0.5 kg ha^{-1} (Saroja and Raju, 1982) and at 0.75 kg ha^{-1} (Rao *et al*., 1985) were found to be effective. Korat *et al*. (1999) observed a relatively low incidence of *C. medinalis* in plots treated with acephate 75 SP (4.38 per cent) compared to untreated check plots (9.30 per cent). Accoridng to Zhong *et al*. (2002) acephate 75 WP gave the best control efficiency of 88.90 per cent three days after application.

Acephate gave good protection against *Nephotettix nigropictus* (Stal) (Hsieh, 1976). Foliar spray of 0.3 per cent acephate gave effective control of *Nephotettix virescens* (Dist.) (Mani and Jayaraj, 1976a). Insecticide combination of carbofuran and acephate was the most effective in controlling *Nephotettix* sp. (Kumar *et al*., 1988).

Acephate 0.3 per cent gave better control of leaf mining larvae of *Hydrellia philippina* Ferino (Mani and Jayaraj, 1976b). Acephate at 0.75 kg a.i. ha^{-1} was less effective against *Hydrellia* spp. (Rao *et al*., 1985).

Acephate 750 g a.i. ha^{-1} caused 100 per cent mortality of *L. acuta* (Kay *et al*., 1993).

According to Hsieh (1976) acephate was effective against *N. lugens*. Acephate 0.3 per cent gave better control of *N. lugens* (Mani and Jayaraj, 1976c). Development of resistance among the field population of *N. lugens* has been favoured by application of acephate since 1981 (Mochida and Basilio, 1983). Acephate effectively controlled *L. pygmaea* in rice plant (Dalvi *et al*., 1985). Acephate 75 SP in combination with hexaconazole 5 EC proved to be the best in controlling the incidence of plant hoppers (Rao *et al*., 2001).

2.2.1.2 Imidacloprid

In China, Hai (1996) reported that imidacloprid alone and in mixtures were effective in controlling *C. medinalis*. Mer *et al*. (2001) reported that imidacloprid gave better control of *C. medinalis*. Imidacloprid @ 25 g a.i. ha^{-1} was less effective (Krishnaiah *et al*., 2002) whereas imidacloprid 0.005 per cent was effective (Lekha, 2003) against *C. medinalis*.

According to Xin and Xi (1995) imidacloprid caused significant mortality of Hemiptera. Manjunatha and Shivanna (2001) reported that imidacloprid treated plots showed mortality of 65.12 per cent and 80.43 per cent of *Nephotettix* sp. at 100 ml ha^{-1} and 400 ml ha^{-1} respectively. Widiarta *et al*. (2001) observed that fecundity of *N. virescens* and *Nephotettix cinticeps* Uhler exposed to imidacloprid treated rice seedlings was reduced to one third and half respectively that of insects not exposed. He had also reported that sublethal dosage application of imidacloprid did not cause physiological resurgence in both species but it induced ecological resurgence.

Misra (2003) observed that imidacloprid 200 SL @ 50 ml a.i. ha^{-1} proved significantly effective in controlling *Leptocorisa* sp. up to ten days after spraying.

Imidacloprid controlled *N. lugens* and the effect lasted upto 60 days after application (Ishii *et al*., 1994). Imidacloprid was found very effective against *N. lugens* as it killed 100 per cent of fifth instar nymphs upto seven days. In the same study it was also found that the insecticide did not reduce the rate of oviposition but could reduce the larval hatching to 25.5 per cent (CRRI, 1995). A season long control of *N. lugens* was obtained with the application of imidacloprid at 200 g a.i. ha^{-1} (Iwaya *et al*., 1998). According to Manjunatha and Shivanna (2001) imidacloprid treated plots showed mortality of 69.28 per cent and 85.68 per cent of *N. lugens* at 100 ml ha^{-1} and 400 ml ha^{-1} respectively. Ryeol *et al*. (2001) reported that residual effect of imidacloprid at 0.3 kg a.i. ha^{-1} granule formulation in *N. lugens* lasted for 40 days and for 30 and 20 days at half and one fourth of the dose respectively while imidacloprid at 0.032 a.i. ha^{-1} formulation lasted for 40 days for full and half dose and 30 days for quarter dose. Krishnaiah *et al*. (2002) reported that imidacloprid @ 25 g a.i. ha^{-1} was less effective against *S. incertulas*. A high degree of efficiency of thiamethoxam and imidacloprid at 25 g a. i. ha^{-1} against *N. lugens* was reported by Krishnaiah *et al*. (2003). Cent per cent mortality of *N. lugens* within four hours of exposure to imidacloprid was recorded by Reddy and Krishnaiah (2003).

2.2.1.3 Chlorpyrifos 50 EC + Cypermethrin 5 EC

According to Wakil *et al*. (2001) cypermethrin + chlorpyrifos (Nurelle-D) proved better for the control of *C. medinalis*. Combination product chlorpyrifos 50 per cent + cypermethrin 5 per cent @ 344 g a.i. ha^{-1} exhibited efficacy against *C. medinalis* and increased grain yield (Krishnaiah *et al*., 2002).

Wakil *et al*. (2001) reported that cypermethrin + chlorpyrifos (Nurelle-D) gave effective control of *S. incertulas*. Krishnaiah *et al*. (2002) found that chlorpyrifos 50 per cent + cypermethrin 5 per cent @ 344 g a.i. ha^{-1} exhibited efficacy against *S. incertulas*.

2.2.1.4 Azadirachtin

Kannamani (1992) found that neem formulations effected good mortality of larvae of rice leaf folder. According to Naganagouda *et al*. (1997), Nimbecidine was least effective in controlling *C. medinalis* compared to monocrotophos and neem oil. Krishnaiah *et al*. (1999) revealed that neem formulations with lower azadirachtin content were more effective against *C. medinalis* compared to water based formulations with high azadirachtin content. Lingaiah *et al*. (1999) reported that one per cent each of Neemgold, NeemAzal T/S and Rakshak exhibited considerable feeding deterrence of *C. medinalis*. Ajayakumar (2000) reported that Nimbecidine two per cent reduced the population of *C. medinalis* but long lasting effect on suppression of the pest was not observed. Lal (2000) found Neemgold and NeemAzal to be moderately effective in managing *C. medinalis*. Ajayakumar and Nalinakumari (2002) reported that Nimbecidine four per cent was effective in protecting the leaf against the attack of *C. medinalis*. According to Ambikadevi and Satheesan (2002) Neemax two per cent, Neemgold two per cent and Achook three per cent were effective in controlling *C. medinalis*. Dhaliwal *et al*. (2002) found that incidence of *C. medinalis* was minimum when sprayed with NeemAzal five per cent.

According to Maheshkumar *et al*. (1999) NeemAzal T/S and Nimbecidine caused significant reduction in reproduction and oviposition of *Nephotettix* sp.. Krishnaiah *et al.* (2001) reported that NG 4 (300 ppm azadirachtin), Rakshak (1500 ppm azadirachtin) and NeemAzal T/S (10,000 ppm azadirachtin) exhibited significant feeding deterrent effect on *N. virescens*.

Ajayakumar (2000) found that Nimbecidine two per cent was not effective against *L. acuta*.

Dash *et al*. (1994) found that neem derivatives produced no effective control of *O. oryzae*. Krishnaiah *et al*. (1999) recorded toxic effect of Nimbecidine against *N. lugens*. Maheshkumar *et al*. (1999) observed that Nimbecidine solution with 50 ppm azadirachtin reduced oviposition and 10 ppm azadirachtin reduced reproduction of *N. lugens*. Neemax two per cent was reported to be effective against *S. incertulas* where as Achook two per cent was effective against *O. oryzae* (KAU, 2001). Krishnaiah *et al*. (2001) reported that NG4 (300 ppm azadirachtin), Rakshak (1500 ppm azadirachtin) and NeemAzal T/S (10,000 ppm azadirachtin) exhibited significant deterrent effects on *N. lugens* and *S. furcifera*. Rath (2001) found that neem products were effective to a limited extent against *S. incertulas*.

2.2.1.5 Bacillus thuringiensis var. kurstaki

Panda *et al*. (1999) reported that formulation of *Bacillus thuringiensis* var. kurstaki, Bioasp, Biolep and Biotox at 2.0 kg a.i. ha^{-1} were highly effective against *C. medinalis*. Lal (2001) observed the commercial products of biopesticides *viz*., Dipel, Delfin, BTK-II and Biolep applied at 2000 g ha^{-1} were as effective as chlorpyrifos 20 EC at 1250 ml ha^{-1} in managing *C. medinalis*. Biopesticide, *Bacillus thuringiensis* var. kurstaki played a significant role in mitigating *C. medinalis* damage (Sehrawat *et al*., 2002). Rao and Singh (2003) reported that management of *C. medinalis* in rice through systemic insecticides in combination with the biopesticide-Biobit was economical as well as ecofriendly.

According to Panda *et al*. (1999) formulation of *Bacillus thuringiensis* var. kurstaki was effective to a limited extent against *S. incertulas*. According to Tripathy *et al*. (1999) Bt preparations tested were found to be effective against lepidopteran pests. Chemical control and Bt treatment did not show any significant difference with that of untreated control in terms of *S. incertulas* (Tandon *et al*., 2003).

2.2.1.6 Carbofuran

Significant control of *C. medinalis* was obtained with carbofuran 0.5 kg a.i. ha^{-1}, 1.0 kg a.i. ha^{-1} (Pillai, 1981) and 0.4 kg a.i. ha^{-1} (Saroja and Raju, 1982). Rice root zone placement of carbofuran granules @ 1.0 kg a.i. ha^{-1} in the form of clay soil balls was found to be effective against *C. medinalis* (Barwal, 2000). Granular furadan application was proved to be the best in controlling the attack of *C. medinalis* (Wakil *et al*., 2001).

Carbofuran 0.5 kg a.i. ha^{-1} and 1.0 kg a.i. ha^{-1} gave significant control of grasshoppers in the rice field (Pillai, 1981).

Carbofuran was found to be very effective against *Nephotettix* sp. (Hsieh, 1976). Carbofuran 0.5 kg a.i. ha^{-1} and 1.0 kg a.i. ha^{-1} gave better control of *Nephotettix* sp. (Pillai, 1981). Satisfactory control of

N. cincticeps was obtained in one or two applications of granules containing three per cent carbofuran (Kim *et al.*, 1984). Against *Nephotettix* sp. carbofuran exhibited high toxicity with 100 per cent mortality of the pests (Krishnaiah *et al.*, 2003).

Carbofuran 1.0 kg a.i. ha^{-1} was found to be effective against *H. philippina* (Pillai, 1981 and KAU, 1993). Rice root zone placement of carbofuran granules @ 1.0 kg a.i. ha^{-1} in the form of clay soil balls was found to be effective against *Hydrellia* sp. (Barwal, 2000).

Carbofuran 1000 g a.i. ha^{-1} was ineffective against *L. acuta* (Kay *et al.*, 1993).

Very effective control of *N. lugens* was obtained with carbofuran (Hsieh, 1976). Carbofuran 0.4 kg a.i. ha^{-1} was found to be effective against *S. incertulas* (Saroja and Raju, 1982). Carbofuran highly reduced the population of *S. furcifera* (Garg and Sethi, 1984). Carbofuran treatments resulted in significant control of stem borers (Ukwungwu, 1987; Wakil *et al.*, 2001; Panda *et al.*, 2002). Furadan 3G @ 1 kg a.i. ha^{-1} gave better control of *Leptispa* sp. and *S. incertulas* (KAU, 1993). Carbofuran 3G at 1.0 kg a.i. ha^{-1} afforded better control of *S. incertulas* (Tripathy *et al.*, 1999), *O. oryzae* (Dash *et al.*, 2001a) and *N. lugens* (Vardhani and Rao, 2002). Krishnaiah *et al.* (2003) reported that carbofuran exhibited high toxicity against *N. lugens.*

2.2.2 Predators

2.2.2.1 Acephate

According to Chiu and Cheng (1976) acephate was relatively safe to the spiders, *L. pseudoannulata* and *Oedothorax insecticeps* (Boesenberg and Strand). Fabellar and Heinrichs (1984) reported that acephate was less toxic to *L. pseudoannulata*. Acephate reduced the growth and predation of the spiders to some extent (Thang *et al.*, 1987). Significantly low mortality of *L. pseudoannulata* and *O. javanus* was observed on treatment with acephate (Kumar and Velusamy, 1996).

Ku and Wang (1981) found that acephate was toxic to the non-target organisms. Fabellar and Heinrichs (1984) reported that acephate was less toxic to *C. lividipennis* and *M. atrolineata*. Acephate was found safe to *P. fuscipes* and *M. atrolineata* (Kumar and Velusamy, 2000). Acephate at 1200 ppm was found safe to the *M. atrolineata* (Krishnaiah *et al*., 2001), *Tylthus parviceps* Reut. (Lakshmi *et al*., 2001a) and *C. lividipennis* (Lakshmi *et al*., 2001b). According to Sun *et al*. (2002) three formulations of acephate (25 EC, 50 WP and 75 SP) had low toxicity to aquatic organisms and they were safe for use in rice fields. Among these formulations, acephate 75 SP had a low potential risk to aquatic organisms.

2.2.2.2 Imidacloprid

Population of *Agriocnemis* spp. was adversely affected by imidacloprid (Lekha, 2003).

Imidacloprid caused no deleterious effect on spiders (Mao and Liang, 1995; Satheesan *et al*., 2002). Imidacloprid of 100 ml ha^{-1} and 400 ml ha^{-1} was found toxic to predatory spiders (Manjunatha and Shivanna, 2001). The number of *N. virescens* adults consumed by *Pardosa pseudoannulata* (Bosenberg and Strand) which was exposed to imidacloprid treated rice seedlings for the last 24 h before experiment was significantly lower than that on untreated ones (Widiarta *et al*., 2001). Population of spiders was adversely affected by imidacloprid at different growth stages of the crop (Lekha, 2003).

Imidacloprid at 0.20 kg a.i. ha^{-1} was safe to natural enemies and quite promising (Panda and Mishra, 1998). Imidacloprid was found to be safe to natural enemies of rice plant hoppers (Katole and Patel, 2000). Imidacloprid at 50 ppm was toxic to *T. parviceps* (Lakshmi *et al*. 2001a) and *C. lividipennis* (Lakshmi *et al*., 2001b). Imidacloprid at 100 ml ha^{-1} and 400 ml ha^{-1} was found to be toxic to mirid bugs (Manjunatha and Shivanna, 2001). Survival of *C. lividipennis* and proportion of *N. ciniticeps* eggs preyed by bug exposed to imidacloprid treated seedling were significantly lower than those of untreated ones (Widiarta *et al*., 2001). Imidacloprid was safe to natural enemy population of *Cyrtorhinus* sp. (Satheesan *et al*., 2002). Imidacloprid did not hamper the predatory efficiency of mirid bugs under practical field situations (Krishnaiah *et al*., 2003). Population of predatory beetles was not adversely affected by synthetic insecticides like imidacloprid while the population of predatory bugs and *Conocephalus* sp. were adversely affected at different growth stages of the crop (Lekha, 2003).

2.2.2.3 Chlorpyrifos 50 EC + Cypermethrin 5 EC

According to Kodandaram and Dhingra (2003) Nurelle D (cypermethrin + chlorpyrifos of relative toxicity value 3.11) was found to be more toxic to *Coccinella septempunctata* (Linn.) whereas Anaconda (cypermethrin + chlorpyrifos of relative toxicity value 0.75) was found to be safe.

2.2.2.4 Azadirachtin

Significant increase in the population of *M. crocea* was recorded in treatment with Nimbecidine while it did not produce any adverse effect on the population of *O. nigrofasciata* (Ajayakumar, 2000). Though there was an initial reduction in number of *L. pseudoannulata* in neem treated plots, recolonisation was better (Mohan *et al*., 1991). Neem products did not affect the population of *O. javanus* (TNAU, 1992). According to Ajayakumar (2000), Nimbecidine did not show any toxic action or antifeedant effect on *L. pseudoannulata.* Dash *et al*. (2001b) found that plots receiving neem sprays harboured more population of natural enemies *viz*., spiders (*L. pseudoannulata*, *T. maxillosa*), *Argiope catenulata* (Doleschall) than insecticide treated plots.

Mohan *et al*. (1991) observed that though there was an initial reduction in number of *C. lividipennis* in neem treated plots, recolonisation was better. Lakshmi *et al*. (1998) reported that Neemgold at 0.50 per cent and Neemax at 20 per cent were safe to predators. Dash *et al*. (2001b) found more number of *C. lividipennis* in plots receiving neem sprays.

2.2.2.5 Bacillus thuringiensis var. kurstaki

According to Mendoza (1972), a spray of Thuricide 90 TS (Bt) was least injurious to Coccinelids. Rao and Singh (2003) reported that biopesticide Biobit (Bt subsp kurstaki) showed moderate effect on population of coccinellids.

Biopesticide, Biobit (Bt subsp kurstaki) showed moderate effect on population of *O. nigrofasciata* (Rao and Singh, 2003).

A spray of Thuricide 90 TS was least injurious to spiders in rice ecosystem (Mendoza, 1972). Biopesticide Biobit showed moderate toxicity on population of spiders (Rao and Singh, 2003).

Mendoza (1972) reported that a spray of Thuricide 90 TS (Bt) was least injurious to several predators such as Reduvids and Chrysopids in rice ecosystem. Latha *et al*. (1994) found that Bt subsp. kurstaki (2.5 l ha^{-1}) was safe to predators. Rao and Singh (2003) reported that biopesticide Biobit (Bt subsp. kurstaki) showed moderate effect on population of *P. fuscipes*.

2.2.2.6 Carbofuran

Population of *Agriocnemis* sp. was considerably reduced by carbofuran (Khusakul *et al.,* 1979).

Carbofuran reduced predation by *Brumoides suturalis* (Fabricius) (Garg and Sethi, 1984). Furadan granules did not appreciably reduce the population of *H octomaculata* and *M. discolor* (Rajendram, 1994).

Chiu and Cheng (1976) reported that carbofuran was the most toxic compound to *L. pseudoannulata*. Spider population (*Tetragnatha* spp., *Oxyopes* spp., *L. pseudoannulata*) was severely reduced by carbofuran (Khusakul *et al*., 1979). Kim *et al*. (1984) found that population density of spiders preying on planthoppers was more even with the use of two applications of carbofuran, compared with the usual insecticide treatment. Panda *et al*. (2002) reported carbofuran to be safe to spiders. According to Vardhani and Rao (2002) carbofuran 1.0 and 0.5 kg a.i. ha^{-1} were injurious to predatory spiders.

Carbofuran reduced the population of *C. lividipennis* considerably (Khusakul, *et al.* 1979). Furadan granules did not appreciably reduce the population of *C. lividipennis* (Rajendram, 1994). Carbofuran was found to be toxic to *M. atrolineata* and *C. lividipennis* (Kumar and Velusamy, 2000).

2.2.3 Parasitoids

2.2.3.1 Acephate

Singh *et al*. (1994) found that acephate 0.5 kg a.i. ha^{-1} was toxic to *Telenomus dignoides* Nixon, an egg parasitoid of *S. incertulas*. Highest number of *S. incertulas* parasite emergence and parasitised galls were noticed in Asataf 75 WP treated plots (KAU, 1995).

2.2.3.2 Imidacloprid

Kumar and Santharam (1999) observed no significant adverse effect of imidacloprid on adult emergence and percentage parasitism of *T. chelonis*. According to Lekha (2003) *G. triangulifer,* a specific parasite of rice leaf roller was unaffected by imidacloprid whereas in the case of *X. flavolineata* and *Cotesia* sp. there was an initial suppression in the population when treated with this insecticide but later recolonization occurred.

2.2.3.3 Chlorpyrifos 50 EC + Cypermethrin 5 EC

According to Logiswaram *et al*. (1987) percentage parasitism by *Platygaster* sp. was lowest in plots treated with chlorpyrifos 40 EC and highest in plots treated with chlorpyrifos 10 G.

2.2.3.4 Azadirachtin

Schmutterer *et al*. (1983) observed that growth and development of endoparasitic hymenopterans on the larvae of *C. medinalis* exposed to rice leaves treated with neem were unaffected. Dash *et al.* (1994) found that attack by the parasitoid *Platygaster oryzae* (Cameron) was not adversely affected by neem derivatives alone or in combination with monocrotophos or chlorpyrifos. According to Markandeya and Divakar (1999) eggs of *T. chelonis* treated with Margosam 1500 ppm offered 45 per cent parasitism. *G. triangulifer* was unaffected by azadirachtin and in the case of *X. flavolineata* and *Cotesia* sp. there was an initial suppression in the population when treated with azadirachtin + half dose of synthetic insecticides (quinalphos and imidacloprid) but later recolonization occurred (Lekha, 2003). Survival of the parasitoid *Trichogramma minutum* Riley after one day was significantly reduced by Azatin EC and Neem EC at 500 g azadirachtin per ha (Lyons *et al*., 2003).

2.2.3.5 Bacillus thuringiensis var. kurstaki

A spray of Bt formulation was least injurious to several dipteran and hymenopteran parasites (Mendoza, 1972). *Bacillus thuringiensis* subsp. kurstaki at 2.5 l ha^{-1} was safe to parasitoids (Latha *et al*., 1994).

2.2.3.6 Carbofuran

Carbofuran did not affect the population of *Telenomus* spp., *Apanteles* spp., *Tetrastichus* spp., *Elasmus* sp. and *Tropobracon* sp.

(Khusakul *et al*., 1979). Population density of egg parasitoid, A*nagrus* spp. was very high even with two applications of carbofuran (Kim *et al*., 1984). Percentage parastistun of *Platygaster* sp. was low in plots treated with carbofuran (Logiswaram *et al*., 1987). Carbofuran was less toxic to *T. dignoides* an egg parasitoid of *S. incertulas* (Singh *et al*., 1994; Singh and Sharma, 1998). Furadan 3G treated plots showed highest number of parasitised galls of *S. incertulas* (KAU, 1995).

2.2.4 Neutrals

2.2.4.1 Acephate

Klass and Olson (1985) observed reduced survival of the second instar larvae of *Psorophora columbiae* (Dyar and Knab) when treated with acephate. According to Fei *et al*. (1999), *Culex fatigans* (Wiedemann) (*Culex quinquefasciatus* Say) developed resistance to acephate due to frequent use of the insecticide.

2.2.4.2 Imidacloprid

According to Song and Brown (1998) *Aedes taeniorhynchus* (Wiedemann) was more susceptible and *Artemia* sp. was more tolerant to imidacloprid. The mortality did not increase over time except at the highest concentration of these insecticides.

2.2.4.3 Chlorpyrifos 50 EC + Cypemethrin 5 EC

Padmavathi and Pandian (1999) studied the toxicity of chlorpyrifos 50 EC + cypermethrin 5 EC (Nurelle D-505) to fourth instar larvae and pupae of *C. quinquefasciatus* and found that LC 50 for larvae and pupae were 0.000070 and 0.032 ppm respectively.

2.2.4.4 Azadirachtin

A significant antifeedancy was indicated at 5 ppm and 10 ppm azadirachtin for all formulations (Azad, Azatin and Neemix) against *Culex tarsalis* (Coquillett) and *C.quinquefasciatus* in rice field (Yun and

Mulla, 1998a). The degree of ovicidal activity of neem products was influenced by concentration of azadirachtin, age of egg rafts, age of the neem preparations, formulation and mosquito species involved. The formulated neem products were more persistent and effective than the technical azadirachtin and the wettable powder formulation was slightly more persistent and effective than the emulsifiable concentrate (Yun and Mulla, 1998b).

2.2.4.5 Bacillus thuringiensis var. kurstaki

According to Ree *et al*. (1983) residual effects of *Bacillus thuringiensis* subsp. *israelensis* formulation at 0.8 – 1.2 l ha^{-1} lasted for only 24 h and the recovery of mosquito population densities after treatment depended both on reproduction of the strain of *Culex tritaeniorhynchus* Giles present and on habitat conditions such as the presence of predacious dyticid larvae in the rice field. Rate of larval resurgence of *Anopheles subpictus* Grassi, *Anopheles nigerrimus* Giles and *C. tritaeniorhynchus* in rice fields treated with *Bacillus sphaericus* and *Bacillus thuringiensis* formulations showed that these bacteria did not persist in rice fields (Kramer, 1984). About 92 to 100 per cent reduction in larvae of *Anopheles crucians* (Wiedemann) *and Anopheles quadrimaculatus* Say in rice fields was observed 48 h after aerial application of granular formulations of *Bacillus thurigiensis* var. *israelensis* (Lacey and Inmann, 1985).

2.2.4.6 Carbofuran

Klass and Olson (1985) observed reduced survival of second instar larvae of *P. columbiae* when treated with carbofuran.

Materials and Methods

3. MATERIALS AND METHODS

Assessment of the population status of pests, natural enemies and neutrals in the rice ecosystem was carried out and evaluation of the efficacy of insecticides on these organisms in the ecosystem was conducted at Cropping Systems Research Centre (CSRC), Karamana during the second crop season from October 2003 to January 2004. The materials used and methods adopted are given under.

3.1 ASSESSMENT OF THE POPULATION STATUS OF ARTHROPOD COMMUNITY IN RICE ECOSYSTEM OF CSRC, KARAMANA

A field trial was conducted to assess the population status of pests, natural enemies and neutrals in the rice ecosystem of CSRC, Karamana. An area of 30 cents was maintained for taking observations. Rice variety *Aiswarya* (PTB 52), a medium duration high yielding variety released from Regional Agricultural Research Station (RARS), Pattambi, was used for the study. Seedlings were transplanted at the rate of three seedlings per hill at 30 days after sowing. Application of fertilizers and other crop husbandry practices such as planting, weeding and irrigation were done as envisaged in the Package of Practices Recommendations of the Kerala Agricultural University (KAU, 2002) excluding the plant protection measures.

Assessment of the population of pests, natural enemies and neutrals from the field were recorded at 15 days interval during the entire crop season by the method followed by Reissig *et al*. (1986). As such five observations were recorded. The arthropods present on upper parts and inside the leaf canopy of plants were collected by sweepnets, diagonal to the plots. The symptoms of pest attack with live stages of the pests and the natural enemies present at the base of the plants were counted and recorded.

This was done by examining the leaf and stem of the plants from randomly selected ten hills, by moving from one corner to the opposite corner of the plot. Sweepnet collection was made by moving the net to and fro with full stretched hand as one sweep. From each plot ten sweeps were taken.

The specimens collected were transferred to a polythene bag. Long cotton strip with one end moistened with chloroform was taken and the moistened end was introduced into the polythene bag. The other end was placed at the open end of the polythene bag and tied using a rubber band. After ten minutes, the cotton strip was removed from the polythene bag and again tied with rubber band. These samples were brought to the laboratory for taking count.

3.1.1 Observations

Pests, natural enemies and neutrals present in each bag were separated and counted. The number of pests, natural enemies and neutrals recorded from randomly selected ten hills in each plot was added to the sweepnet count of the same plot. This was treated as the population count of each plot during the period of observation.

3.1.2 Weather Parameters in Rice Ecosystem of Karamana

Weather parameters such as maximum and minimum temperature, morning and evening relative humidity and rainfall during the entire crop season were recorded from the Department of Meteorology, College of Agriculture, Vellayani. The average of the preceding 15 days data was worked out and used for the study (Appendix-I).

3.2 FIELD EVALUATION OF THE EFFECT OF DIFFERENT INSECTICIDES ON ARTHROPOD COMMUNITY IN RICE ECOSYSTEM

A field experiment was conducted to evaluate the effect of different insecticides *viz.,* acephate, imidacloprid, chlorpyrifos 50 EC +

cypermethrin 5 EC, azadirachtin, *Bacillus thuringiensis* var.kurstaki and carbofuran on arthropod community in rice ecosystem. Monocrotophos and carbaryl were treated as check insecticides.

3.2.1 Preparation of the Field

The crop was raised as given in 3.1. The details of the experiment were as follows:

Design	:	RBD
Plot size	:	200 m^2
Spacing	:	20 cm x 10 cm
Replications	:	3
Treatments	:	9

T_1 – Acephate 0.05 per cent

T_2 – Imidacloprid 0.005 per cent

T_3 – Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent

T_4 – Azadirachtin 0.004 per cent

T_5 – *Bacillus thuringiensis* var kurstaki 0.2 per cent

T_6 – Carbofuran 0.75 kg a.i.ha^{-1}

T_7 – Monocrotophos 0.05 per cent

T_8 – Carbaryl 0.2 per cent

T_9 – Control

3.2.2 Preparation of Spray Solution

3.2.2.1 Acephate

A commercial pesticide, Asataf 75 SP of Rallis A Tata Enterprise was used for the experiment. Acephate 0.05 per cent was obtained by dissolving 48 g of the insecticide in 18 litres of water.

3.2.2.2 Imidacloprid

A commercial pesticide, Confidor 200 SL of MS Bayer (India) Limited was used for the experiment. Imidacloprid 0.005 per cent was prepared by mixing nine ml of the insecticide in 18 litres of water.

3.2.2.3 Chlorpyrifos 50 EC + Cypermethrin 5 EC

A commercial pesticide, Action 505 of Tropical Agrosystem (India) Ltd. was used for the study. Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent was prepared by mixing 16.36 ml of the insecticide in 18 litres of water.

3.2.2.4 Azadirachtin

Botanical pesticide, NeemAzal containing azadirachtin one per cent supplied by M/S E10 Parry (I) Ltd. was used for the experiment. Azadirachtin 0.004 per cent was obtained by mixing 72 ml of NeemAzal in 18 litres of water.

3.2.2.5 Bacillus thuringensis* var. *kurstaki

Biopesticide, Delfin WG of Margo Biocontrols Pvt. Ltd was used for the study. *Bacillus thuringiensis* var. kurstaki 0.2 per cent was prepared by dissolving 45 g the insecticide in 18 litres of water.

3.2.2.6 Carbofuran

A commercial insecticide, Furadan 3 G of Rallis India Ltd. was used for the experiment. Carbofuran 0.75 kg a.i. ha^{-1}, 1.5 kg was applied.

3.2.2.7 Monocrotophos

A commercial insecticide, Nuvacron of Sri Saranam Kegisons and Brothers was used. Monocrotophos 0.05 per cent was prepared by mixing 22.5 ml of the insecticide in 18 litres of water.

3.2.2.8 Carbaryl

A commercial insecticide, Sevin of Agrochemical India Ltd. was used for the experiment. Carbaryl 0.2 per cent was prepared by dissolving 72 g in 18 litres of water.

3.2.3 Application of Insecticides

Insecticides were applied at two growth stages in the respective plots, first spray at 30 days after transplanting (DAT) and second spray at 50 DAT except carbofuran which was applied only at 30 DAT.

3.2.4 Assessment of Population of Arthropods

Pretreatment and post treatment counts of pests, natural enemies and neutrals were recorded as described under 3.1. Post treatment counts were taken at one day interval from one to twenty days after both application of insecticides.

3.3 YIELD

Harvest was done on ripening of the crop from each plot. The grain from the plots was dried, winnowed, weighed and expressed in kg ha^{-1}. The straw was dried under sun and the weight was expressed in kg ha^{-1}.

3.4 ASSESSMENT OF RESULTS

Data on the population of arthropods were subjected to analysis of variance (Panse and Sukhatme, 1978). F test was done by analysis of variance.

Results

4. RESULTS

The arthropod community present in the unsprayed rice fields throughout the cropping season, along with the weather parameters recorded and the results obtained from the field experiment to find out the impact of insecticides on the population of pests, natural enemies and neutrals are presented in this chapter.

4.1 POPULATION STATUS OF ARTHROPOD COMMUNITY IN RICE ECOSYSTEM DURING THE EXPERIMENTAL PERIOD

The major pests recorded in the unsprayed field were rice leaf roller *Cnaphalocrocis medinalis* (Guenee) and rice bug *Leptocorisa acuta* (Thunberg). High population of small rice grasshopper *Oxya chinensis* (Thunberg), green leaf hoppers *Nephotettix* spp. and whorl maggot *Hydrellia philippina* Ferino were also recorded. Various other pests *viz*., red spotted earhead bug *Menida histrio* Fabricius, rice black bug *Scotinophara* sp., rice hispa *Dicladispa armigera* (Olivier), stripped bug *Tetroda histeroides* Fab., rice leptispa *Leptispa pygmoea* Baly, white backed rice plant hopper *Sogatella furcifera* (Horvath), rice white leaf hopper *Cofana spectra* (Distant), flea beetle *Monolepta signata* Oliv., brown plant hopper *Nilaparvata lugens* (Stal) and rice stem borer *Scirpophaga incertulas* (Walker) were present in very few numbers. Major predators observed were damselfly *Agriocnemis* spp., ground beetle *Ophionea nigrofasciata* (Schmidt and Goebel), coccinellids [*Micraspis crocea* (Mulsant), *Menochilus sexmaculatus* (Fab.) and *Harmonia octomaculata* (Fab.)] and spiders *viz*., *Tetragnatha maxillosa* Thorell, *Lycosa pseudoannulata* (Boesenberg and Strand) and *Oxyopes javanus* Thorell. Parasitoids *viz*., *Cotesia flavipes* Cameron, *Charops brachypterum* (Cameron), *Xanthopimpla flavolineata* Cameron, *Tetrastichus schoenobii* Ferriere and *Telenomus rowani* (Gahan). were present in the observational fields. Neutrals present in the field came under the families Chironomidae, Culicidae, Tanyderidae, Otitidae and Sciomyzidae (Plate 1).

Chironomidae

Culicidae

Tanyderidae

Otitidae

Sciomyzidae

Plate 1. Neutrals observed in the rice ecosystem

The mean total population of pests, natural enemies and neutrals over five growth stages of the crop and weather parameters recorded during the period are presented in Fig.1. The lowest mean total population of pests (8.33) was recorded at 15 DAT, the population then increased to 75.33 at 30 DAT. The highest total population of 109.67 was observed at 45 DAT. The total mean population showed a gradual reduction from 45 DAT onwards, the values being 104.33 at 60 DAT and 56.33 at 75 DAT.

The same trend was observed in the population fluctuation of predators except in the population peak. The lowest mean total population of predators (14.67) was recorded at 15 DAT. The highest population of 47.67 was observed during 30 DAT and then the mean total population reduced to 35.67, 20.33 and 16.34 at 45, 60 and 75 DAT respectively.

Mean total population of parasitoids was the lowest as in the case of pests and predators, and reached the maximum at 60 DAT. The population observed (2.33) at 15 DAT increased to 8.00 at 30 DAT, 16.33 at 45 DAT and 19.00 at 60 DAT and then decreased to 9.67 at 75 DAT.

A different trend was observed in the mean population of neutrals. The maximum population of 35.67 was recorded at 15 DAT and thereafter there was a gradual reduction from 30 DAT to 75 DAT, the values being 30.67, 18.00, 9.67 and 2.33 respectively.

The mean maximum temperature ranged between 30.28°C and 31.23°C and the mean minimum temperature between 21.28°C and 23.50°C during the growth period of the crop. Relative humidity during morning hours ranged between 93.33 and 94.00 per cent and that during evening hours was between 59.10 and 74.53 per cent.

The rainfall was observed only during the vegetative phase of the crop. The highest mean rainfall of 18.26 mm was recorded at 15 DAT and then gradually reduced to 9.67 at 30 DAT and 1.45 mm at 45 DAT. Thereafter no rainfall occurred during the remaining crop period.

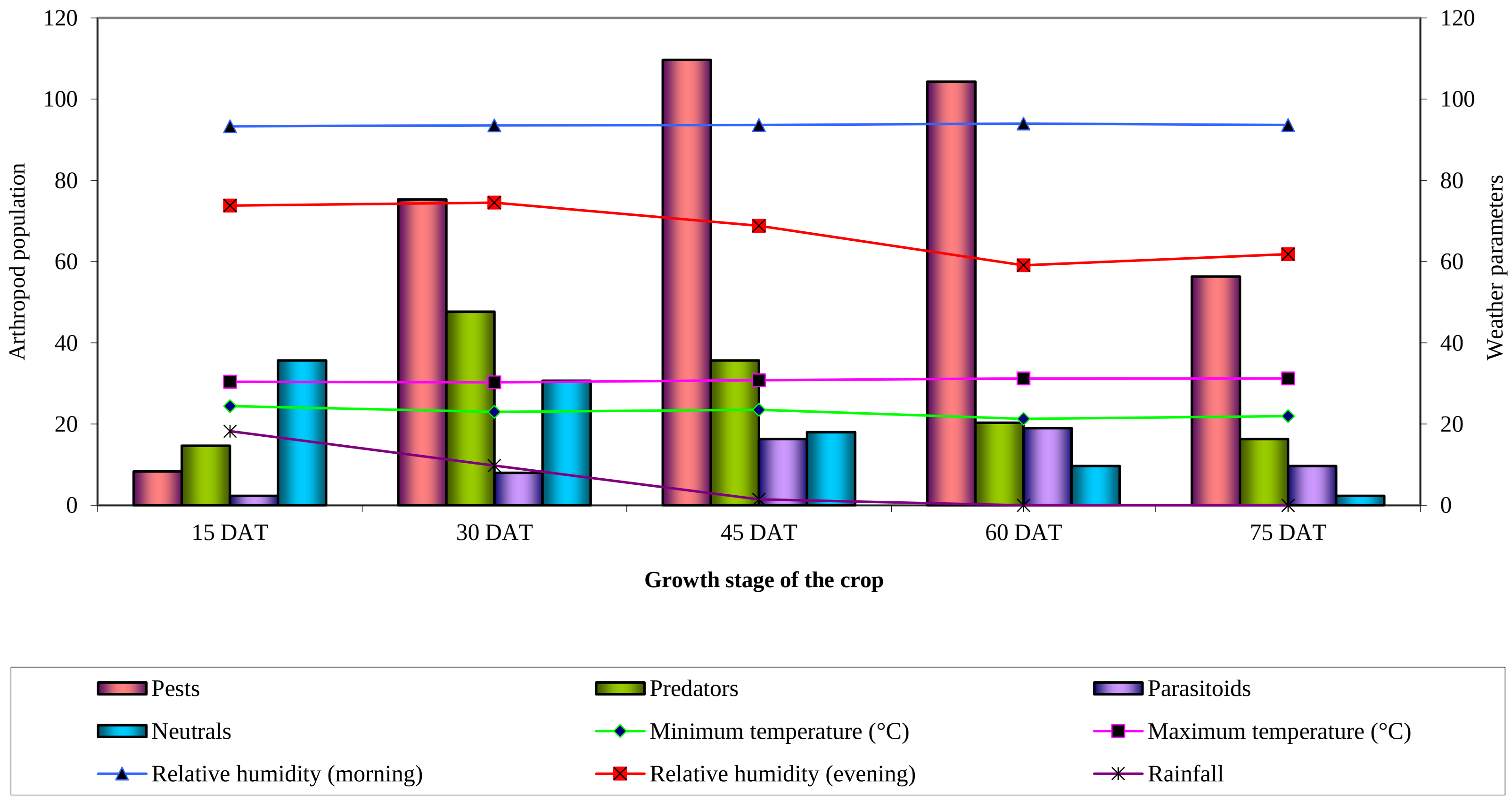


Fig. 1. Arthropod community in untreated rice fields at different growth stages of the crop in relation to the prevailing weather parameters

4.2 EFFECT OF DIFFERENT INSECTICIDES ON ARTHROPOD COMMUNITY IN RICE ECOSYSTEM

4.2.1 Effect of Insecticides on Population of Pests

Results presented include the data recorded from one to 10 days after two applications of insecticides at 30 DAT and 50 DAT except carbofuran which was applied only once at 30 DAT.

4.2.1.1 Population Variation Recorded on C. medinalis

The population of *C. medinalis* recorded upto 10 days after application of insecticides at 30 DAT is presented in Table 1.

One day after application, significantly lower population was noticed in plots receiving chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (9.94), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (11.64), acephate 0.05 per cent (12.25), azadirachtin 0.004 per cent (12.66), imidacloprid 0.005 per cent (14.60), monocrotophos 0.05 per cent (10.99) and carbaryl 0.2 per cent (9.23) as compared with control (20.33). Imidacloprid was statistically similar to carbofuran. Among the effective treatments, chlorpyrifos 50 EC + cypermethrin 5 EC, *Bacillus thuringiensis* var. kurstaki and acephate were found to be equally effective as the check treatments. Azadirachtin and imidacloprid were on par with acephate and *Bacillus thuringiensis* var. kurstaki.

The trend observed on the reduction of *C. medinalis* population on the first day was followed on the second day also. Significantly lower population of *C. medinalis* was observed in treatments with imidacloprid 0.005 per cent (11.61), azadirachtin 0.004 per cent (11.64), chlorpyrifos 50 EC + cypermethrin 5 EC (11.91), acephate 0.05 per cent (13.90) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (15.23) as compared to control (20.66). Monocrotophos 0.05 per cent (9.30) and carbaryl 0.02 per cent (10.24) significantly reduced the population of *C. medinalis.* Carbofuran 0.75 kg a.i. ha^{-1} (20.99) alone was found to be on par with control. Imidacloprid, azadirachtin and chlorpyrifos 50 EC + cypermethrin

5 EC were found to be on par with monocrotophos and carbaryl. Acephate and *Bacillus thuringiensis* var. kurstaki gave statistically similar effect as that of chlorpyrifos 50 EC + cypermethrin 5 EC, azadirachtin and imidacloprid.

All the treatments except carbofuran 0.75 kg a.i. ha^{-1} (18.29) recorded significant reduction in the mean population of *C. medinalis* when compared to control (21.99) at three days after application. The population recorded was 14.31, 13.97, 13.96, 15.64, 17.28, 11.61, 11.25 when sprayed with acephate 0.05 percent, imidacloprid 0.005 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent, monocrotophos 0.05 per cent and carbaryl 0.2 per cent respectively. Chlorpyrifos 50 EC + cypermethrin 5 EC, imidacloprid, acephate and monocrotophos were equally effective as carbaryl. *Bacillus thuringiensis* var. kurstaki and azadirachtin were on par with carbofuran, acephate and imidacloprid.

On the fourth day, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (15.56), azadirachtin 0.004 per cent (16.94), acephate 0.05 per cent (17.28), carbaryl 0.2 per cent (13.92) and monocrotophos 0.05 per cent (14.92) were significantly superior in suppressing *C. medinalis* when compared to control (22.99). *Bacillus thuringiensis* var. kurstaki 0.2 per cent (18.92), carbofuran 0.75 kg a.i. ha^{-1} (19.31) and imidacloprid 0.005 per cent (19.65) did not cause any significant reduction with control.

No significant reduction in *C. medinalis* population was observed in any of the treatments *viz*., acephate 0.05 per cent, imidacloprid 0.005 per cent, chlorpyrifos 50 EC + cypermethrin 5EC 0.05 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent and carbofuran 0.75 kg a.i. ha^{-1} when compared to control (20.99) except the check insecticides, carbaryl 0.2 per cent (14.91) and monocrotophos 0.05 per cent (16.31) at five days after application, the population ranged from 17.60 to 21.33. All the treatments except carbaryl (15.60) were found to be on par with control (21.32) on the sixth day after spraying and the population ranged from 18.29 to 21.32.

Table 1. Effect of insecticides on the population of *C. medinalis* at 30 days after transplanting

Treatments	Mean number of pests observed at different intervals (days) after application									
	1	2	3	4	5	6	7	8	9	10
Acephate 0.05%	12.25 (3.64)	13.90 (3.86)	14.31 (3.91)	17.28 (4.28)	17.60 (4.31)	20.32 (4.62)	19.95 (4.58)	21.97 (4.79)	19.94 (4.58)	21.63 (4.76)
Imidacloprid 0.005%	14.60 (3.95)	11.61 (3.55)	13.97 (3.87)	19.65 (4.54)	21.32 (4.72)	20.99 (4.69)	19.30 (4.51)	19.99 (4.58)	21.99 (4.80)	20.99 (4.69)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	9.94 (3.31)	11.91 (3.59)	13.96 (3.87)	15.56 (4.07)	17.99 (4.36)	18.29 (4.39)	19.65 (4.54)	20.65 (4.65)	20.27 (4.61)	20.62 (4.65)
Azadirachtin 0.004%	12.66 (3.70)	11.64 (3.56)	15.64 (4.08)	16.94 (4.24)	17.94 (4.35)	19.65 (4.54)	20.66 (4.65)	21.65 (4.76)	21.66 (4.76)	22.33 (4.83)
Bacillus thuringiensis var. kurstaki 0.2%	11.64 (3.55)	15.23 (4.03)	17.28 (4.28)	18.92 (4.46)	20.28 (4.61)	20.99 (4.69)	20.32 (4.62)	21.32 (4.72)	20.66 (4.65)	22.29 (4.83)
Carbofuran 0.75 kg a. i./ha	17.31 (4.28)	20.99 (4.69)	18.29 (4.39)	19.31 (4.51)	21.33 (4.73)	20.66 (4.65)	19.66 (4.55)	17.65 (4.32)	17.96 (4.36)	16.63 (4.20)
Monocrotophos 0.05%	10.99 (3.46)	9.30 (3.21)	11.61 (3.55)	14.92 (4.00)	16.31 (4.16)	19.30 (4.51)	19.97 (4.58)	20.32 (4.62)	21.32 (4.72)	21.99 (4.80)
Carbaryl 0.2%	9.23 (3.20)	10.24 (3.35)	11.25 (3.50)	13.92 (3.86)	14.91 (3.99)	15.60 (4.08)	16.61 (4.20)	18.99 (4.47)	19.66 (4.55)	20.66 (4.65)
Control	20.33 (4.62)	20.66 (4.65)	21.99 (4.80)	22.99 (4.90)	20.99 (4.69)	21.32 (4.73)	18.66 (4.43)	19.66 (4.55)	20.33 (4.62)	21.32 (4.72)
CD (0.05)	0.461	0.526	0.416	0.522	0.424	0.331	-	-	-	-

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

None of the treatments showed significant reduction in population of *C. medinalis* when compared to control from seventh to tenth day after application.

The population of *C medinalis* observed daily upto ten days after spraying insecticides at 50 DAT (carbofuran applied only at 30 DAT) is depicted in Table 2.

One day after spraying, acephate 0.05 per cent (10.30), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (11.99), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (20.99), azadirachtin 0.004 per cent (21.32), imidacloprid 0.005 per cent (21.66), carbaryl 0.2 per cent (11.99) and monocrotophos 0.05 per cent (18.65) reduced the *C. medinalis* population significantly when compared to control (31.31). Among these treatments, acephate was found to be on par with chlorpyrifos 50 EC + cypermethrin 5 EC and carbaryl. *Bacillus thuringiensis* var. kurstaki gave statistically similar effect as that of azadirachtin, imidacloprid and monocrotophos.

Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (11.33), acephate 0.05 per cent (12.28), azadirachtin 0.004 per cent (14.33), *Bacillus thuringiensis* var. kurstaki 0.2 percent (16.61), imidacloprid 0.005 per cent (18.66), monocrotophos 0.05 per cent (9.65) and carbaryl 0.2 per cent (9.94) were significantly superior to control (30.32) in reducing the population of *C. medinalis* on the second day after spraying. Chlorpyrifos 50 EC + cypermethrin 5 EC was statistically similar to the check treatments. Azadirachtin was found to be on par with acephate and *Bacillus thuringiensis* var. kurstaki.Carbofuran 0.75 kg a.i. ha^{-1} at 22 days after application (30.66) did not record any significant reduction in *C. medinalis* population.

On the third day, all treatments except carbofuran 0.75 kg a.i. ha^{-1} at 23 days after application (34.55), reduced the population significantly, compared to control (37.67). The population of *C. medinalis* recorded in treatments with chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, acephate 0.05 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent, imidacloprid 0.005 per cent, carbaryl 0.2 per cent and monocrotophos 0.05 per cent was 10.33, 13.96, 18.66, 18.99, 21.65, 11.64 and 11.64 respectively. *Bacillus thuringiensis* var. kurstaki was found to be on par with azadirachtin and imidacloprid. Chlorpyrifos 50 EC + cypermethrin 5 EC gave statistically similar effect as that of the insecticides used as check.

Significantly lower population of *C. medinalis* was observed in chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, acephate 0.05 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent, imidacloprid 0.005 per cent, monocrotophos 0.05 per cent and carbaryl 0.2 per cent treated plots, the population being 14.93, 14.99, 19.99, 22.62, 25.99, 15.93 and 17.31 respectively. Chlorpyrifos 50 EC + cypermethrin 5 EC gave statistically same effect as that of acephate and the check treatments while *Bacillus thuringiensis* var. kurstaki was on par with azadirachtin and imidacloprid on the fourth day observations.

All the treatments except carbofuran 0.75 kg a.i. ha^{-1} at 25 days after application (34.00) reduced the population significantly when compared to control (37.66) on the fifth day also.The population recorded with chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, acephate 0.05 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent, imidacloprid 0.005 per cent, carbaryl 0.2 per cent and monocrotophos 0.05 per cent was 16.27, 17.63, 25.32, 26.33, 30.30, 17.94 and 19.32 respectively. Acephate showed statistically similar effect as that of chlorpyrifos 50 EC + cypermethrin 5 EC and monocrotophos while azadirachtin was on par with *Bacillus thuringiensis* var. kurstaki.

Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (18.62), acephate 0.05 per cent (21.97), carbaryl 0.2 per cent (20.58) and monocrotophos 0.05 per cent (25.32) significantly reduced the *C. medinalis* population when compared to control (32.32) at six days after treatment. Chlorpyrifos 50 EC + cypermethrin 5 EC showed statistically same effect as that of carbaryl while imidacloprid 0.005 per cent (28.66) and azadirachtin 0.004 per cent (28.66) were found to be on par with monocrotophos. Acephate alone was on par with both the checks. Imidacloprid, azadirachtin, carbofuran 0.75 kg a.i. ha^{-1} (at 26 days after application) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent did not record any significant reduction in the *C. medinalis* population and it ranged from 28.66 to 32.94.

On the seventh day after spraying, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (22.32), acephate 0.05 per cent (24.99) and carbaryl 0.2 per cent (24.60) recorded significant reduction in *C. medinalis* population when compared to control (29.99). Imidacloprid 0.005 per cent, azadirachtin 0.004 per cent, monocrotophos 0.05 per cent and carbofuran 0.75 kg a.i. ha^{-1} (at 27 days after application) did not produce any significant reduction in the pest count and the population ranged from 29.66 to 30.66. Significantly higher population was noticed in treatment with *Bacillus thuringiensis* var. kurstaki 0.2 per cent (34.97) against control.

Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (24.96) alone significantly reduced the population of *C. medinalis* at eight days after spraying. Acephate 0.05 per cent, azadirachtin 0.004 per cent, monocrotophos 0.05 per cent, carbaryl 0.2 per cent and carbofuran 0.75 kg a.i. ha^{-1}(at 28 days after application) were on par with control (28.66), the population ranged from 28.65 to 31.31. Significantly higher population was observed in treatments with imidacloprid 0.005 per cent (31.64) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (32.31) than control.

No significant reduction in the population of *C. medinalis* was noticed with any of the treatments on the ninth and tenth day after treatment.

4.2.1.2 Population Variation Recorded on O. chinensis.

The population of *O. chinensis* noticed at one-day interval upto 10 days after application of insecticides at 30 DAT is depicted in Table 3.

One day after application, acephate 0.05 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, azadirachtin 0.004 per cent, imidacloprid 0.005 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent, carbaryl 0.2 per cent and monocrotophos 0.05 per cent reduced the population of *O. chinensis* significantly when compared to control (14.96), the population being 5.90, 6.98, 8.25, 8.29,

Table 2. Effect of insecticides on the population of *C. medinalis* at 50 days after transplanting

Treatments	Mean number of pests observed at different intervals (days) after application									
	1	2	3	4	5	6	7	8	9	10
Acephate 0.05%	10.30 (3.36)	12.28 (3.64)	13.96 (3.87)	14.99 (4.00)	17.63 (4.32)	21.97 (4.79)	24.99 (5.10)	28.65 (5.45)	30.98 (5.66)	32.28 (5.77)
Imidacloprid 0.005%	21.66 (4.76)	18.66 (4.43)	21.65 (4.76)	25.99 (5.20)	30.30 (5.59)	28.66 (5.45)	29.98 (5.57)	31.64 (5.71)	33.30 (5.86)	31.95 (5.74)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	11.99 (3.60)	11.33 (3.51)	10.33 (3.37)	14.93 (3.99)	16.27 (4.16)	18.62 (4.43)	22.32 (4.83)	24.96 (5.10)	29.28 (5.50)	30.98 (5.66)
Azadirachtin 0.004%	21.32 (4.72)	14.33 (3.92)	18.66 (4.43)	19.99 (4.58)	25.32 (5.13)	28.66 (5.45)	29.99 (5.57)	31.31 (5.68)	29.66 (5.54)	31.33 (5.69)
Bacillus thuringiensis var. kurstaki 0.2%	20.99 (4.69)	16.61 (4.20)	18.99 (4.47)	22.62 (4.86)	26.33 (5.23)	32.94 (5.83)	34.97 (6.00)	32.31 (5.77)	32.26 (5.77)	33.32 (5.86)
Carbofuran 0.75 kg a. i./ha*	29.32 (5.51)	30.66 (5.63)	34.55 (5.96)	32.66 (5.80)	34.00 (5.92)	32.33 (5.77)	30.66 (5.63)	29.66 (5.54)	30.32 (5.60)	31.65 (5.71)
Monocrotophos 0.05%	18.65 (4.43)	9.65 (3.26)	11.64 (3.56)	15.93 (4.11)	19.32 (4.51)	25.32 (5.13)	29.66 (5.54)	29.33 (5.51)	30.96 (5.65)	32.66 (5.80)
Carbaryl 0.2%	11.99 (3.60)	9.94 (3.31)	11.64 (3.56)	17.31 (4.28)	17.94 (4.35)	20.58 (4.65)	24.60 (5.06)	29.65 (5.54)	31.98 (5.74)	31.32 (5.69)
Control	31.31 (5.68)	30.32 (5.60)	37.67 (6.22)	32.96 (5.83)	37.66 (6.22)	32.32 (5.77)	29.99 (5.57)	28.66 (5.45)	30.99 (5.66)	31.64 (5.71)
CD (0.05)	0.262	0.349	0.279	0.383	0.328	0.341	0.290	0.243	-	-

Figures in parenthesis are $\sqrt{x + 1}$ transformed values
* Carbofuran applied at 30 days after transplanting

9.66, 3.25 and 10.63 respectively. Among these treatments, highest significant reduction in *O. chinensis* population was noticed in carbaryl 0.2 per cent treated plots. Acephate, chlorpyrifos 50 EC + cypermethrin 5 EC, azadirachtin and imidacloprid were found to be equally effective. *Bacillus thuringiensis* var. kurstaki recorded statistically similar effect as that of chlorpyrifos 50 EC + cypermethrin 5 EC, azadirachtin, imidacloprid, carbofuran 0.75 kg a.i. ha^{-1} (12.66) and monocrotophos.

Treatments *viz*., chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (5.61), acephate 0.05 per cent (6.98), imidacloprid 0.005 per cent (9.89), azadirachtin 0.004 per cent (10.61), carbaryl 0.2 per cent (3.65) and monocrotophos 0.05 per cent (5.61) were found to be significantly superior to control (14.32) on the second day after application. Among these treatments, chlorpyrifos 50 EC + cypermethrin 5 EC recorded statistically similar effect as that of acephate and the insecticides used as check.

Three days after application, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (7.62), acephate 0.05 per cent (8.29), carbaryl 0.2 per cent (4.26) and monocrotophos 0.05 per cent (7.62) were significantly superior in reducing the population of *O. chinensis* when compared to control (13.62). Chlorpyrifos 50 EC + cypermethrin 5 EC, acephate and monocrotophos were found to be on par with azadirachtin 0.004 per cent (10.27) and imidacloprid 0.005 per cent (10.59).

On the superiority of the treatments in reducing the population of *O. chinensis*, the trend shown on the third day was repeated on the fourth day also. Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (8.33), acephate 0.05 per cent (9.30), carbaryl 0.2 per cent (6.92) and monocrotophos 0.05 per cent (10.33) effected significant suppression of *O. chinensis* population when compared to control (13.64). Chlorpyrifos 50 EC + cypermethrin 5 EC and acephate gave the same effect as carbaryl. Azadirachtin 0.004 per cent (12.25), carbofuran 0.75 kg a.i. ha^{-1} (13.59), imidacloprid 0.005 per cent (14.27) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (15.31) did not produce any significant reduction in the *O. chinensis* population.

On the fifth day after application, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (10.30) and carbaryl 0.2 per cent (7.62) caused significant reduction of the pest population when compared to control (15.64). Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent was on par with acephate 0.05 per cent, imidacloprid 0.005 per cent and carbofuran 0.75 kg a.i. ha^{-1}, the population being 12.59, 12.92 and 12.95 respectively.

Only carbaryl 0.2 per cent (8.98) was significantly superior to control (16.31) during the sixth day after spraying. All other treatments were found to be on par with control and the population ranged from 13.92 to 16.31.

From the seventh day onwards, none of the treatments recorded significant reduction in the population of *O. chinensis* when compared to control.

The population of *O. chinensis* recorded at one day interval upto 10 days after spraying insecticides at 50 DAT (carbofuran applied only at 30 DAT) is presented in Table 4.

One day after spraying, acephate 0.05 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent, monocrotophos 0.05 per cent and carbaryl 0.2 per cent reduced *O. chinensis* population significantly when compared to control (17.31), the population being 5.27, 5.81, 9.63, 9.94, 9.98, 10.99 and 3.86 respectively. Among these treatments, carbaryl, acephate, and chlorpyrifos 50 EC + cypermethrin 5 EC were found to be on par and the same effect was reflected with imidacloprid, azadirachtin, *Bacillus thuringiensis* var. kurstaki and monocrotophos.

The above trend was observed on the second day also. Among the effective treatments, highest significant reduction was observed in carbaryl 0.2 per cent (3.97) treated plots. Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (5.90) and acephate 0.05 per cent (6.28) were statistically similar to monocrotophos 0.05 per cent (6.66). Azadirachtin 0.004 per cent (9.31) was on par with *Bacillus thuringiensis* var. kurstaki 0.2 per cent (11.64). Carbofuran 0.75 kg a.i. ha^{-1} (15.64) was statistically similar to control (15.31) at 22 days after application.

Table 3. Effect of insecticides on the population of *O. chinensis* at 30 days after transplanting

Treatments	Mean number of pests observed at different intervals (days) after application									
	1	2	3	4	5	6	7	8	9	10
Acephate 0.05%	5.90 (2.63)	6.98 (2.83)	8.29 (3.05)	9.30 (3.21)	12.59 (3.69)	13.92 (3.86)	12.30 (3.65)	13.96 (3.87)	14.96 (4.00)	15.99 (4.12)
Imidacloprid 0.005%	8.29 (3.05)	9.89 (3.30)	10.59 (3.40)	14.27 (3.91)	12.92 (3.73)	14.64 (3. 95)	14.64 (3.95)	14.96 (4.00)	14.31 (3.91)	14.96 (4.00)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	6.98 (2.83)	5.61 (2.57)	7.62 (2.94)	8.33 (3.05)	10.30 (3.36)	14.31 (3.91)	13.97 (3.87)	15.31 (4.04)	14.31 (3.91)	15.99 (4.12)
Azadirachtin 0.004%	8.25 (3.03)	10.61 (3.41)	10.27 (3.36)	12.25 (3.64)	14.62 (3.95)	15.60 (4.08)	14.64 (3.96)	15.31 (4.04)	16.64 (4.20)	16.32 (4.16)
Bacillus thuringiensis var. kurstaki 0.2%	9.66 (3.27)	11.30 (3.51)	14.31 (3.91)	15.31 (4.04)	15.99 (4.12)	16.31 (4.16)	15.62 (4.08)	16.29 (4.16)	15.65 (4.08)	16.31 (4.16)
Carbofuran 0.75 kg a. i./ha	12.66 (3.70)	14.99 (4.00)	15.27 (4.03)	13.59 (3.82)	12.95 (3.74)	13.96 (3.87)	11.64 (3.56)	13.64 (3.83)	13.26 (3.78)	12.99 (3.74)
Monocrotophos 0.05%	10.63 (3.41)	5.61 (2.57)	7.62 (2.94)	10.33 (3.37)	14.28 (3.91)	15.56 (4.07)	14.62 (3.96)	15.31 (4.04)	15.27 (4.03)	16.31 (4.16)
Carbaryl 0.2%	3.25 (2.06)	3.65 (2.16)	4.26 (2.29)	6.92 (2.81)	7.62 (2.94)	8.98 (3.16)	12.64 (3.69)	14.64 (3.96)	15.62 (4.08)	16.31 (4.16)
Control	14.96 (4.00)	14.32 (3.91)	13.62 (3.82)	13.64 (3.83)	15.64 (4.08)	16.31 (4.16)	16.64 (4.20)	16.29 (4.16)	16.63 (4.20)	16.99 (4.24)
CD (0.05)	0.463	0.445	0.506	0.441	0.477	0.301	-	-	-	-

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

Acephate 0.05 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent, carbaryl 0.2 per cent and monocrotophos 0.05 per cent significantly suppressed the *O. chinensis* count, the population being 6.66, 7.66, 10.30, 11.64, 13.96, 4.97 and 5.98 respectively at three days after spraying. Acephate, chlorpyrifos 50 EC + cypermethrin 5 EC and carbaryl were on par with monocrotophos whereas imidacloprid and azadirachtin produced same effect.

Four days after spraying, acephate 0.05 per cent (7.24), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (8.25), carbaryl 0.2 per cent (5.61) and monocrotophos 0.05 per cent (7.62) significantly suppressed the *O. chinensis* population when compared to control (14.96). All other treatments recorded statistically similar effect as that of control, the population ranged from 11.95 to 14.97.

Trend observed on the fourth day was repeated on the fifth day also. Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, acephate 0.05 per cent, monocrotophos 0.05 per cent and carbaryl 0.2 per cent reduced the pest count significantly, the population being 8.66, 8.98, 11.30 and 6.92 respectively. Among these effective treatments, carbaryl produced the highest significant reduction. Imidacloprid 0.005 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent and carbofuran 0.75 kg a.i. ha^{-1}(at 24 days after application) were statistically similar to that of control (14.32) and the population ranged from 13.31 to 15.64.

Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (9.98) and carbaryl 0.2 per cent (6.61) alone produced significant suppression of the population when compared to control (12.91) on the sixth day after spraying. Significantly higher population was noticed on *Bacillus thuringiensis* var. kurstaki 0.2 per cent (16.31) treated plots when compared with control.

Significantly lower population of *O. chinensis* was noticed on carbaryl 0.2 per cent treated plots, the population being 9.33, whereas significantly higher population was recorded on *Bacillus thuringiensis* var. kurstaki 0.2 per cent

Table 4. Effect of insecticides on the population of *O. chinensis* at 50 days after transplanting

Treatments	Mean number of pests observed at different intervals (days) after application									
	1	2	3	4	5	6	7	8	9	10
Acephate 0.05%	5.27 (2.51)	6.28 (2.70)	6.66 (2.77)	7.24 (2.87)	8.98 (3.16)	11.30 (3.51)	12.95 (3.74)	15.33 (4.04)	15.99 (4.12)	15.96 (4.12)
Imidacloprid 0.005%	9.63 (3.26)	7.98 (3.00)	10.30 (3.36)	11.95 (3.60)	13.31 (3.78)	14.32 (3.91)	14.62 (3.95)	15.31 (4.04)	15.97 (4.12)	16.31 (4.16)
Chlorpyrifos 50 EC+Cypermethrin 5 EC 0.05%	5.81 (2.61)	5.90 (2.63)	7.66 (2.94)	8.25 (3.04)	8.66 (3.11)	9.98 (3.31)	10.94 (3.46)	13.96 (3.87)	15.99 (4.12)	16.29 (4.16)
Azadirachtin 0.004%	9.94 (3.31)	9.31 (3.21)	11.64 (3.56)	12.95 (3.74)	14.33 (3.92)	15.31 (4.04)	16.31 (4.16)	15.66 (4.08)	17.31 (4.28)	16.99 (4.24)
Bacillus thuringiensis var. kurstaki 0.2%	9.98 (3.31)	11.64 (3.56)	13.96 (3.87)	13.99 (3.87)	15.64 (4.08)	16.31 (4.16)	17.66 (4.32)	16.61 (4.20)	17.65 (4.32)	16.99 (4.24)
Carbofuran 0.75 kg a. i./ha*	16.64 (4.20)	15.64 (4.08)	16.99 (4.24)	14.97 (4.00)	14.99 (4.00)	13.96 (3.87)	14.64 (3.96)	15.32 (4.04)	15.29 (4.04)	16.64 (4.20)
Monocrotophos 0.05%	10.99 (3.46)	6.66 (2.77)	5.98 (2.64)	7.62 (2.94)	11.30 (3.51)	14.96 (4.00)	13.96 (3.87)	15.29 (4.04)	14.66 (3.96)	15.64 (4.08)
Carbaryl 0.2%	3.86 (2.21)	3.97 (2.23)	4.97 (2.44)	5.61 (2.57)	6.92 (2.81)	6.61 (2.76)	9.33 (3.21)	11.64 (3.56)	14.62 (3.95)	14.96 (4.00)
Control	17.31 (4.28)	15.31 (4.04)	17.94 (4.35)	14.96 (4.00)	14.32 (3.91)	12.91 (3.73)	13.92 (3.86)	14.97 (4.00)	15.66 (4.08)	16.64 (4.20)
CD (0.05)	0.448	0.357	0.312	0.428	0.285	0.375	0.407	-	-	-

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

* Carbofuran applied at 30 days after transplanting

(17.66) treated plots on the seventh day after spraying when compared to control (13.92). All other treatments did not show any significant reduction with control and the population ranged from 10.94 to 16.31.

4.2.1.3 Population Variation Recorded on Nephotettix spp.

The population of *Nephotettix* spp. observed daily up to 10 days after application of insecticides at 30 DAT is depicted in Table 5.

On the first day after application, imidacloprid 0.005 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, azadirachtin 0.004 per cent, acephate 0.05 per cent, carbaryl 0.2 per cent and monocrotophos 0.05 per cent significantly reduced *Nephotettix* spp. population compared to control (9.98), the population being 3.25, 4.97, 6.61, 3.97 and 5.98 respectively. Among these effective treatments imidacloprid was on par with carbaryl whereas chlorpyrifos 50 EC + cypermethrin 5 EC, azadirachtin and acephate were found to be on par with monocrotophos. *Bacillus thuringiensis* var. kurstaki 0.2 per cent (8.63) and carbofuran 0.75 kg a.i. ha^{-1} (10.63) did not record any significant reduction in population of *Nephotettix* spp.

Significantly lower population was recorded in imidacloprid 0.005 per cent (0.00), azadirachtin 0.004 per cent (5.61), acephate 0.05 per cent (5.90), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (7.24), monocrotophos 0.05 per cent (3.25) and carbaryl 0.2 per cent (3.32) treated plots when compared to control (10.65) at two days after application. Among these effective treatments, cent per cent reduction was recorded with imidacloprid. Azadirachtin was found to be on par with acephate, chlorpyrifos 50 EC + cypermethrin 5 EC and carbaryl. *Bacillus thuringiensis* var. kurstaki 0.2 per cent (7.59) and carbofuran 0.75 kg a.i. ha^{-1} (9.98) were statistically similar to control.

Three days after application, imidacloprid 0.005 per cent (0.55), monocrotophos 0.05 per cent (0.00) and carbaryl 0.2 per cent (3.97) significantly reduced the population of *Nephotettix* spp. Imidacloprid was statistically similar in effect to monocrotophos. All other treatments were statistically similar to control (8.98), the population ranging from 7.62 to 9.30.

Almost similar trend was observed on the fourth day also. Imidacloprid 0.005 per cent (0.63) recorded significant reduction in the population of *Nephotettix* spp. population and was found to be on par with monocrotophos 0.05 per cent (1.64). All other treatments except carbaryl 0.2 per cent (4.89) did not produce any significant effect in the count of *Nephotettix* spp. and the population ranged from 8.29 to 9.94.

Five days after spraying, imidacloprid 0.005 per cent (2.22) and monocrotophos 0.05 per cent (2.05) produced significant suppression in the population of *Nephotettix* spp. and were on par. All other treatments were statistically similar to control (10.27) and the population ranged from 7.31 to 11.30.

The result shown on the fifth day was repeated on the sixth day also. The population reduction in the treatments ranged from 4.59 to 10.99 with a population of 9.98 in control.

Population of *Nephotettix* spp. recorded at 11 to 20 days after application of carbofuran 0.75 kg a.i. ha^{-1} is presented in Table 13.

No significant effect of carbofuran was noted on *Nephotettix* spp. from 11 to 14 days after application when compared to control. From 15 days onwards, carbofuran significantly reduced the population of the pest, the count being 5.97, 5.53, 5.32, 5.17, 4.97 and 3.32 from 15 to 20 days after treatment. The population of *Nephotettix* spp. recorded in control plots on these days ranged from 9.93 to 12.64.

The population of *Nephotettix* spp. recorded daily after the insecticide application upto 10 days at 50 DAT (carbofuran applied only at 30 DAT) is depicted in Table 6.

On the first day after second application, significant suppression in the pest population was noticed in treatments with chlorpyrifos 50 EC + cypermethrin 5

Table 5. Effect of insecticides on the population of *Nephotettix* spp.* at 30 days after transplanting

Treatments	Mean number of pests observed at different intervals (days) after application									
	1	2	3	4	5	6	7	8	9	10
Acephate 0.05%	6.61 (2.76)	5.90 (2.63)	7.62 (2.94)	8.29 (3.05)	7.59 (2.93)	9.66 (3.27)	10.63 (3.41)	9.63 (3.26)	10.30 (3.36)	9.63 (3.26)
Imidacloprid 0.005%	3.25 (2.06)	0.00 (1.00)	0.55 (1.24)	0.63 (1.28)	2.22 (1.79)	4.63 (2.37)	6.28 (2.70)	8.63 (3.10)	9.66 (3.27)	9.30 (3.21)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	4.97 (2.44)	7.24 (2.87)	8.98 (3.16)	9.94 (3.31)	9.63 (3.26)	8.63 (3.10)	9.94 (3.31)	10.30 (3.36)	9.66 (3.27)	10.94 (3.46)
Azadirachtin 0.004%	6.61 (2.76)	5.61 (2.57)	7.92 (2.99)	9.63 (3.26)	10.27 (3.35)	10.99 (3.46)	8.98 (3.16)	10.30 (3.36)	9.94 (3.31)	9.66 (3.27)
Bacillus thuringiensis var. kurstaki 0.2%	8.63 (3.10)	7.59 (2.93)	9.30 (3.21)	9.94 (3.31)	11.30 (3.50)	10.99 (3.46)	8.63 (3.10)	9.63 (3.26)	10.66 (3.42)	9.98 (3.31)
Carbofuran 0.75 kg a. i./ha	10.63 (3.41)	9.98 (3.31)	9.30 (3.21)	8.63 (3.10)	8.98 (3.16)	9.94 (3.31)	8.95 (3.16)	8.29 (3.05)	7.59 (2.93)	6.66 (2.77)
Monocrotophos 0.05%	5.98 (2.64)	3.25 (2.06)	0.00 (1.00)	1.64 (1.63)	2.05 (1.75)	4.59 (2.37)	8.63 (3.10)	9.60 (3.26)	9.94 (3.31)	9.30 (3.21)
Carbaryl 0.2%	3.97 (2.23)	3.32 (2.08)	3.97 (2.23)	4.89 (2.43)	7.31 (2.88)	9.63 (3.26)	10.30 (3.36)	10.99 (3.46)	10.63 (3.41)	9.98 (3.31)
Control	9.98 (3.31)	10.65 (3.41)	8.98 (3.16)	9.30 (3.21)	10.27 (3.36)	9.98 (3.31)	9.94 (3.31)	9.30 (3.21)	9.63 (3.26)	9.33 (3.21)
CD (0.05)	0.455	0.488	0.451	0.491	0.618	0.381	-	-	-	-

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

**N. virescens*, *N. nigropictus*

EC 0.05 per cent, azadirachtin 0.004 per cent, imidacloprid 0.005 per cent, acephate 0.05 per cent, carbaryl 0.2 per cent, monocrotophos 0.05 per cent and carbofuran 0.75 kg a.i. ha^{-1} (21 days after application) the population being 3.97, 5.27, 5.30, 5.98, 4.77, 6.28 and 3.97 respectively. *Bacillus thuringiensis* var. kurstaki 0.2 per cent (7.29) did not show any significant effect on the suppression of the population of *Nephotettix* spp when compared to control (9.94).

Imidacloprid 0.005 per cent (0.55), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 percent (3.25), acephate 0.05 per cent (5.61), azadirachtin 0.004 percent (6.58), carbaryl 0.2 per cent (3.97) and monocrotophos 0.05 per cent (4.63) at second day after spraying and carbofuran 0.75 kg a.i. ha^{-1} at 22 days after application (4.55), significantly reduced *Nephotettix* spp. population when compared to control (10.99). Imidacloprid was found to be the most effective among the treatments. Chlorpyrifos 50 EC + cypermethrin 5 EC, carbofuran and acephate were found to be statistically similar to the insecticides taken as check. Azadirachtin was on par with carbofuran, acephate and monocrotophos.

Third day after the second spraying, imidacloprid 0.005 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, acephate 0.05 per cent, azadirachtin 0.004 per cent, monocrotophos 0.05 per cent, carbaryl 0.2 per cent and carbofuran 0.75 kg a.i. ha^{-1} (23 days after application) gave effective suppression of *Nephotettix* spp., when compared with control (11.91), the population being 0.00, 4.97, 6.58, 8.29, 0.00, 3.91 and 4.26 respectively. Imidacloprid was found to be on par with monocrotophos. Carbofuran and chlorpyrifos 50 EC + cypermethrin 5 EC were statistically similar to carbaryl. Azadirachtin was on par with acephate and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (9.63).

Treatments *viz*., imidacloprid 0.005 per cent (0.00), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (5.90), monocrotophos 0.05 per cent (1.78) and carbaryl 0.2 per cent (5.56) at four days after spraying and carbofuran 0.75 kg a.i. ha^{-1} at 24 days after application (4.97) significantly reduced *Nephotettix* spp. population when compared to control (10.63). Acephate 0.05 per cent (7.92), azadirachtin 0.004 per cent (9.33) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (10.94) did not record any significant suppression in the population.

At five days after second spraying, imidacloprid 0.005 per cent (1.21), monocrotophos 0.05 per cent (1.94) and carbofuran 0.75 kg a.i. ha^{-1}at 25 days after application (5.90) produced significant suppression of the *Nephotettix* spp. All other treatments were statistically similar to control (9.63) in producing toxic effect and the population ranged from 6.64 to 11.99. Imidacloprid was found to be on par with monocrotophos. Carbofuran was on par with chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (7.59) and carbaryl 0.2 per cent (6.64).

Similar trend was observed during sixth day after treatment with imidacloprid 0.005 per cent, monocrotophos 0.05 per cent and carbofuran 0.75 kg a.i. ha^{-1} (at 26 days after application) producing significant suppression in the population of *Nephotettix* spp. as compared to control (10.30), the population of the effective treatments being 2.32, 3.25 and 6.61 respectively. The population of *Nephotettix* spp. ranged from 7.98 to 10.30 for all other ineffective treatments.

On the seventh day after spraying, imidacloprid 0.005 per cent (3.97), monocrotophos 0.05 per cent (5.27) and carbofuran 0.75 kg a.i. ha^{-1} at 27 days after application (6.92) effectively reduced *Nephotettix* spp. population and their effect was statistically same. All other treatments were on par with control (10.31). Eight days after spraying, imidacloprid (7.88), monocrotophos (7.21) and carbofuran at 28 days after application (7.92) significantly reduced the pest population and were found to be on par. On the ninth and tenth day after spraying none of the treatments significantly reduced *Nephotettix* spp. population.

4.2.1.4 Population Variation Recorded on H. philippina

The population of *H. Philippina* recorded each day upto 10 days after spraying insecticides at 30 DAT is presented in Table 7.

On the first day after application, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (5.61), acephate 0.05 per cent (7.24), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (11.30), azadirachtin 0.004 per cent (11.30), imidacloprid

Table 6. Effect of insecticides on the population of *Nephotettix* spp.* at 50 days after transplanting

Treatments	Mean number of pests observed at different intervals (days) after application									
	1	2	3	4	5	6	7	8	9	10
Acephate 0.05%	5.98 (2.64)	5.61 (2.57)	6.58 (2.75)	7.92 (2.99)	8.98 (3.16)	11.30 (3.51)	11.95 (3.60)	12.33 (3.65)	13.99 (3.87)	12.99 (3.74)
Imidacloprid 0.005%	5.30 (2.51)	0.55 (1.24)	0.00 (1.00)	0.00 (1.00)	1.21 (1.49)	2.32 (1.82)	3.97 (2.23)	7.88 (2.98)	8.85 (3.14)	11.31 (3.51)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	3.97 (2.23)	3.25 (2.06)	4.97 (2.44)	5.90 (2.63)	7.59 (2.93)	7.98 (3.00)	9.94 (3.31)	11.95 (3.60)	11.99 (3.60)	12.95 (3.74)
Azadirachtin 0.004%	5.27 (2.51)	6.58 (2.75)	8.29 (3.05)	9.33 (3.21)	10.30 (3.36)	11.95 (3.60)	12.30 (3.65)	13.96 (3.87)	12.66 (3.70)	12.64 (3.69)
Bacillus thuringiensis var. kurstaki 0.2%	7.92 (2.99)	7.54 (2.92)	9.63 (3.26)	10.94 (3.46)	11.99 (3.60)	12.91 (3.73)	12.65 (3.70)	13.31 (3.79)	13.26 (3.78)	12.99 (3.74)
Carbofuran 0.75 kg a. i./ha**	3.97 (2.23)	4.55 (2.36)	4.26 (2.29)	4.97 (2.44)	5.90 (2.63)	6.61 (2.76)	6.92 (2.81)	7.92 (2.99)	9.89 (3.30)	10.90 (3.45)
Monocrotophos 0.05%	6.28 (2.70)	4.63 (2.37)	0.00 (1.00)	1.78 (1.67)	1.94 (1.72)	3.25 (2.06)	5.27 (2.51)	7.21 (2.87)	9.66 (3.27)	11.95 (3.60)
Carbaryl 0.2%	4.77 (2.40)	3.97 (2.23)	3.91 (2.22)	5.56 (2.56)	6.64 (2.76)	8.29 (3.05)	9.94 (3.31)	12.28 (3.64)	12.92 (3.73)	13.31 (3.78)
Control	9.94 (3.31)	10.99 (3.46)	11.91 (3.59)	10.63 (3.41)	9.63 (3.26)	10.30 (3.36)	10.31 (3.36)	12.30 (3.65)	9.56 (3.25)	11.96 (3.60)
CD (0.05)	0.595	0.563	0.382	0.586	0.513	0.481	0.472	0.498	-	-

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

**N. virescens*, *N. nigrapictus*

** Carbofuran applied at 30 days after transplanting

0.005 per cent (11.30), carbaryl 0.2 per cent (1.17) and monocrotophos 0.05 per cent (9.26) significantly reduced the population of *H. philippina* when compared to control (15.31). Acephate, *Bacillus thuringiensis* var. kurstaki, azadirachtin and imidacloprid were on found to be on par with monocrotophos.

Acephate 0.05 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent, azadirachtin 0.004 per cent, imidacloprid 0.005 per cent, carbaryl 0.2 per cent and monocrotophos 0.05 per cent showed significant reduction in pest count, the population being 5.61, 7.98, 8.98, 10.63, 2.96 and 6.23 respectively. Statistically similar effect was shown by acephate, chlorpyrifos 50 EC + cypermethrin 5 EC, *Bacillus thuringiensis* var. kurstaki and monocrotophos. *Bacillus thuringiensis* var. kurstaki was on par with azadirachtin and imidacloprid.

Same trend was also observed on the third day after application. Acephate 0.05 per cent (5.50), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (6.28) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (7.62) were statistically similar to carbaryl 0.2 per cent (5.27) in producing toxic effect to *H. philippina*. *Bacillus thuringiensis* var. kurstaki, azadirachtin 0.004 per cent (8.29), imidacloprid 0.005 per cent (8.63) and monocrotophos 0.05 per cent (10.30) were found to be on par.

Fourth day after application, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (7.29), acephate 0.05 per cent (8.29), carbaryl 0.2 per cent (7.62) and monocrotophos 0.05 per cent (10.63) produced significant suppression of *H. philippina* and were found to be on par with control (14.31). Azadirachtin 0.004 per cent (11.30), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (11.50), imidacloprid 0.005 per cent (12.28) and carbofuran 0.75 kg a.i. ha (17.99) did not show any significant suppression of the pest.

Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (9.26) produced highest significant reduction of the pest during fifth day after application. Acephate 0.05 per cent (12.28) and carbaryl 0.2 per cent (11.30) produced significant suppression of the *H. philippina* when compared to control (18.65) and

Table 7. Effect of insecticides on the population of *H. philippina* at 30 days after transplanting

Treatments	Mean number of pests observed at different intervals (days) after application									
	1	2	3	4	5	6	7	8	9	10
Acephate 0.05%	7.24 (2.87)	5.61 (2.57)	5.50 (2.55)	8.29 (3.05)	12.28 (3.64)	14.28 (3.91)	16.64 (4.20)	15.60 (4.08)	17.31 (4.28)	17.97 (4.36)
Imidacloprid 0.005%	11.30 (3.51)	10.63 (3.41)	8.63 (3.10)	12.28 (3.64)	15.64 (4.08)	14.31 (3.91)	17.65 (4.32)	17.96 (4.36)	16.97 (4.24)	18.31 (4.40)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	5.61 (2.57)	6.23 (2.69)	6.28 (2.70)	7.29 (2.88)	9.26 (3.20)	10.27 (3.36)	13.28 (3.78)	13.96 (3.87)	15.31 (4.04)	16.64 (4.20)
Azadirachtin 0.004%	11.30 (3.51)	8.98 (3.16)	8.29 (3.05)	11.30 (3.51)	15.56 (4.07)	14.64 (3.96)	15.29 (4.04)	15.96 (4.12)	17.31 (4.28)	15.99 (4.12)
Bacillus thuringiensis var. kurstaki 0.2%	11.30 (3.51)	7.98 (3.00)	7.62 (2.94)	11.50 (3.54)	15.56 (4.07)	14.62 (3.95)	17.65 (4.32)	17.28 (4.28)	16.31 (4.16)	17.31 (4.27)
Carbofuran 0.75 kg a. i./ha	13.96 (3.87)	17.65 (4.32)	15.29 (4.04)	17.99 (4.36)	15.99 (4.12)	14.96 (4.00)	14.66 (3.96)	14.23 (3.90)	13.31 (3.78)	12.99 (3.74)
Monocrotophos 0.05%	9.26 (3.20)	5.98 (2.64)	10.30 (3.36)	10.63 (3.41)	13.31 (3.78)	15.31 (4.04)	16.64 (4.20)	17.31 (4.28)	19.31 (4.51)	17.31 (4.28)
Carbaryl 0.2%	1.17 (1.47)	2.96 (1.99)	5.27 (2.51)	7.62 (2.94)	11.30 (3.51)	14.27 (3.91)	14.64 (3.96)	16.29 (4.16)	16.31 (4.16)	17.66 (4.32)
Control	15.31 (4.04)	14.64 (3.96)	18.33 (4.40)	14.31 (3.91)	18.65 (4.43)	13.96 (3.87)	17.99 (4.36)	17.31 (4.28)	15.96 (4.12)	17.28 (4.28)
CD (0.05)	0.516	0.435	0.509	0.479	0.377	-	-	-	-	-

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

were found to be on par. None of the treatments recorded significant reduction in the pest count from sixth to tenth day after application.

The population of *H. philippina* recorded daily upto 10 days after spraying insecticides at 50 DAT (carbofuran applied only at 30 DAT) is depicted in Table 8.

Significantly lower population of *H. philippina* when compared with control (14.64) was recorded with chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, acephate 0.05 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent, imidacloprid 0.005 per cent, carbaryl 0.2 per cent and monocrotophos 0.05 per cent, the population being 4.18, 6.61, 8.63, 9.30, 10.63, 1.21 and 10.63 respectively. Chlorpyrifos 50 EC + cypermethrin 5 EC and acephate were found to be on par. Azadirachtin and *Bacillus thuringiensis* var. kurstaki were on par with acephate, imidacloprid and monocrotophos.

Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (3.91), acephate 0.05 per cent (4.59), azadirachtin 0.004 per cent (4.92), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (5.61), imidacloprid 0.005 per cent (9.63), carbaryl 0.2 per cent (1.21) and monocrotophos 0.05 per cent (3.97) significantly reduced the population of *H. philippina* as compared to control (15.29) on the second day after spraying. Carbaryl was the most effective treatment. Chlorpyrifos 50 EC + cypermethrin 5 EC, acephate, azadirachtin, *Bacillus thuringiensis* var. kurstaki and monocrotophos were found to be similar in producing the toxic effect.

Same trend was observed on the third day after spraying also, with carbaryl 0.2 per cent being the most effective treatment. The population of *H. philippina* recorded was 5.27, 5.61, 5.90, 6.61, 8.98, 4.55 and 4.59 for chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, acephate 0.05 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent, imidacloprid 0.005 per cent, carbaryl 0.2 per cent and monocrotophos 0.05 per cent respectively.

On the fourth day after spraying, chlorpyrifos 50 EC + cypermethrin 5 EC (6.61), acephate 0.05 per cent (7.62), azadirachtin 0.004 per cent (9.26), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (9.75), imidacloprid 0.005 per cent (10.63), monocrotophos 0.05 per cent (11.30) and carbaryl 0.2 per cent (7.62) significantly reduced the *H. philippina* population as compared to control (15.99). Chlorpyrifos 50 EC + cypermethrin 5 EC was on par with acephate, azadirachtin, *Bacillus thuringiensis* var. kurstaki and carbaryl. Azadirachtin, *Bacillus thuringiensis* var. kurstaki and imidacloprid were similar in effect to monocrotophos 0.05 per cent.

All treatments significantly reduced the population of *H. philippina* at five days after spraying except carbofuran 0.75 kg a.i. ha^{-1} at 25 days after application (17.31) when compared to control (18.33). Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (8.98) was on par with acephate 0.05 per cent (9.63) and carbaryl 0.2 per cent (9.98). Imidacloprid 0.005 per cent (11.95), azadirachtin 0.004 per cent (11.99) and monocrotophos 0.05 per cent (12.30) were also on par with carbaryl.

On the sixth day after spraying, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (11.96), acephate 0.05 per cent (12.30) and carbaryl 0.2 per cent (11.30) recorded significant reduction in *H. philippina* population when compared to control (16.99) and were statistically similar in producing the toxic effect. The population of *H. philippina* for all other treatments ranged from 14.62 to 17.33. Carbofuran 0.75 kg a.i. ha^{-1} applied at 30 DAT did not record any significant reduction in the population of *H. philippina* in any of these days.

None of the treatments effected significant reduction in the population of *H. philippina* from seventh to tenth days after spraying.

4.2.1.5 Population Variation Recorded on L. acuta

The population of *L. acuta* recorded each day upto 10 days after spraying insecticides at 50 DAT (carbofuran applied only at 30 DAT) is depicted in Table 9 as the pest was observed in the experiment plots only at 50 DAT.

Table 8. Effect of insecticides on the population of *H. philippina* at 50 days after transplanting

Treatments	Mean number of pests observed at different intervals (days) after application									
	1	2	3	4	5	6	7	8	9	10
Acephate 0.05%	6.61 (2.76)	4.59 (2.37)	5.61 (2.57)	7.62 (2.94)	9.63 (3.26)	12.30 (3.65)	14.31 (3.91)	15.97 (4.12)	16.31 (4.16)	16.99 (4.24)
Imidacloprid 0.005%	10.63 (3.41)	9.63 (3.26)	8.98 (3.16)	10.63 (3.41)	11.95 (3.60)	15.23 (4.03)	14.65 (3.96)	16.31 (4.16)	16.96 (4.24)	17.32 (4.28)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	4.18 (2.28)	3.91 (2.22)	5.27 (2.50)	6.61 (2.76)	8.98 (3.16)	11.96 (3.60)	12.99 (3.74)	14.64 (3.95)	16.29 (4.16)	17.31 (4.28)
Azadirachtin 0.004%	8.63 (3.10)	4.92 (2.43)	5.90 (2.63)	9.26 (3.20)	11.99 (3.60)	14.64 (3.95)	15.64 (4.08)	15.99 (4.12)	17.33 (4.28)	18.31 (4.39)
Bacillus thuringiensis var. kurstaki 0.2%	9.30 (3.21)	5.61 (2.57)	6.61 (2.76)	9.75 (3.28)	13.92 (3.86)	14.62 (3.95)	18.31 (4.39)	15.99 (4.12)	17.32 (4.28)	16.96 (4.24)
Carbofuran 0.75 kg a. i./ha*	14.96 (3.99)	15.23 (4.03)	18.31 (4.39)	16.66 (4.20)	17.31 (4.28)	17.33 (4.28)	17.65 (4.32)	16.64 (4.20)	16.99 (4.24)	15.96 (4.12)
Monocrotophos 0.05%	10.63 (3.41)	3.97 (2.23)	4.59 (2.37)	11.30 (3.51)	12.30 (3.65)	14.64 (3.95)	15.28 (4.03)	17.65 (4.32)	14.99 (4.00)	16.31 (4.16)
Carbaryl 0.2%	1.21 (1.49)	1.21 (1.49)	4.55 (2.35)	7.62 (2.94)	9.98 (3.31)	11.30 (3.51)	15.64 (4.08)	17.29 (4.28)	15.64 (4.08)	17.99 (4.36)
Control	14.64 (3.95)	15.29 (4.04)	19.31 (4.51)	15.99 (4.12)	18.33 (4.40)	16.99 (4.24)	18.31 (4.39)	16.93 (4.23)	17.99 (4.36)	16.97 (4.24)
CD (0.05)	0.535	0.496	0.486	0.552	0.379	0.411	-	-	-	-

Figures in parenthesis are $\sqrt{x + 1}$ transformed values
* Carbofuran applied at 30 days after transplanting

On the first day after application, all the treatments produced significant reduction of *L. acuta* population when compared to control (21.65). Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (8.63), azadirachtin 0.004 per cent (9.30), acephate 0.05 per cent (9.60), carbaryl 0.2 per cent (6.92) and monocrotophos 0.05 per cent (8.25) were found to be statistically similar in effect. Azadirachtin, acephate, imidacloprid 0.005 per cent (10.27), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (11.64) and carbofuran 0.75 kg a.i. ha^{-1} at 21 days after application (12.62) were found to be on par.

Similar trend was observed on the second day after spraying with imidacloprid 0.005 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, acephate 0.05 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent, monocrotophos 0.05 per cent, carbaryl 0.2 per cent and carbofuran 0.75 kg a.i. ha^{-1}at 22 days after application, the population being 8.59, 10.63, 11.61, 13.64, 14.65, 6.98, 7.92 and 13.64 respectively. Chlorpyrifos 50 EC + cypermethrin 5 EC was on par with imidacloprid and acephate.

All treatments except *Bacillus thuringiensis* var. kurstaki 0.2 per cent (19.31) significantly reduced the *L. acuta* population on the third day after spraying and the count ranged from 9.63 to 16.31. Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, imidacloprid 0.005 per cent, acephate 0.05 per cent and carbofuran 0.75 kg a.i. ha^{-1} (at 23 days after application) were found to be on par.

Fourth day after spraying, imidacloprid 0.005 per cent (14.64), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (16.27), acephate 0.05 per cent (17.63), azadirachtin 0.004 per cent (18.65), monocrotophos 0.05 per cent (11.26), carbaryl 0.2 per cent (15.96) and carbofuran 0.75 kg a.i. ha^{-1} at 24 days after application (17.25) reduced the pest population significantly when compared to control (25.96). Imidacloprid was statistically similar to monocrotophos. Imidacloprid, chlorpyrifos 50 EC + cypermethrin 5 EC, acephate, azadirachtin, carbaryl and carbofuran were found to be on par. *Bacillus thuringiensis* var.

kurstaki 0.2 per cent (21.32) did not record any significant reduction when compared to control.

Same trend was observed on the fifth day after spraying also. *Bacillus thuringiensis* var. kurstaki 0.2 per cent (26.32) was similar to control (27.64). The population of *L. acuta* for all other treatments ranged from 14.31 to 22.32. The effect of imidacloprid 0.005 per cent was statistically same as that of check treatments. Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent was equally effective as acephate 0.05 per cent and azadirachtin 0.004 per cent.

On the sixth day after application of insecticides, monocrotophos 0.05 per cent (15.99), carbaryl 0.2 per cent (20.63) and carbofuran 0.75 kg a.i. ha^{-1}applied at 30 DAT (18.59) were found to be significantly effective and all other treatments were insignificant with control (25.32) and the population ranged from 21.95 to 28.64. Same trend was observed on the seventh day after spraying.

Eight days after spraying, monocrotophos 0.05 per cent (22.97), carbaryl 0.2 per cent (24.65) and carbofuran 0.75 kg a.i. ha^{-1} at 28 days after application (21.97) were found to be significantly effective in controlling *L. acuta* when compared to control (30.32). Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (27.98), acephate 0.05 per cent (28.64), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (29.64), imidacloprid 0.005 per cent (30.65) and azadirachtin 0.004 per cent (31.32) were on par with control. On the ninth and tenth day after spraying no significant reduction in *L. acuta* population was noticed with any of the treatments.

4.2.1.6 Population Variation Recorded on Other Pests

The population of other pests (other than *C. medinalis, O. chinensis, Nephotettix spp., H. philippina* and *L. acuta*) recorded each day upto 10 days after spraying insecticides at 30 DAT is depicted in Table 10.

Significant reduction in the counts of other pests was recorded with chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, acephate 0.05 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis*

Table 9 Effect of insecticides on the population of *L. acuta* at 50 days after transplanting

Treatments	Mean number of pests observed at different intervals (days) after application									
	1	2	3	4	5	6	7	8	9	10
Acephate 0.05%	9.60 (3.26)	11.61 (3.55)	13.31 (3.78)	17.63 (4.32)	22.30 (4.83)	25.98 (5.19)	24.65 (5.06)	28.64 (5.44)	28.65 (5.45)	30.64 (5.63)
Imidacloprid 0.005%	10.27 (3.36)	8.59 (3.10)	12.59 (3.69)	14.64 (3.95)	16.31 (4.16)	21.95 (4.79)	27.98 (5.38)	30.65 (5.63)	29.98 (5.57)	29.65 (5.54)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	8.63 (3.10)	10.63 (3.41)	11.95 (3.60)	16.27 (4.16)	20.99 (4.69)	24.65 (5.06)	25.65 (5.16)	27.98 (5.38)	26.65 (5.26)	28.30 (5.41)
Azadirachtin 0.004%	9.30 (3.21)	13.64 (3.83)	16.31 (4.16)	18.65 (4.43)	22.32 (4.83)	25.99 (5.20)	29.98 (5.57)	31.32 (5.69)	28.65 (5.45)	29.65 (5.54)
Bacillus thuringiensis var. kurstaki 0.2%	11.64 (3.55)	14.65 (3.96)	19.31 (4.51)	21.32 (4.72)	26.32 (5.23)	28.64 (5.44)	31.32 (5.69)	29.64 (5.54)	30.63 (5.62)	29.30 (5.50)
Carbofuran 0.75 kg a. i./ha*	12.62 (3.69)	13.64 (3.83)	14.64 (3.95)	17.25 (4.27)	19.65 (4.54)	18.59 (4.43)	19.93 (4.57)	21.97 (4.79)	23.97 (5.00)	28.99 (5.48)
Monocrotophos 0.05%	8.25 (3.04)	6.98 (2.82)	9.63 (3.26)	11.26 (3.50)	14.31 (3.91)	15.99 (4.12)	19.97 (4.58)	22.97 (4.90)	25.65 (5.16)	26.98 (5.29)
Carbaryl 0.2%	6.92 (2.81)	7.92 (2.99)	10.63 (3.41)	15.96 (4.12)	17.66 (4.32)	20.63 (4.65)	21.65 (4.76)	24.65 (5.06)	29.28 (5.50)	28.99 (5.48)
Control	21.65 (4.76)	23.97 (5.00)	22.65 (4.86)	25.96 (5.19)	27.64 (5.35)	25.32 (5.13)	26.61 (5.25)	30.32 (5.60)	27.98 (5.38)	28.95 (5.47)
CD (0.05)	0.512	0.316	0.373	0.475	0.283	0.358	0.379	0.267	-	-

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

* Carbofuran applied at 30 days after transplanting

var. kurstaki 0.2 per cent, carbaryl 0.2 per cent and monocrotophos 0.05 per cent, the population being 4.97, 5.56, 6.66, 7.33, 7.98, 4.55 and 5.32 respectively at one day after application. Chlorpyrifos 50 EC + cypermethrin 5 EC and acephate were statistically similar to carbaryl. Imidacloprid and azadirachtin were on par with monocrotophos.

Two days after application, acephate 0.05 per cent (6.64), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (6.64), imidacloprid 0.005 per cent (6.98), azadirachtin 0.004 per cent (7.54), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (9.26), monocrotophos 0.05 per cent (4.26) and carbaryl 0.2 per cent (5.32) were found to produce significant suppression of these pests. Acephate, chlorpyrifos 50 EC + cypermethrin 5 EC, imidacloprid and azadirachtin were on par with carbaryl. Imidacloprid, azadirachtin and carbofuran 0.75 kg a.i. ha^{-1} (11.95) were statistically similar to *Bacillus thuringiensis* var. kurstaki.

Acephate 0.05 per cent, azadirachtin 0.004 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, imidacloprid 0.005 per cent, monocrotophos 0.05 per cent and carbaryl 0.2 per cent were found to cause significant reduction in the counts of pests, the population being 8.93, 8.98, 9.23, 9.33, 5.98 and 6.28 respectively on the third day after application. Acephate, azadirachtin, chlorpyrifos 50 EC + cypermethrin 5 EC and imidacloprid showed similar toxic effect.

Fourth day after application, acephate 0.05 per cent (10.30), azadirachtin 0.004 per cent (10.63), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (10.66), imidacloprid 0.005 per cent (11.30), monocrotophos 0.05 per cent (7.33) and carbaryl 0.2 per cent (8.29) reduced the population significantly when compared to control (13.64). *Bacillus thuringiensis* var. kurstaki 0.2 per cent (12.33) and carbofuran 0.75 kg a.i. ha^{-1}(13.96) were found to be ineffective.

On the fifth and sixth days after spraying, only the check treatments were found to be effective. From the seventh day after application onwards no significant reduction in pest population was observed with any of the treatments.

Table 10. Effect of insecticides on the population of other pests at 30 days after transplanting

Treatments	Mean number of pests observed at different intervals (days) after application									
	1	2	3	4	5	6	7	8	9	10
Acephate 0.05%	5.56 (2.56)	6.64 (2.76)	8.93 (3.15)	10.30 (3.36)	12.62 (3.69)	12.30 (3.65)	13.31 (3.78)	13.99 (3.87)	13.64 (3.83)	14.28 (3.91)
Imidacloprid 0.005%	6.66 (2.77)	6.98 (2.82)	9.33 (3.21)	11.30 (3.51)	12.99 (3.74)	13.31 (3.78)	13.66 (3.83)	13.27 (3.78)	13.62 (3.82)	13.99 (3.87)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	4.97 (2.44)	6.64 (2.76)	9.23 (3.20)	10.66 (3.41)	13.31 (3.78)	13.59 (3.82)	13.64 (3.83)	14.31 (3.91)	12.99 (3.74)	13.64 (3.83)
Azadirachtin 0.004%	7.33 (2.89)	7.54 (2.92)	8.98 (3.16)	10.63 (3.41)	11.99 (3.60)	12.33 (3.65)	14.31 (3.91)	13.99 (3.87)	14.32 (3.91)	13.31 (3.78)
Bacillus thuringiensis var. kurstaki 0.2%	7.98 (3.00)	9.26 (3.20)	11.30 (3.51)	12.33 (3.65)	13.31 (3.78)	13.31 (3.78)	13.99 (3.87)	13.96 (3.87)	14.62 (3.95)	14.64 (3.95)
Carbofuran 0.75 kg a. i./ha	10.63 (3.41)	11.95 (3.60)	13.31 (3.78)	13.96 (3.87)	13.99 (3.87)	14.62 (3.95)	13.31 (3.78)	12.99 (3.74)	13.33 (3.79)	13.99 (3.87)
Monocrotophos 0.05%	5.32 (2.51)	4.26 (2.29)	5.98 (2.64)	7.33 (2.89)	8.59 (3.10)	9.98 (3.31)	10.99 (3.46)	13.31 (3.78)	13.99 (3.87)	14.33 (3.92)
Carbaryl 0.2%	4.55 (2.35)	5.32 (2.51)	6.28 (2.70)	8.29 (3.05)	9.33 (3.21)	10.33 (3.37)	12.64 (3.69)	13.96 (3.87)	13.92 (3.86)	13.65 (3.83)
Control	12.64 (3.69)	12.59 (3.69)	13.33 (3.79)	13.64 (3.83)	13.32 (3.78)	13.99 (3.87)	13.96 (3.87)	14.32 (3.91)	13.96 (3.87)	14.64 (3.95)
CD (0.05)	0.375	0.411	0.297	0.199	0.332	0.363	-	-	-	-

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

The population of other pests recorded each day upto 10 days after spraying insecticides at 50 DAT (carbofuran applied only at 30 DAT) is depicted in Table 11.

One day after spraying, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (7.98), azadirachtin 0.004 per cent (8.59), acephate 0.05 per cent (9.30), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (9.94), imidacloprid 0.005 per cent (10.66), carbaryl 0.2 per cent (6.61) and monocrotophos 0.05 per cent (7.33) recorded significant suppression of the pests when compared to control (16.31). Chlorpyrifos 50 EC + cypermethrin 5 EC was on par with the check treatments. Azadirachtin and acephate were statistically similar in effect to monocrotophos. Azadirachtin 0.004 per cent, acephate 0.05 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent and imidacloprid 0.005 per cent were found to be similar in producing the toxic effect.

Two days after spraying, acephate 0.05 per cent, imidacloprid 0.005 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent, monocrotophos 0.05 per cent and carbaryl 0.2 per cent were found to be effective when compared to control (18.65), the population being 6.98, 7.92, 8.63, 10.63, 11.27, 6.58 and 8.66 respectively. Acephate and imidacloprid were on par with chlorpyrifos 50 EC + cypermethrin 5 EC and the insecticides used as check.

On the third day after spraying, acephate 0.05 per cent (9.94), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (10.61), imidacloprid 0.005 per cent (10.99), azadirachtin 0.004 per cent (12.66), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (12.66), monocrotophos 0.05 per cent (8.59) and carbaryl 0.2 per cent (10.30) were found to cause significant reduction in the population of other pests. Among these, acephate, chlorpyrifos 50 EC + cypermethrin 5 EC and imidacloprid showed the same effect as the check insecticides. Imidacloprid, azadirachtin and *Bacillus thuringiensis* var kurstaki gave similar toxic effect.

Fourth day after spraying, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (12.99), acephate 0.05 per cent (12.99), imidacloprid 0.005 per cent

(14.65), azadirachtin 0.004 per cent (14.96), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (15.31), monocrotophos 0.05 per cent (9.94) and carbaryl 0.2 per cent (11.61) were found to cause significant suppression in the population of other pests. Chlorpyrifos 50 EC + cypermethrin 5 EC and acephate were on par with imidacloprid, azadirachtin, *Bacillus thuringiensis* var. kurstaki and carbaryl.

On the fifth day after spraying, acephate 0.05 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, azadirachtin 0.004 per cent, imidacloprid 0.005 per cent, *Bacillus thuringiensis* var. kurstaki 0.2 per cent, monocrotophos 0.05 per cent and carbaryl 0.2 per cent were found to be significantly effective in reducing the population of other pests when compared to control (19.99), the population being 14.31, 15.64, 16.31, 16.33, 17.33, 12.66 and 13.64 respectively. Acephate was on par with chlorpyrifos 50 EC + cypermethrin 5 EC and monocrotophos. Chlorpyrifos 50 EC + cypermethrin 5 EC, imidacloprid, azadirachtin and *Bacillus thuringiensis* var. kurstaki were found to be statistically similar in producing toxic effect. Carbofuran 0.75 kg a.i. ha^{-1} was found to be ineffective on all these days.

None of the treatments proved to be effective against the population of other pests when compared to control from the sixth day onwards.

4.2.1.7 Population Variation Recorded on Total Pests

The population of total pests recorded daily upto 10 days after application insecticides at 30 DAT is depicted in Table 12.

All treatments except carbofuran 0.75 kg a.i. ha^{-1} (65.28) significantly reduced the total pest population when compared to control (73.26) at one day after application. Highest reduction was noticed in carbaryl 0.2 per cent (22.54) treated plots. Acephate 0.05 per cent (37.97) was on par with chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (32.51) and monocrotophos 0.05 per cent (42.33) while imidacloprid 0.005 per cent (45.00), azadirachtin 0.004 per cent (46.33) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (49.32) were found to be on par with monocrotophos.

Table 11. Effect of insecticides on the population of other pests at 50 days after transplanting

Treatments	Mean number of pests observed at different intervals (days) after application									
	1	2	3	4	5	6	7	8	9	10
Acephate 0.05%	9.30 (3.21)	6.98 (2.82)	9.94 (3.31)	12.99 (3.74)	14.31 (3.91)	15.99 (4.12)	18.33 (4.40)	19.95 (4.58)	18.92 (4.46)	19.30 (4.51)
Imidacloprid 0.005%	10.66 (3.41)	7.92 (2.99)	10.99 (3.46)	14.65 (3.96)	16.33 (4.16)	17.31 (4.28)	18.65 (4.43)	19.33 (4.51)	19.66 (4.55)	19.99 (4.58)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	7.98 (3.00)	8.63 (3.10)	10.61 (3.41)	12.99 (3.74)	15.64 (4.08)	17.65 (4.32)	19.31 (4.51)	20.66 (4.65)	19.66 (4.55)	20.32 (4.62)
Azadirachtin 0.004%	8.59 (3.10)	10.63 (3.41)	12.66 (3.70)	14.96 (3.99)	16.31 (4.16)	17.33 (4.28)	17.99 (4.36)	18.99 (4.47)	18.99 (4.47)	19.66 (4.55)
Bacillus thuringiensis var. kurstaki 0.2%	9.94 (3.31)	11.27 (3.50)	12.66 (3.70)	15.31 (4.04)	17.33 (4.28)	18.63 (4.43)	19.99 (4.58)	19.63 (4.54)	20.65 (4.65)	21.32 (4.72)
Carbofuran 0.75 kg a. i./ha*	14.96 (3.99)	16.31 (4.16)	16.99 (4.24)	17.63 (4.32)	19.66 (4.54)	16.99 (4.24)	18.65 (4.43)	18.65 (4.43)	19.31 (4.51)	19.33 (4.51)
Monocrotophos 0.05%	7.33 (2.89)	6.58 (2.75)	8.59 (3.10)	9.94 (3.31)	12.66 (3.70)	14.31 (3.91)	15.62 (4.08)	17.65 (4.32)	19.65 (4.54)	20.65 (4.65)
Carbaryl 0.2%	6.61 (2.76)	8.66 (3.11)	10.30 (3.36)	11.61 (3.55)	13.64 (3.83)	15.56 (4.07)	16.56 (4.19)	18.66 (4.43)	19.63 (4.54)	19.99 (4.58)
Control	16.31 (4.16)	18.65 (4.43)	15.93 (4.12)	19.31 (4.51)	19.99 (4.58)	18.33 (4.40)	17.31 (4.28)	19.30 (4.51)	19.97 (4.58)	20.95 (4.68)
CD (0.05)	0.319	0.311	0.412	0.382	0.234	-	-	-	-	-

Figures in parenthesis are $\sqrt{x + 1}$ transformed values
* Carbofuran applied at 30 days after transplanting

On the second day after application, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (37.88), acephate 0.05 per cent (39.31), imidacloprid 0.005 per cent (39.32), azadirachtin 0.004 per cent (44.57), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (51.28), carbaryl 0.2 per cent (25.53) and monocrotophos 0.05 per cent (28.58) were found to cause significant reduction in total pest population. Chlorpyrifos 50 EC + cypermethrin 5 EC, acephate, imidacloprid and azadirachtin exhibited same toxic effect.

Almost similar trend was observed on the third day also. Carbaryl 0.2 per cent (31.27) and monocrotophos 0.05 per cent (35.62) recorded highest significant reduction in total pest population. Imidacloprid 0.005 per cent (43.27), acephate 0.05 per cent (44.99) and chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (46.33) reduced the population significantly and were on par. Azadirachtin 0.004 per cent and *Bacillus thuringiensis* var. kurstaki 0.2 per cent recorded a population of 51.23 and 59.95 respectively. Carbofuran 0.75 kg a.i. ha^{-1} (71.31) alone did not record any significant reduction when compared to control (76.32).

All treatments except carbofuran 0.75 kg a.i. ha^{-1} (73.61) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (67.95) recorded significant reduction in pest population when compared to control (73.99) on the fourth day after application.

On the fifth day after application, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (60.67), acephate 0.05 per cent (62.95), imidacloprid 0.005 per cent (64.99), azadirachtin 0.004 per cent (69.99), carbaryl 0.2 per cent (50.61) and monocrotophos 0.05 per cent (54.94) reduced the population significantly when compared to control (78.99). Chlorpyrifos 50 EC + cypermethrin 5 EC, acephate and imidacloprid exhibited the same effect. Azadirachtin was on par with acephate and imidacloprid.

Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (65.08), imidacloprid 0.005 per cent (67.66) and acephate 0.05 per cent (69.32) significantly reduced the pest population as in the case of check treatments, carbaryl 0.2 per cent (58.98) and monocrotophos 0.05 per cent (64.99) compared to control (75.60) on the sixth day after application. Chlorpyrifos 50 EC +

cypermethrin 5 EC was on par with monocrotophos and carbaryl. Azadirachtin 0.004 per cent (73.32) and carbofuran 0.75 kg a.i. ha^{-1} (74.32) were statistically similar to acephate.

Seven days after application, carbofuran 0.75 kg a.i. ha^{-1} (68.33), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (70.63), imidacloprid 0.005 per cent (71.65), monocrotophos 0.05 per cent (71.00) and carbaryl 0.2 per cent (66.97) significantly reduced the total pest population when compared to control (77.33). Chlorpyrifos 50 EC + cypermethrin 5 EC and carbofuran were on par with the check treatments. Acephate 0.05 per cent (73.00), azadirachtin 0.004 per cent (73.97) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (76.32) did not record any significant reduction in total pest count.

On the eighth day, only carbofuran 0.75 kg a.i. ha^{-1} (66.99) recorded significant reduction in pest count. All other treatments were on par with control (76.99) and the population ranged from 74.65 to 78.63. Same trend was also observed on the ninth day after spraying. All the treatments except carbofuran (63.31) were ineffective when compared to control (79.66) on the tenth day after application.

Population of total pests recorded at 11 to 20 days after application of carbofuran 0.75 kg a.i. ha^{-1} is presented in Table 13.

Carbofuran 0.75 kg a.i. ha^{-1} significantly reduced the population of total pests all these days when compared to control. The mean population of total pests ranged from 61.67 to 90.67 in carbofuran treated plots and 79.67 to 111.67 in control plots.

The population of total pests recorded each day upto 10 days after application of insecticides at 50 DAT (carbofuran applied only at 30 DAT) is presented in Table 14.

From the first day to fifth day after spraying, all the treatments reduced the total pest population significantly when compared to control. The values ranged from 35.94 to 111.32 on the first day, 35.95 to 114.66 on the second day, 40.63 to

Table 12. Effect of insecticides on the population of total pests at 30 days after transplanting

Treatments	Mean number of pests observed at different intervals (days) after application									
	1	2	3	4	5	6	7	8	9	10
Acephate 0.05%	37.97 (6.24)	39.31 (6.35)	44.99 (6.78)	53.65 (7.39)	62.95 (8.00)	69.32 (8.38)	73.00 (8.60)	75.29 (8.73)	76.31 (8.79)	79.66 (8.98)
Imidacloprid 0.005%	45.00 (6.78)	39.32 (6.35)	43.27 (6.65)	58.26 (7.70)	64.99 (8.12)	67.66 (8.29)	71.65 (8.52)	75.00 (8.72)	76.61 (8.81)	77.64 (8.87)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	32.51 (5.79)	37.88 (6.24)	46.33 (6.88)	51.87 (7.27)	60.67 (7.85)	65.08 (8.13)	70.63 (8.46)	74.65 (8.70)	72.63 (8.58)	78.00 (8.89)
Azadirachtin 0.004%	46.33 (6.88)	44.57 (6.75)	51.23 (7.23)	61.00 (7.87)	69.66 (8.41)	73.32 (8.62)	73.97 (8.66)	77.30 (8.85)	79.99 (9.00)	77.62 (8.87)
Bacillus thuringiensis var. kurstaki 0.2%	49.32 (7.09)	51.28 (7.23)	59.95 (7.81)	67.95 (8.30)	76.31 (8.79)	76.31 (8.79)	76.32 (8.79)	78.63 (8.92)	77.97 (8.89)	80.66 (9.04)
Carbofuran 0.75 kg a. i./ha	65.28 (8.14)	75.66 (8.76)	71.31 (8.50)	73.61 (8.64)	73.32 (8.62)	74.32 (8.68)	68.33 (8.33)	66.99 (8.25)	65.63 (8.16)	63.31 (8.02)
Monocrotophos 0.05%	42.33 (6.58)	28.58 (5.44)	35.62 (6.05)	45.61 (6.83)	54.94 (7.48)	64.99 (8.12)	71.00 (8.49)	75.98 (8.77)	79.92 (9.00)	79.32 (8.96)
Carbaryl 0.2%	22.54 (4.85)	25.53 (5.15)	31.27 (5.68)	41.97 (6.56)	50.61 (7.18)	58.98 (7.74)	66.97 (8.24)	74.98 (8.72)	76.30 (8.79)	78.32 (8.91)
Control	73.26 (8.62)	72.96 (8.60)	76.32 (8.79)	73.99 (8.66)	78.99 (8.94)	75.60 (8.75)	77.33 (8.85)	76.99 (8.83)	76.65 (8.81)	79.66 (8.98)
CD (0.05)	0.505	0.513	0.429	0.445	0.324	0.389	0.256	0.314	0.407	0.263

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

Table 13. Effect of carbofuran on the population of *Nephotettix* spp. and total population of pests observed at 11 to 20 days after application*

Treatments	Mean population of *Nephotettix* spp. observed at different intervals (days) after application									
	11	12	13	14	15	16	17	18	19	20
Carbofuran 0.75 kg a.i. ha^{-1}	6.64 (2.58)	6.90 (2.63)	6.61 (2.57)	6.63 (2.58)	5.97 (2.44)	5.53 (2.37)	5.32 (2.31)	5.17 (2.28)	4.97 (2.23)	3.32 (1.82)
Control	9.93 (3.15)	10.30 (3.21)	9.63 (3.10)	10.63 (3.26)	10.33 (3.21)	9.93 (3.15)	9.98 (3.16)	10.98 (3.31)	10.94 (3.31)	12.64 (3.55)
CD (0.05)	–	–	–	–	0.519	0.483	0.470	0.500	0.442	0.516
	Mean population of total pests observed at different intervals (days) after application									
	11	12	13	14	15	16	17	18	19	20
Carbofuran 0.75 kg a.i. ha^{-1}	61.67 (7.85)	62.67 (7.91)	67.67 (8.22)	68.33 (8.27)	72.00 (8.48)	75.00 (8.66)	82.33 (9.07)	85.00 (9.22)	89.33 (9.45)	90.67 (9.52)
Control	79.67 (8.92)	84.33 (9.18)	88.33 (9.40)	93.00 (9.64)	96.00 (9.80)	99.67 (9.98)	103.67 (10.18)	104.00 (10.20)	108.33 (10.40)	111.67 (10.57)
CD (0.05)	0.488	0.516	0.376	0.424	0.300	0.348	0.398	0.376	0.368	0.330

Figures in parenthesis are $\sqrt{x}$ transformed values

*Complete data given in Appendix – VI and II

125.56 on the third day, 58.27 to 119.91 on the fourth day, and 71.98 to 127.64 on the fifth day after the application of insecticides.

On the sixth day, azadirachtin 0.004 per cent (113.97) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (124.22) did not record any significant reduction in pest population when compared to control (116.33). All the synthetic insecticides showed significant suppression of the total population of pests. Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (90.99) was on par with acephate 0.05 per cent (98.87) and monocrotophos 0.05 per cent (88.67). Carbofuran 0.75 kg a.i. ha^{-1} at 26 days after application (105.97) was found to be on par with acephate, imidacloprid 0.005 per cent (99.95) and azadirachtin.

Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (101.32), acephate 0.05 per cent (107.33), monocrotophos 0.05 per cent (99.98), carbaryl 0.2 per cent (98.00) and carbofuran 0.75 kg a.i. ha^{-1} at 27 days after application (108.60), significantly reduced the total pest population when compared to control (116.61) on the seventh day after spraying. Chlorpyrifos 50 EC + cypermethrin 5 EC was on par with acephate and the check treatments. Imidacloprid 0.005 per cent (109.96) and azadirachtin 0.004 per cent (122.29) did not record any significant reduction in total pest population. Significantly higher population was noticed on *Bacillus thuringiensis* var. kurstaki 0.2 per cent (134.99) treated plots.

Eighth day after spraying, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (111.30), monocrotophos 0.05 per cent (110.32), carbaryl 0.2 per cent (114.24) and carbofuran 0.75 kg a.i. ha^{-1} at 28 days after application (110.32) reduced the population significantly. Acephate 0.05 per cent (118.66), imidacloprid 0.005 per cent (121.29), azadirachtin 0.004 per cent (127.31) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (127.64) did not produce any significant reduction in pest count when compared to control (122.65).

Significantly higher population was recorded in *Bacillus thuringiensis* var. kurstaki 0.2 per cent (131.89) treated plots. All other treatments were found to be on par with control (122.31) and the population ranged from 115.66 to

Table 14. Effect of insecticides on the population of total pests at 50 days after transplanting

Treatments	Mean number of pests observed at different intervals (days) after application)									
	1	2	3	4	5	6	7	8	9	10
Acephate 0.05%	47.32 (6.95)	47.54 (6.97)	56.29 (7.57)	68.66 (8.35)	81.99 (9.11)	98.87 (9.99)	107.33 (10.41)	118.66 (10.94)	124.96 (11.22)	128.30 (11.37)
Imidacloprid 0.005%	70.50 (8.45)	53.62 (7.39)	64.65 (8.10)	77.99 (8.89)	89.63 (9.52)	99.95 (10.05)	109.96 (10.53)	121.29 (11.06)	124.95 (11.22)	126.65 (11.30)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	42.93 (6.63)	43.99 (6.71)	51.00 (7.21)	65.23 (8.14)	78.28 (8.90)	90.99 (9.59)	101.32 (10.12)	111.30 (10.60)	119.94 (11.00)	126.32 (11.28)
Azadirachtin 0.004%	63.29 (8.02)	59.67 (7.79)	73.65 (8.64)	85.27 (9.29)	100.66 (10.08)	113.97 (10.72)	122.29 (11.10)	127.31 (11.33)	124.65 (11.21)	128.65 (11.39)
Bacillus thuringiensis var. kurstaki 0.2%	69.90 (8.42)	66.95 (8.24)	82.53 (9.14)	93.83 (9.74)	111.66 (10.61)	124.22 (11.19)	134.99 (11.66)	127.64 (11.34)	131.89 (11.53)	130.98 (11.49)
Carbofuran 0.75 kg a. i./ha*	92.65 (9.68)	96.24 (9.87)	103.63 (10.23)	104.27 (10.26)	111.65 (10.61)	105.97 (10.34)	108.60 (10.47)	110.32 (10.55)	116.00 (10.82)	123.66 (11.17)
Monocrotophos 0.05%	64.33 (8.08)	38.58 (6.29)	40.63 (6.45)	58.27 (7.70)	71.98 (8.54)	88.67 (9.47)	99.98 (10.05)	110.32 (10.55)	115.66 (10.80)	124.30 (11.19)
Carbaryl 0.2%	35.94 (6.08)	35.95 (6.08)	46.26 (6.87)	63.96 (8.06)	72.97 (8.60)	83.29 (9.18)	98.00 (9.95)	114.24 (10.73)	124.28 (11.19)	126.65 (11.30)
Control	111.32 (10.60)	114.66 (10.75)	125.56 (11.25)	119.91 (11.00)	127.64 (11.34)	116.33 (10.83)	116.61 (10.84)	122.65 (11.12)	122.31 (11.10)	127.30 (11.33)
CD (0.05)	0.380	0.376	0.368	0.543	0.297	0.403	0.308	0.281	0.369	-

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

* Carbofuran applied at 30 days after transplanting

124.95 on the ninth day after spraying. On the tenth day after spraying all the treatments were found to be statistically similar to control.

4.2.2 Effect of Insecticides on the Population of Predators

4.2.2.1 Population Variation Recorded on Agriocnemis spp.

The population of *Agriocnemis* spp. recorded each day upto five days after application of insecticides at different growth stages (carbofuran applied only at 30 DAT) of the crop is presented in Table 15.

At 30 DAT

On the first day after application, chlorpyrifos 50 EC + cypermethrin 5 EC 0.005 per cent (4.97), azadirachtin 0.004 per cent (5.66), acephate 0.05 per cent (6.61), *Bacillus thuringensis* var. kurstaki 0.2 per cent (6.61), carbaryl 0.2 per cent (4.66) and monocrotophos 0.05 per cent (6.66) significantly reduced the population of *Agriocnemis* spp. while imidacloprid 0.005 per cent (7.29) and carbofuran 0.75 kg a.i. ha^{-1} (8.63) were found to be less toxic to the predators when compared to control (8.98). Chlorpyrifos 50 EC + cypermethrin 5 EC and azadirachtin were statistically similar in effect to acephate, *Bacillus thuringensis* var. kurstaki and carbaryl.

Two days after application, the check insecticides *viz.*, carbaryl 0.2 per cent (3.91) and monocrotophos 0.05 per cent (5.98) alone reduced the population of *Agriocnemis* spp. significantly. All other treatments were comparatively safe when compared to control (9.30), the population being 6.84, 7.33, 7.62, 8.33, 8.63 and 8.98 for azadirachtin 0.004 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, acephate 0.05 per cent, imidacloprid 0.005 per cent, *Bacillus thuringensis* var. kurstaki 0.2 per cent and carbofuran 0.75 kg a.i. ha^{-1} respectively.

Carbaryl 0.2 per cent (6.28) alone was toxic to *Agriocnemis* spp. at three days after application when compared to control (9.60). The population recorded in the treatments showing less toxicity to *Agriocnemis* spp. ranged from 7.92 to

10.33. All the treatments were found to be safe to *Agriocnemis* spp. on the fourth and fifth day after application.

At 50 DAT

No significant reduction in population of the predator was noticed in any of the observations from the first day to fifth day after second application. All the treatments were found to be safe to *Agriocnemis* spp. The values ranged from 2.32 to 4.97 on the first day, 2.32 to 5.27 on the second day, 3.65 to 5.66 on the third day, 4.66 to 5.93 on the fourth day and 5.66 to 6.98 on the fifth day of observations.

4.2.2.2 Population Variation Recorded on Coccinellids

The population of coccinellids recorded at daily interval upto five days after application of insecticides at different growth stages (carbofuran applied only at 30 DAT) of the crop is depicted in Table 16.

At 30 DAT

Carbaryl 0.2 per cent (1.31) alone showed adverse effect on the predator population at one day after application when compared to control (4.89). All other treatments *viz*., acephate 0.05 per cent (2.89), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (3.25), azadirachtin 0.004 per cent (3.97), *Bacillus thuringensis* var. kurstaki 0.2 per cent (4.32), imidacloprid 0.005 per cent (4.89), carbofuran 0.75 kg a.i. ha^{-1} (5.56) and monocrotophos 0.05 (2.96) were not found detrimental to coccinellid population.

From the second day to fifth day after application, all the treatments were found to be safe to coccinellids.

At 50 DAT

One day after spraying, acephate 0.05 per cent (1.49) and carbaryl 0.2 per cent (0.55) reduced the coccinellid population significantly and were on par. All other treatments were found to be safe and were on par when compared to control (3.97), the population ranged from 2.32 to 3.52.

Table 15. Effect of insecticides on the population of *Agriocnemis* spp.* during various growth stages of the crop

Treatments	Mean number of predators observed at different intervals (days) after application									
	30 DAT					50 DAT				
	1	2	3	4	5	1	2	3	4	5
Acephate 0.05%	6.61 (2.76)	7.62 (2.94)	8.63 (3.10)	9.94 (3.31)	9.63 (3.26)	2.89 (1.97)	3.86 (2.20)	4.97 (2.44)	5.66 (2.58)	6.61 (2.76)
Imidacloprid 0.005%	7.29 (2.88)	8.33 (3.05)	9.94 (3.31)	9.33 (3.21)	10.66 (3.41)	3.65 (2.16)	4.29 (2.30)	5.27 (2.50)	5.93 (2.63)	6.33 (2.71)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	4.97 (2.44)	7.33 (2.89)	8.66 (3.11)	8.64 (3.11)	9.60 (3.26)	2.32 (1.82)	3.65 (2.16)	4.29 (2.30)	4.59 (2.37)	5.90 (2.63)
Azadirachtin 0.004%	5.66 (2.58)	6.84 (2.80)	7.92 (2.99)	6.61 (2.76)	9.33 (3.21)	3.13 (2.03)	4.26 (2.29)	3.97 (2.23)	4.97 (2.44)	6.30 (2.70)
Bacillus thuringiensis var. kurstaki 0.2%	6.61 (2.76)	8.63 (3.10)	10.33 (3.37)	8.93 (3.15)	9.26 (3.20)	3.52 (2.13)	4.59 (2.37)	4.97 (2.44)	5.66 (2.58)	6.98 (2.82)
Carbofuran 0.75 kg a. i./ha**	8.63 (3.10)	8.98 (3.16)	9.98 (3.31)	9.60 (3.26)	8.66 (3.11)	4.97 (2.44)	4.97 (2.44)	5.32 (2.51)	4.89 (2.43)	5.66 (2.58)
Monocrotophos 0.05%	6.66 (2.77)	5.98 (2.64)	8.63 (3.10)	7.33 (2.89)	8.98 (3.16)	3.32 (2.08)	2.96 (1.99)	4.26 (2.29)	4.89 (2.43)	5.93 (2.63)
Carbaryl 0.2%	4.66 (2.38)	3.91 (2.22)	6.28 (2.70)	7.92 (2.99)	9.60 (3.26)	2.61 (1.90)	2.32 (1.82)	3.65 (2.16)	4.66 (2.38)	5.98 (2.64)
Control	8.98 (3.16)	9.30 (3.21)	9.60 (3.26)	9.98 (3.31)	8.98 (3.16)	4.89 (2.43)	5.27 (2.50)	5.66 (2.58)	4.97 (2.44)	5.90 (2.63)
CD (0.05)	0.365	0.490	0.375	-	-	-	-	-	-	-

Figures in parenthesis are $\sqrt{x + 1}$ transformed values
*A.. *pygmaea*, *A. femina femina*, DAT – Days after transplanting
** Carbofuran applied only at 30 DAT

Table 16. Effect of insecticides on the population of coccinellids* during various growth stages of the crop

Treatments	Mean number of predators observed at different intervals (days) after application									
	30 DAT					50 DAT				
	1	2	3	4	5	1	2	3	4	5
Acephate 0.05%	2.89 (1.97)	3.52 (2.13)	5.27 (2.50)	5.90 (2.63)	5.32 (2.51)	1.49 (1.58)	2.26 (1.80)	3.86 (2.20)	3.58 (2.14)	3.97 (2.23)
Imidacloprid 0.005%	4.89 (2.43)	4.26 (2.29)	5.98 (2.64)	5.98 (2.64)	5.90 (2.63)	2.96 (1.99)	2.32 (1.82)	3.97 (2.23)	3.97 (2.23)	4.66 (2.38)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	3.25 (2.06)	2.89 (1.97)	4.63 (2.37)	5.61 (2.57)	5.66 (2.58)	2.65 (1.91)	1.94 (1.72)	3.32 (2.08)	3.97 (2.23)	3.58 (2.14)
Azadirachtin 0.004%	3.97 (2.23)	3.97 (2.23)	5.90 (2.63)	6.61 (2.76)	6.23 (2.69)	3.32 (2.08)	3.58 (2.14)	3.89 (2.21)	3.97 (2.23)	4.32 (2.31)
Bacillus thuringiensis var. kurstaki 0.2%	4.32 (2.31)	4.63 (2.37)	5.56 (2.56)	6.33 (2.71)	5.56 (2.56)	2.65 (1.91)	3.25 (2.06)	3.58 (2.14)	3.65 (2.16)	4.59 (2.37)
Carbofuran 0.75 kg a. i./ha**	5.56 (2.56)	5.61 (2.57)	5.93 (2.63)	5.30 (2.51)	4.92 (2.43)	3.52 (2.13)	3.25 (2.06)	3.65 (2.16)	3.65 (2.16)	3.97 (2.23)
Monocrotophos 0.05%	2.96 (1.99)	3.32 (2.08)	4.59 (2.37)	4.89 (2.43)	5.98 (2.64)	2.32 (1.82)	2.61 (1.90)	3.52 (2.13)	3.97 (2.23)	4.26 (2.29)
Carbaryl 0.2%	1.31 (1.52)	3.25 (2.06)	3.97 (2.23)	5.56 (2.56)	5.27 (2.50)	0.55 (1.24)	1.64 (1.63)	2.65 (1.91)	3.25 (2.06)	3.65 (2.16)
Control	4.89 (2.43)	4.55 (2.35)	4.97 (2.44)	5.63 (2.58)	6.23 (2.69)	3.97 (2.23)	3.65 (2.16)	3.97 (2.23)	4.26 (2.29)	3.58 (2.14)
CD (0.05)	0.555	-	-	-	-	0.526	-	-	-	-

Figures in parenthesis are $\sqrt{x + 1}$ transformed values
**M. crocea, H. octomaculata, M. sexmaculatus* DAT – Days after transplanting
** Carbofuran applied only at 30 DAT

4.2.2.3 Population Variation Recorded on O. nigrofasciata

The population of *O. nigrofasciata* recorded at one day interval upto five days after application of insecticides at 30 DAT and 50 DAT (carbofuran applied only at 30 DAT) is presented in Table 17.

At 30 DAT

Azadirachtin 0.004 per cent (3.25), *Bacillus thuringensis* var. kurstaki 0.2 per cent (3.86) and carbofuran 0.75 kg a.i. ha^{-1} (5.66) were not harmful to *O. nigrofasciata* when compared to control (4.97) at one day after application. Acephate 0.05 per cent (2.61), chlorpyrifos 50 EC + cypermethrin 5 EC (2.65), imidacloprid 0.005 per cent (2.65), carbaryl 0.2 per cent (0.91) and monocrotophos 0.05 per cent (2.65) significantly reduced the predator population.

Two days after application, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, imidacloprid 0.005 per cent, acephate 0.05 per cent, monocrotophos 0.05 per cent and carbaryl 0.2 per cent showed significant reduction in the *O. nigrofasciata* population, the count being 1.94, 2.96, 2.96, 2.32 and 2.65 respectively. All these treatments were statistically similar in effect. Azadirachtin 0.004 per cent (3.97), *Bacillus thuringensis* var. kurstaki 0.2 per cent (4.66) and carbofuran 0.75 kg a.i. ha^{-1} (5.30) were found to be less toxic to *O. nigrofasciata* when compared to control (5.27).

On the third, fourth and fifth day after spraying, all the treatments were not harmful to the predator, *O. nigrofasciata*, the values ranged from 2.61 to 5.90, 4.59 to 5.90 and 5.56 to 6.52 respectively.

At 50 DAT

At one day after spraying, carbaryl 0.2 per cent (1.94) recorded highest significant reduction in population. The other treatments *viz*., monocrotophos 0.05 per cent, imidacloprid 0.005 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, acephate 0.05 per cent and *Bacillus thuringensis* var. kurstaki 0.2 per cent significantly reduced the population, which ranged from 5.27 to 7.29.

Carbofuran 0.75 kg a.i. ha^{-1}at 21 days after application (10.99) was found to be safe when compared to control (11.30).

Azadirachtin 0.004 per cent (6.98), *Bacillus thuringensis* var. kurstaki 0.2 per cent (8.93) and carbofuran 0.75 kg a.i. ha^{-1}at 22 days after application (10.63) were not detrimental to *O. nigrofasciata* when compared to control (10.27) at two days after second spraying. Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (4.92), imidacloprid 0.005 per cent (5.27), acephate 0.05 per cent (6.58), monocrotophos 0.05 per cent (4.26) and carbaryl 0.2 per cent (5.27) significantly reduced *O. nigrofasciata* population and were found to be on par.

On the third (6.58 to 10.66), the fourth (8.29 to 11.66) and fifth (10.54 to 12.64) day after spraying and 23, 24 and 25 days after application of carbofuran 0.75 kg a.i. ha^{-1} no harmful effect was noticed with any of the treatments.

4.2.2.4 Population Variation Recorded on Spiders

The population of spiders recorded at daily interval upto five days after application of insecticides at 30 DAT and 50 DAT (carbofuran applied only at 30 DAT) is presented in Table 18.

At 30 DAT

Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (4.97), azadirachtin 0.004 per cent (5.66), imidacloprid 0.005 per cent (7.92), carbaryl 0.2 per cent (3.97) and monocrotophos 0.05 per cent (4.97) significantly reduced spider population at one day after application. Acephate 0.05 per cent (8.64), *Bacillus thuringensis* var. kurstaki 0.2 per cent (9.23) and carbofuran 0.75 kg a.i. ha^{-1} (11.30) were found to be comparatively safe when compared to control (10.66).

Two days after application, *Bacillus thuringiensis* var. kurstaki 0.2 per cent (8.95) acephate 0.05 per cent (9.30) and carbofuran 0.75 kg ha^{-1} (11.61) were found to be safe to spiders when compared to control (11.30). All other treatments *viz*., chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (4.97), azadirachtin 0.004 per cent (7.29), imidacloprid 0.005 per cent (8.66), carbaryl 0.2 per cent

Table 17. Effect of insecticides on the population of *O. nigrofasciata* during various growth stages of the crop

Treatments	Mean number of predators observed at different intervals (days) after application									
	30 DAT					50 DAT				
	1	2	3	4	5	1	2	3	4	5
Acephate 0.05%	2.61 (1.90)	2.96 (1.99)	4.66 (2.38)	5.32 (2.51)	5.61 (2.57)	5.98 (2.64)	6.58 (2.75)	9.56 (3.25)	10.94 (3.46)	11.33 (3.51)
Imidacloprid 0.005%	2.65 (1.91)	2.96 (1.99)	4.59 (2.37)	5.50 (2.55)	6.33 (2.71)	5.32 (2.51)	5.27 (2.50)	8.63 (3.10)	11.66 (3.56)	11.95 (3.60)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	2.65 (1.91)	1.94 (1.72)	2.61 (1.90)	4.59 (2.37)	5.98 (2.64)	5.98 (2.64)	4.92 (2.43)	6.58 (2.75)	8.29 (3.05)	11.33 (3.51)
Azadirachtin 0.004%	3.25 (2.06)	3.97 (2.23)	5.66 (2.58)	5.27 (2.50)	6.33 (2.71)	5.90 (2.63)	6.98 (2.82)	7.98 (3.00)	9.33 (3.21)	11.61 (3.55)
Bacillus thuringiensis var. kurstaki 0.2%	3.86 (2.20)	4.66 (2.38)	5.61 (2.57)	5.32 (2.51)	5.90 (2.63)	7.29 (2.88)	8.93 (3.15)	9.66 (3.27)	10.65 (3.41)	11.99 (3.60)
Carbofuran 0.75 kg a. i./ha*	5.66 (2.58)	5.30 (2.51)	5.17 (2.48)	5.90 (2.63)	5.56 (2.56)	10.99 (3.46)	10.63 (3.41)	10.66 (3.41)	11.30 (3.51)	10.99 (3.46)
Monocrotophos 0.05%	2.65 (1.91)	2.32 (1.82)	3.97 (2.23)	5.61 (2.57)	6.52 (2.74)	5.27 (2.50)	4.26 (2.29)	7.86 (2.98)	11.64 (3.55)	12.64 (3.69)
Carbaryl 0.2%	0.91 (1.38)	2.65 (1.91)	3.97 (2.23)	4.63 (2.37)	5.98 (2.64)	1.94 (1.72)	5.27 (2.50)	6.61 (2.76)	8.63 (3.10)	10.54 (3.40)
Control	4.97 (2.44)	5.27 (2.50)	5.90 (2.63)	5.90 (2.63)	5.56 (2.56)	11.30 (3.51)	10.27 (3.36)	9.98 (3.31)	11.64 (3.55)	11.30 (3.51)
CD (0.05)	0.500	0.415	-	-	-	0.394	0.514	-	-	-

Figures in parenthesis are $\sqrt{x+1}$ transformed values DAT – Days after transplanting
* Carbofuran applied only at 30 DAT

(3.32) and monocrotophos 0.05 per cent (5.61) significantly reduced spider population.

Treatments *viz*., chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (7.92), imidacloprid 0.005 per cent (9.60), azadirachtin 0.004 per cent (9.66), acephate 0.05 per cent (9.94), *Bacillus thuringensis* var. kurstaki 0.2 per cent (9.98) and carbofuran 0.75 kg a.i. ha^{-1} (10.99) were not harmful to population of spiders when compared to control (10.33) on the third day after application. Only the check treatments, carbaryl 0.2 per cent (4.32) and monocrotophos 0.05 per cent (6.61) recorded significant reduction in spider population.

On the fourth day after application also the above trend was observed. Carbaryl 0.2 per cent (7.33) and monocrotophos 0.05 per cent (8.33) reduced the population significantly when compared to control (11.61).

All the treatments except carbaryl 0.2 per cent (8.64) were found to be less toxic to spiders at five days after application. The population observed were 10.33, 11.27, 10.66 and 11.90 in treatments with carbofuran 0.75 kg a.i. ha^{-1}, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, monocrotophos 0.05 per cent and control respectively. Increase in spider population was noticed in imidacloprid 0.005 per cent (11.95), acephate 0.05 per cent (12.30) *Bacillus thuringensis* var. kurstaki 0.2 per cent (12.33) and azadirachtin 0.004 per cent (12.59) treated plots but were on par with control.

At 50 DAT

One day after spraying, *Bacillus thuringensis* var. kurstaki 0.2 per cent (9.94) and carbofuran 0.75 kg a.i. ha^{-1}at 21 days after application (11.99) were found to be safe to spiders when compared to control (11.95). Other treatments such as chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (5.30), azadirachtin 0.004 per cent (6.58), acephate 0.05 per cent (7.59), imidacloprid 0.005 per cent (8.63), carbaryl 0.2 per cent (4.32) and monocrotophos 0.05 per cent (6.33) significantly reduced the spider population.

Same trend was observed on the second day also. *Bacillus thuringensis* var. kurstaki 0.2 per cent (10.61) and carbofuran 0.75 kg a.i. ha^{-1} at 22 days after application (12.59) were on par with control (13.33). All other treatments caused significant reduction in spider population which ranged from 3.97 to 8.66.

On the third, fourth and fifth days after spraying and twenty third, twenty fourth and twenty fifth days after application of carbofuran none of the treatments recorded significant reduction in spider population when compared to control and the values ranged from 5.98 to 11.64, 8.63 to 12.30 and 10.30 to 12.64 respectively.

4.2.2.5 Population Variation Recorded on Other Predators

The population of other predators recorded daily upto five days after application of insecticides at 30 DAT and 50 DAT (carbofuran applied only at 30 DAT) is depicted in Table 19.

At 30 DAT

All treatments except carbofuran 0.75 kg a.i. ha^{-1} (15.29) recorded significant reduction in predator population when compared to control (17.66) at one day after application. Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (8.98) was on par with monocrotophos 0.05 per cent (9.30) and carbaryl 0.2 per cent (7.29). The population recorded were 9.63, 10.63, 11.31 and 12.99 in treatments with acephate 0.05 per cent, imidacloprid 0.005 per cent, azadirachtin 0.004 per cent and *Bacillus thuringiensis* var. kurstaki 0.2 per cent respectively.

Two days after application also, carbofuran 0.75 kg a.i. ha^{-1} (16.64) alone was found to be safe to predator, the values recorded from the other treatments ranged from 3.32 to 16.64. Imidacloprid 0.005 per cent (9.30), acephate 0.05 per cent (9.65) and chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (9.66) were found to be statistically similar to monocrotophos 0.05 per cent (8.29) in effecting toxicity.

Imidacloprid 0.005 per cent (8.66), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (10.63), acephate 0.05 per cent (10.66) and monocrotophos 0.05

Table 18. Effect of insecticides on the population of spiders* during various growth stages of the crop

Treatments	Mean number of spiders observed at different intervals (days) after application									
	30 DAT					50 DAT				
	1	2	3	4	5	1	2	3	4	5
Acephate 0.05%	8.64 (3.11)	9.30 (3.21)	9.94 (3.31)	10.91 (3.45)	12.30 (3.65)	7.59 (2.93)	8.66 (3.11)	10.30 (3.36)	11.30 (3.51)	12.64 (3.69)
Imidacloprid 0.005%	7.92 (2.98)	8.66 (3.11)	9.60 (3.26)	10.30 (3.36)	11.95 (3.60)	8.63 (3.10)	7.92 (2.99)	9.33 (3.21)	10.61 (3.40)	12.25 (3.64)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	4.97 (2.00)	4.97 (2.44)	7.92 (2.99)	8.98 (3.17)	11.27 (3.50)	5.30 (2.51)	5.98 (2.64)	8.29 (3.05)	9.94 (3.31)	11.95 (3.60)
Azadirachtin 0.004%	5.66 (2.58)	7.29 (2.88)	9.66 (3.27)	10.63 (3.41)	12.59 (3.69)	6.58 (2.75)	8.25 (3.04)	10.33 (3.37)	11.30 (3.51)	12.62 (3.69)
Bacillus thuringiensis var. kurstaki 0.2%	9.23 (3.20)	8.95 (3.15)	9.98 (3.31)	11.64 (3.55)	12.33 (3.65)	9.94 (3.31)	10.61 (3.41)	11.64 (3.55)	11.99 (3.60)	12.33 (3.65)
Carbofuran 0.75 kg a. i./ha**	11.30 (3.51)	11.61 (3.55)	10.99 (3.46)	10.99 (3.46)	10.33 (3.37)	11.99 (3.60)	12.59 (3.69)	11.25 (3.50)	12.30 (3.65)	12.33 (3.65)
Monocrotophos 0.05%	4.97 (2.44)	5.61 (2.57)	6.61 (2.76)	8.33 (3.05)	10.66 (3.41)	6.33 (2.71)	3.97 (2.23)	8.89 (3.14)	9.94 (3.31)	11.66 (3.56)
Carbaryl 0.2%	3.97 (2.23)	3.32 (2.08)	4.32 (2.31)	7.33 (2.89)	8.64 (3.11)	4.32 (2.31)	6.28 (2.70)	5.98 (2.64)	8.63 (3.10)	10.30 (3.36)
Control	10.66 (3.41)	11.30 (3.51)	10.33 (3.37)	11.61 (3.55)	11.90 (3.59)	11.95 (3.60)	13.33 (3.79)	11.61 (3.55)	11.96 (3.60)	12.21 (3.63)
CD (0.05)	0.416	0.362	0.411	0.383	0.345	0.464	0.448	-	-	-

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

**T. maxillosa, L. pseudoannulata, O. javanus* DAT – Days after transplanting
** Carbofuran applied only at 30 DAT

per cent (8.95) reduced the predator population significantly and were on par at three days after spraying. Carbaryl 0.2 per cent (4.97) recorded highest significant reduction in population. Azadirachtin 0.004 per cent (12.99), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (14.64) and carbofuran 0.75 kg a.i. ha^{-1} (15.99) were not detrimental to predators when compared to control (14.99). Same trend was observed on the fourth day after spraying also. But on the fifth day in addition to azadirachtin (15.64), *Bacillus thuringiensis* var. kurstaki (15.64) and carbofuran (17.33), acephate (14.31) was also found safe to predators when compared to control (15.99).

At 50 DAT

One day after second spraying, carbofuran 0.75 kg a.i. ha^{-1} applied at 30 DAT (6.58) was found to be safe to predators when compared to control (7.29). All other treatments significantly reduced the predator population and it ranged from 3.25 to 4.29. Similar trend was also noticed on the second day after spraying, the range being 1.21 to 7.98.

On the third day after spraying, acephate 0.05 per cent (4.55), monocrotophos 0.05 per cent (3.28) and carbaryl 0.2 per cent (3.32) significantly reduced the predator population when compared to control (7.29). The population recorded with all other treatments ranged from 4.92 to 7.62.

Treatments *viz*., azadirachtin 0.004 per cent (7.29), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (7.54), acephate 0.05 per cent (7.62), imidacloprid 0.005 per cent (7.92), chlorpyrifos 50 EC + cypermethrin 5 EC (7.98) and carbofuran 0.75 kg a.i. ha^{-1} (7.98) were not detrimental to predators when compared to control (8.29), whereas monocrotophos 0.05 per cent (3.97) and carbaryl 0.2 per cent (4.89) significantly reduced the population of predators at four days after spraying. All the treatments were found to be safe to predators at five days after spraying, the range being 5.90 to 9.96.

Table 19. Effect of insecticides on the population of other predators during various growth stages of the crop

Treatments	Mean number of predators observed at different intervals (days) after application									
	30 DAT					50 DAT				
	1	2	3	4	5	1	2	3	4	5
Acephate 0.05%	9.63 (3.26)	9.65 (3.26)	10.66 (3.41)	12.99 (3.74)	14.31 (3.91)	3.32 (2.08)	3.65 (2.16)	4.55 (2.35)	7.62 (2.94)	8.98 (3.16)
Imidacloprid 0.005%	10.63 (3.41)	9.30 (3.21)	8.66 (3.11)	10.30 (3.36)	12.99 (3.74)	4.29 (2.30)	3.97 (2.23)	5.90 (2.63)	7.92 (2.99)	9.94 (3.31)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	8.98 (3.16)	9.66 (3.27)	10.63 (3.41)	11.64 (3.55)	12.95 (3.74)	3.25 (2.06)	5.27 (2.50)	4.92 (2.43)	7.98 (3.00)	9.96 (3.31)
Azadirachtin 0.004%	11.31 (3.51)	12.66 (3.70)	12.99 (3.74)	16.31 (4.16)	15.64 (4.08)	3.91 (2.22)	3.97 (2.23)	5.61 (2.57)	7.29 (2.88)	9.23 (3.20)
Bacillus thuringiensis var. kurstaki 0.2%	12.99 (3.74)	13.28 (3.78)	14.64 (3.95)	15.33 (4.04)	15.64 (4.08)	3.97 (2.23)	4.26 (2.29)	4.97 (2.44)	7.54 (2.92)	9.60 (3.26)
Carbofuran 0.75 kg a. i./ha*	15.29 (4.04)	16.64 (4.20)	15.99 (4.12)	16.99 (4.24)	17.33 (4.28)	6.58 (2.75)	7.62 (2.94)	7.62 (2.94)	7.98 (3.00)	7.66 (2.94)
Monocrotophos 0.05%	9.30 (3.21)	8.29 (3.05)	8.95 (3.15)	9.98 (3.31)	11.30 (3.51)	3.97 (2.23)	2.65 (1.91)	3.28 (2.07)	3.97 (2.23)	5.90 (2.63)
Carbaryl 0.2%	7.29 (2.88)	3.32 (2.08)	(4.97 2.44)	8.29 (3.05)	9.94 (3.31)	3.32 (2.08)	1.21 (1.49)	3.32 (2.08)	4.89 (2.43)	6.33 (2.71)
Control	17.66 (4.32)	16.64 (4.20)	14.99 (4.00)	17.31 (4.28)	15.99 (4.12)	7.29 (3.88)	7.98 (3.00)	7.29 (2.88)	8.29 (3.05)	7.92 (2.99)
CD (0.05)	0.334	0.280	0.295	0.312	0.337	0.416	0.438	0.505	0.407	-

Figures in parenthesis are $\sqrt{x + 1}$ transformed values DAT – Days after transplanting

* Carbofuran applied only at 30 DAT

4.2.2.6 Population Variation Recorded on Total Predators

The population of total predators recorded each day upto five days after application of insecticides at two growth stages (carbofuran applied only at 30 DAT) of the crop is presented in Table 20.

At 30 DAT

One day after application, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (24.96), azadirachtin 0.004 per cent (29.95), acephate 0.05 per cent (30.63), imidacloprid 0.005 per cent (34.29), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (37.25), monocrotophos 0.05 per cent (27.64) and carbaryl 0.2 per cent (18.31) reduced the predator population significantly when compared to control (47.30). Chlorpyrifos 50 EC + cypermethrin 5 EC, azadirachtin and acephate were statistically similar in toxicity to monocrotophos. Same trend was observed on the second day after spraying, the values ranged from 16.54 to 48.31.

Azadirachtin 0.004 per cent (42.32), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (46.33) and carbofuran 0.75 kg a.i. ha^{-1} (48.33) were found to be safe when compared to control (45.95) at three days after application. Carbaryl 0.2 per cent (23.64) recorded highest significant reduction in predator population. Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (34.65) and monocrotophos 0.05 per cent (32.99) showed the same effect.

Four days after application, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (39.62), imidacloprid 0.005 per cent (41.59), monocrotophos 0.05 per cent (36.28) and carbaryl 0.2 per cent (33.97) significantly reduced the predator population. Acephate 0.05 per cent (45.33), azadirachtin 0.004 per cent (45.63), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (47.65) and carbofuran 0.75 kg a.i. ha^{-1} (48.96) were not harmful to the population of total predators when compared to control (50.62).

Carbaryl 0.2 per cent (39.60) alone produced significant reduction in predator population at five days after spraying. All other treatments were found less toxic when compared to control (48.82) and the population ranged from 43.67 to 50.19.

At 50 DAT

On the first day and second day after second application, carbofuran 0.75 kg a.i. ha^{-1} (applied at 30 DAT) alone was found to be safe to predators when compared to control. The population of predators observed in the treatments with acephate 0.05 per cent, imidacloprid 0.005 per cent, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent, azadirachtin 0.004 per cent, *Bacillus thuringiensis*var. kurstaki 0.2 per cent, carbofuran, monocrotophos 0.05 per cent, carbaryl 0.2 per cent and control were 21.65, 24.96, 19.63, 23.25, 27.60, 38.15, 21.32, 12.95 and 39.67 on the first day and 25.23, 23.95, 21.92, 27.13, 31.97, 39.32, 16.56, 16.96 and 40.57 on the second day respectively.

Three days after spraying insecticides, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (27.55), monocrotophos 0.05 per cent (27.94) and carbaryl 0.2 per cent (22.32) recorded significant reduction in predator population when compared to control (38.66). The total predator population in all other treatments ranged from 31.89 to 38.60. Similar trend was observed on the fourth day after spraying also. Azadirachtin 0.004 per cent (36.97), acephate 0.05 per cent (39.32), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (39.64), imidacloprid 0.005 per cent (40.28) and carbofuran 0.75 kg a.i. ha^{-1} at 24 days after application (40.32) were found to be safe to predators when compared to control (41.24).

4.2.3 Effect of Insecticides on Population of Parasitoids

4.2.3.1 Population Variation Recorded on Parasitoids

The population of parasitoids recorded daily upto five days after applying insecticides at 30 DAT and 50 DAT (carbofuran applied only at 30 DAT) is presented in Table 21.

Table 20. Effect of insecticides on the population of total predators during various growth stages of the crop

Treatments	Mean number of predators observed at different intervals (days) after application									
	30 DAT					50 DAT				
	1	2	3	4	5	1	2	3	4	5
Acephate 0.05%	30.63 (5.62)	33.16 (5.84)	39.26 (6.35)	45.33 (6.81)	47.22 (6.94)	21.65 (4.76)	25.23 (5.12)	33.42 (5.87)	39.32 (6.35)	43.66 (6.68)
Imidacloprid 0.005%	34.29 (5.94)	33.66 (5.89)	38.97 (6.32)	41.59 (6.53)	47.96 (7.00)	24.96 (5.09)	23.95 (5.00)	33.27 (5.85)	40.28 (6.43)	45.18 (6.80)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	24.96 (5.09)	26.95 (5.29)	34.65 (5.97)	39.62 (6.37)	45.63 (6.83)	19.63 (4.54)	21.92 (4.79)	27.55 (5.34)	34.90 (5.99)	42.93 (6.63)
Azadirachtin 0.004%	29.95 (5.56)	34.94 (6.00)	42.32 (6.58)	45.63 (6.83)	50.19 (7.15)	23.25 (4.92)	27.13 (5.30)	31.89 (5.74)	36.97 (6.16)	44.21 (6.72)
Bacillus thuringiensis var. kurstaki 0.2%	37.25 (6.18)	39.97 (6.40)	46.33 (6.88)	47.65 (6.98)	48.98 (7.07)	27.60 (5.35)	31.97 (5.74)	34.93 (5.99)	39.64 (6.37)	45.67 (6.83)
Carbofuran 0.75 kg a. i./ha*	46.58 (6.90)	48.31 (7.02)	48.33 (7.02)	48.96 (7.07)	46.95 (6.92)	38.15 (6.26)	39.32 (6.35)	38.60 (6.29)	40.32 (6.43)	40.66 (6.45)
Monocrotophos 0.05%	27.64 (5.35)	25.57 (5.15)	32.99 (5.83)	36.28 (6.11)	43.67 (6.68)	21.32 (4.72)	16.56 (4.19)	27.94 (5.38)	34.55 (5.96)	40.64 (6.45)
Carbaryl 0.2%	18.31 (4.39)	16.54 (4.19)	23.64 (4.96)	33.97 (5.91)	39.60 (6.37)	12.95 (3.74)	16.96 (4.24)	22.32 (4.83)	30.27 (5.59)	36.98 (6.16)
Control	47.30 (6.95)	47.33 (6.95)	45.95 (6.85)	50.62 (7.18)	48.82 (7.06)	39.67 (6.38)	40.57 (6.48)	38.66 (6.30)	41.24 (6.50)	41.24 (6.50)
CD (0.05)	0.425	0.508	0.324	0.387	0.434	0.386	0.424	0.693	0.437	-

Figures in parenthesis are $\sqrt{x+1}$ transformed values DAT – Days after transplanting

* Carbofuran applied only at 30 DAT

AT 30 DAT

Treatments *viz.*, acephate 0.05 per cent (4.59), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (4.55) and carbofuran 0.75 kg a.i. ha^{-1} (6.61) did not adversely affect the population of parasitoids compared to control (6.28) at one day after spraying. Carbaryl 0.2 per cent recorded highest significant reduction in parasitoid population with cent per cent mortality.

Second day after spraying, *Bacillus thuringiensis* var. kurstaki 0.2 per cent (4.89), acephate 0.05 per cent (6.33) and carbofuran 0.75 kg a.i. ha^{-1} (7.33) were found to be safe to parasitoids when compared to control (6.92). All other treatments recorded significant reduction in population and the count ranged from 0.00 to 3.97.

Only the check treatments reduced the parasitoid population when compared to control (6.98) at three days after spraying. All other treatments were found to be safe to parasitoids and the population ranged from 4.63 to 6.98. From the fourth day onwards all the treatments were found to be safe to parasitoids, the population range being 3.97 to 6.61 and 5.56 to 7.66 in the fourth and fifth day respectively.

At 50 DAT

Bacillus thuringiensis var. kurstaki 0.2 per cent (13.97) and carbofuran 0.75 kg a.i. ha^{-1} at 21 days after application (14.31) were found to be safe to parasitoids at one day after second spraying when compared to control (16.31). Carbaryl 0.2 per cent (1.21) recorded highest reduction in the population of parasitoids followed by chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (4.89). Azadirachtin 0.004 per cent (9.98), imidacloprid 0.005 per cent (9.94) and acephate 0.05 per cent (10.57) were statistically similar in toxicity to monocrotophos 0.05 per cent (7.62).

Two days after second spraying, acephate 0.05 per cent (14.33), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (15.31) and carbofuran 0.75 kg a.i. ha^{-1} at 22 days after application (16.27) were not detrimental to parasitoids when compared to control (17.31). Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (10.30), azadirachtin 0.004 per cent (11.99), imidacloprid 0.005 per cent (12.66), monocrotophos 0.05 per cent (4.59) and carbaryl 0.02 per cent (4.26) recorded significant reduction in parasitoid count.

Azadirachtin 0.004 per cent (14.93), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (15.31), imidacloprid 0.005 per cent (16.31), carbaryl 0.2 per cent (8.66) and monocrotophos 0.05 per cent (9.30) recorded significant reduction in parasitoid population at three days after spraying. Acephate 0.05 per cent (17.65), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (19.65) and carbofuran 0.75 kg a.i. ha^{-1} at 23 days after application (17.65) were found to be safe to parasitoids when compared to control (20.95).

Fourth day after spraying, all treatments were found to be safe to parasitoids when compared to control (18.97), except monocrotophos 0.05 per cent (15.33) and carbaryl 0.2 per cent (12.66). On the fifth day after spraying, none of the treatments was toxic to parasitoids when compared to control, the values ranged from 17.65 to 21.32.

4.2.4 Effect of Insecticides on Population of Neutrals

4.2.4.1 Population Variation Recorded on Neutrals

The population of neutrals recorded each day upto five days after application of insecticides at different growth stages of the crop *viz*., 30 DAT and 50 DAT (carbofuran applied only at 30 DAT) is presented in Table 22.

At 30 DAT

All the treatments significantly reduced the population of neutrals at one day after application when compared to control (31.98). Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (7.23) was on par with acephate 0.05 per cent (8.63), imidacloprid 0.005 per cent (9.98), monocrotophos 0.05 per cent (9.30) and carbaryl 0.2 per cent (4.89).

Table 21. Effect of insecticides on the population of parasitoids during various growth stages of the crop

Treatments	Mean number of insects observed at different intervals (days) after application									
	30 DAT					50 DAT				
	1	2	3	4	5	1	2	3	4	5
Acephate 0.05%	4.59 (2.37)	6.33 (2.71)	6.58 (2.75)	5.90 (2.63)	7.33 (2.89)	10.57 (3.40)	14.33 (3.92)	17.65 (4.32)	19.31 (4.51)	20.32 (4.62)
Imidacloprid 0.005%	3.65 (2.16)	3.86 (2.20)	5.98 (2.64)	5.66 (2.58)	6.58 (2.75)	9.94 (3.31)	12.66 (3.70)	16.31 (4.16)	19.99 (4.58)	20.99 (4.69)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	2.22 (1.79)	3.25 (2.06)	4.63 (2.37)	5.61 (2.57)	7.29 (2.88)	4.89 (2.43)	10.30 (3.36)	15.31 (4.04)	19.31 (4.51)	20.28 (4.61)
Azadirachtin 0.004%	3.32 (2.08)	3.97 (2.23)	4.89 (2.43)	6.33 (2.71)	6.98 (2.82)	9.98 (3.31)	11.99 (3.60)	14.93 (3.99)	18.99 (4.47)	19.97 (4.58)
Bacillus thuringiensis var. kurstaki 0.2%	4.55 (2.35)	4.89 (2.43)	5.98 (2.64)	6.61 (2.76)	7.66 (2.94)	13.97 (3.87)	15.31 (4.04)	19.65 (4.54)	20.97 (4.69)	21.32 (4.72)
Carbofuran 0.75 kg a. i./ha*	6.61 (2.76)	7.33 (2.89)	6.64 (2.76)	6.19 (2.68)	7.62 (6.94)	14.31 (3.91)	16.27 (4.16)	17.65 (4.32)	18.31 (4.39)	19.31 (4.51)
Monocrotophos 0.05%	3.65 (2.16)	0.00 (1.00)	2.30 (1.82)	3.97 (2.23)	6.66 (2.77)	7.62 (2.94)	4.59 (2.37)	9.30 (3.21)	15.33 (4.04)	19.30 (4.51)
Carbaryl 0.2%	0.00 (1.00)	0.00 (1.00)	3.32 (2.08)	4.18 (2.28)	5.56 (2.56)	1.21 (1.49)	4.26 (2.29)	8.66 (3.11)	12.66 (3.70)	17.65 (4.32)
Control	6.28 (2.70)	6.92 (2.81)	6.98 (2.82)	5.98 (2.64)	6.58 (2.75)	16.31 (4.16)	17.31 (4.28)	20.95 (4.68)	18.97 (4.47)	19.95 (4.58)
CD (0.05)	0.514	0.477	0.546	-	-	0.491	0.372	0.375	0.250	-

Figures in parenthesis are $\sqrt{x + 1}$ transformed values DAT – Days after transplanting
* Carbofuran applied only at 30 DAT

On the second day also all the treatments exhibited the same effect as that on the first day as compared to control (28.96). Chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (11.96), acephate 0.05 per cent (12.62) and imidacloprid 0.005 per cent (13.92) showed the same effect while carbofuran 0.75 kg a.i. ha^{-1} (21.65), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (24.32) and azadirachtin 0.004 per cent (24.65) were found to be on par.

Azadirachtin 0.004 per cent (28.31) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (30.32) were found to be safe to neutrals when compared to control (30.66) on the third day after application. Other treatments significantly reduced the population which ranged from 12.62 to 21.97. Carbofuran 0.75 kg a.i. ha^{-1} (14.31) was statistically similar to monocrotophos 0.05 per cent (14.64) and carbaryl 0.2 per cent (12.62).

Similar trend was also observed on the fourth day after application. *Bacillus thuringiensis* var. kurstaki 0.2 per cent (29.31) and azadirachtin 0.004 per cent (33.98) were found to be on par with control (33.27). Carbofuran 0.75 kg a.i. ha^{-1} (9.98) recorded highest significant reduction in population.

Five days after treatment, carbofuran 0.75 kg a.i. ha^{-1} (7.33), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (28.31), carbaryl 0.2 per cent (22.65) and monocrotophos 0.05 per cent (25.66) recorded significant reduction in population. Carbofuran recorded highest significant reduction. Acephate 0.05 per cent (29.65), imidacloprid 0.005 per cent (31.32), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (31.66) and azadirachtin 0.004 per cent (33.32) were not harmful to neutrals when compared to control (31.32).

At 50 DAT

Carbofuran 0.75 kg a.i. ha^{-1} applied at 30 DAT (13.65) alone was found to be safe to neutrals at one day after second spraying. All other treatments significantly reduced the population of neutrals when compared to control (14.96). The population ranged from 2.65 to 7.62. Acephate 0.05 per cent (3.97) and chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (3.97) were on par with carbaryl 0.2 per cent (2.65).

On the second day after second application also carbofuran 0.75 kg a.i. ha^{-1} applied at 30 DAT (13.31) showed the same trend when compared with control (14.64). All other treatments significantly reduced the population of neutrals, the population ranged from 3.97 to 10.63.

Imidacloprid 0.005 per cent (10.94), azadirachtin 0.004 per cent (12.32), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (12.66) and carbofuran 0.75 kg a.i. ha^{-1} at 23 days after application (13.31) were not detrimental to neutrals when compared to control (13.64) at three days after spraying. Acephate 0.05 per cent (8.29) and chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (8.89) significantly reduced the population of neutrals as seen in carbaryl 0.2 per cent (6.98) and monocrotophos 0.05 per cent (7.29) and were found to be on par.

Four days after spraying, chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (10.99), carbaryl 0.2 per cent (9.98) and monocrotophos 0.05 per cent (10.30) were found to be toxic, as they significantly reduced the population when compared to control (14.31). Other treatments *viz*., acephate 0.05 per cent (12.65), imidacloprid 0.005 per cent (13.31), *Bacillus thuringiensis* var. kurstaki 0.2 per cent (13.62), azadirachtin 0.004 per cent (14.31) and carbofuran 0.75 kg a.i. ha^{-1}at 24 days after application (14.97) were not harmful to neutrals. All the treatments were found to be safe when compared to control (12.62) on the fifth day after spraying, the population ranged from 12.33 to 15.31.

4.2.5 Effect of Insecticides on Overall Population of Arthropods

Overall population of pests, predators, parasitoids and neutrals recorded from one to 20 days after two applications of insecticides at 31 DAT to 70 DAT is depicted in Table 23.

Significantly lower population of total pests was recorded (3248.67 to 3698.33) over control (3898.67) in all treatments. Highest reduction in the

Table 22. Effect of insecticides on the population of neutrals during various growth stages of the crop

Treatments	Mean number of insects observed at different intervals (days) after application									
	30 DAT					50 DAT				
	1	2	3	4	5	1	2	3	4	5
Acephate 0.05%	8.63 (3.10)	12.62 (3.69)	18.65 (4.43)	26.31 (5.23)	29.65 (5.54)	3.97 (2.23)	5.56 (2.56)	8.29 (3.05)	12.65 (3.69)	15.31 (4.04)
Imidacloprid 0.005%	9.98 (3.31)	13.92 (3.86)	21.97 (4.79)	26.32 (5.23)	31.32 (5.69)	4.92 (2.43)	6.92 (2.81	10.94 (3.46)	13.31 (3.78)	12.59 (3.69)
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	7.23 (2.87)	11.96 (3.60)	17.65 (4.32)	22.94 (4.89)	28.31 (5.41)	3.97 (2.23)	6.61) (2.76	8.89 (3.14)	10.99 (3.46)	14.99 (4.00)
Azadirachtin 0.004%	17.32 (4.28)	24.65 (5.06)	28.31 (5.41)	33.98 (5.91)	33.32 (5.86)	7.62 (2.94)	10.63) (3.41	12.32 (3.65)	14.31 (3.91)	14.32 (3.91)
Bacillus thuringiensis var. kurstaki 0.2%	16.96 (4.24)	24.32 (5.03)	30.32 (5.60)	29.31 (5.51)	31.66 (5.71)	6.64 (2.76)	9.33) (3.21)	12.66 (3.70)	13.62 (3.82)	14.57 (3.95)
Carbofuran 0.75 kg a. i./ha*	24.32 (5.03)	21.65 (4.76)	14.31 (3.91)	9.98 (3.31)	7.33 (2.89)	13.65 (3.83)	13.31 (3.78)	13.31 (3.78)	14.97 (4.00)	13.99 (3.87)
Monocrotophos 0.05%	9.30 (3.21)	7.98 (3.00)	14.64 (3.95)	20.95 (4.68)	25.66 (5.16)	4.59 (2.37)	3.97 (2.23)	7.29 (2.88)	10.30 (3.36)	12.65 (3.69)
Carbaryl 0.2%	4.89 (2.43)	7.62 (2.94)	12.62 (3.69)	17.96 (4.35)	22.65 (4.86)	2.65 (1.91)	4.32 (2.31)	6.98 (2.82)	9.98 (3.31)	12.33 (3.65)
Control	31.98 (5.74)	28.96 (5.47)	30.66 (5.63)	33.27 (5.85)	31.32 (5.69)	14.96 (3.99)	14.64 (3.95)	13.64 (3.83)	14.31 (3.91)	12.62 (3.69)
CD (0.05)	0.466	0.395	0.306	0.356	0.200	0.366	0.438	0.371	0.357	-

Figures in parenthesis are $\sqrt{x+1}$ transformed values DAT – Days after transplanting

* Carbofuran applied only at 30 DAT

population of total pests was observed in treatments with chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (3291.00) which was on par with the insecticide checks *viz.*, monocrotophos 0.05 per cent (3305.33) and carbaryl 0.2 per cent (3248.67). Acephate 0.05 per cent recorded a population count of 3363.67 which was significantly lower than treatments *viz.*, imidacloprid 0.005 per cent (3477.33), carbofuran 0.75 kg a.i. ha^{-1} (3489.00), azadirachtin 0.004 per cent (3561.33) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (3698.33). Imidacloprid was found statistically similar to carbofuran.

Similar trend was observed in the suppression of predator population. All the treatments significantly reduced the predators when compared to control (1490.33). Carbaryl 0.2 per cent (1248.33) recorded highest significant reduction in predator population. Acephate 0.05 per cent (1334.33), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (1346.67) and imidacloprid 0.005 per cent (1365.00) were statistically similar in effect to monocrotophos 0.05 per cent (1319.33). Azadirachtin 0.004 per cent (1384.00) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (1385.67) were on par with carbofuran 0.75 kg a.i. ha^{-1} (1421.00).

Acephate 0.05 per cent (533.33) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (546.33) were found to be less toxic to parasitoids when compared to control (548.00). Azadirachtin 0.004 per cent (513.33) and carbofuran 0.75 kg a.i. ha^{-1} (507.67) were found to be statistically similar in effect to imidacloprid 0.005 per cent (517.00) and chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (514.00) and these treatments significantly reduced parasitoid population. Carbofuran was on par with monocrotophos 0.05 per cent (488.67) and carbaryl 0.2 per cent (490.67).

Carbofuran 0.75 kg a.i. ha^{-1} (558.00) significantly reduced the population of neutrals when compared to all other treatments. Azadirachtin 0.004 per cent (744.64) and *Bacillus thuringiensis* var. kurstaki 0.2 per cent (754.33) were found to be less toxic to neutrals when compared to control (763.33). Acephate 0.05 per cent (669.33), chlorpyrifos 50 EC + cypermethrin 5 EC 0.05 per cent (673.00) and

Table 23. Effect of insecticides on overall population of arthropods recorded from 31 to 70 DAT

Treatments	Total Pests	Total Predators	Total Parasitoids	Total Neutrals
Acephate 0.05%	3363.67	1334.33	533.33	669.33
Imidacloprid 0.005%	3477.33	1365.00	517.00	677.33
Chlorpyrifos 50 EC+ Cypermethrin 5 EC 0.05%	3291.00	1346.67	514.00	673.00
Azadirachtin 0.004%	3561.33	1384.00	513.33	744.67
Bacillus thuringiensis var. kurstaki 0.2%	3698.33	1385.67	546.33	754.33
Carbofuran 0.75 kg a. i./ha	3489.00	1421.00	507.67	558.00
Monocrotophos 0.05%	3305.33	1319.33	488.67	668.33
Carbaryl 0.2%	3248.67	1248.33	490.67	642.00
Control	3898.67	1490.33	548.00	763.33
CD (0.05)	56.090	48.952	19.579	51.197

imidacloprid 0.005 per cent (677.33) were statistically similar to monocrotophos 0.05 per cent (668.33) and carbaryl 0.2 per cent (642.00).

4.3 EFFECT OF APPLICATION OF INSECTICIDES ON GRAIN AND STRAW YIELD

The mean grain and straw yield obtained from various treatments in the field experiment are presented in Table 24.

Mean grain yield obtained from different plots receiving various treatments did not record any significant difference. The average yield of grain ranged from 2466.70 to 2923.30 kg ha^{-1}. Mean straw yield obtained from different plots also showed the same trend and the average yield obtained ranged from 3166.70 to 4166.70 kg ha^{-1}.

Table 24. The mean dry weight of grain and straw (kg ha^{-1})

Treatments	Grain Yield	Straw yield
Acephate 0.05%	2923.30	4000.00
Imidacloprid 0.005%	2850.00	4166.70
Chlorpyrifos 50 EC + Cypermethrin 5 EC 0.05%	2750.00	3833.30
Azadirachtin 0.004%	2466.70	3166.70
Bacillus thuringiensis var. kurstaki 0.2%	2616.70	3333.30
Carbofuran 0.75 kg a. i./ha	2666.70	3666.70
Monocrotophos 0.05%	2883.30	3666.70
Carbaryl 0.2%	2783.30	3500.00
Control	2666.70	3500.00
CD (0.05)	-	-

Discussion

5. DISCUSSION

In most part of the rice growing areas of the world, rice is cultivated in wetlands. Under such conditions, a tetra-level interaction exists between plant, pest, natural enemy and neutral. However, species composition and status of pests, natural enemies and neutrals are changing. At times this leads to pest outbreaks because of the influence of environmental factors and human interference. Such status variations of the pests in different rice ecosystems and out breaks of the pests over a period of time were reported by various workers from Kerala (Nair, 1978; KAU, 1995; Nadarajan, 1996; Ambikadevi, 1998). Sucking pests emerged as a serious problem in most of the fields in the last two decades (Heinrichs and Mochida, 1984; Kenmore *et al*., 1984; Heong and Aquino, 1990; Premila, 2003).

Wide spread adoption of high yielding varieties, modern agronomic practices and extensive use of pesticides not only aggravated pest problems but also led to significant changes in the status of the pests. According to Kenmore *et al*. (1985), Kenmore *et al*. (1987) and Bottrell (1993) rice areas in Asia using heavy insecticide applications have experienced destruction of natural enemies resulting in serious outbreaks of pests.

Apart from pests and natural enemies, neutrals (non pest and non beneficial) also play an important role in rice ecosystem as they serve as abundant source of food for generalist predators early in the crop season, enabling the build up of predators even before pests appear. Under normal climatic conditions use of tolerant varieties and conservation of the existing natural enemies is the ‘best mix’ for rice pest management (Pimbert, 1991). It has to be emphasized here that even though the neutrals are very important in rice pest management, not much work has been carried out so far to find out the harmful effect of insecticides on these organisms.

In the wetland situation of Kerala, cultivation of tolerant varieties, detection of pest infestation in the initial stages of attack, avoidance of insecticide application in the vegetative phase of the crop (where the natural enemies out numbered the pests) and pocket application of insecticide in the heavily infested pockets are recommended for ecofriendly pest management (KAU, 2002). As pocket application of insecticides is one of the steps recommended for rice pest management, screening of selective insecticides is necessary. The insecticides screened out should be safe to natural enemies and neutrals and at the same time effectively suppress the pest population. With this view, the present investigation was taken up to fill up the gap in understanding the present status of the pest, natural enemy and neutral complex in the rice ecosystem under the prevailing climatic conditions and to find out the effect of five synthetic insecticides, an insecticide mixture, a plant product and a microbial agent on the three groups of organisms and to explore the possibilities of utilizing them in pest management.

5.1 RELATIVE STATUS OF ARTHROPOD COMMUNITY IN RICE ECOSYSTEM

The arthropod community fluctuations (Fig.1) in the unsprayed rice fields revealed the dominance of neutrals in the initial stage of crop growth when compared to pests and natural enemies. The population of pests, predators and parasitoids gradually increased and reached the peaks at 45, 30 and 60 DAT respectively. The neutrals showed a gradual reduction from the vegetative to reproductive stage of the crop. This condition of arthropod community in the wetland rice ecosystem was well documented by Settle *et al*. (1996), Nalinakumari *et al*. (1996) and Nalinakumari and Hebsybai (2002). Analysis of the arthropod community (Fig.2a) showed the dominance of pests (55.31 per cent), followed by predators (20.99 per cent), neutrals (15.05 per cent) and parasitoids (8.65 per cent). Detailed examination of the pest population (Fig.2b) revealed that only two major pests *C. medinalis* (26.27 per cent) and *L. acuta* (16.48 per cent) existed in the observational fields. Moderate levels of *H. philippina* (16.38 per cent), *O. chinensis* (13.28 per cent) and *Nephotettix* spp. (10.92 per cent), which are considered as minor pests, were recorded. The population of ten more pests observed was very low and their percentage occurrence ranged from 0.28 to 2.64. The population of sucking pests was low (38.05 per cent) as compared with those of tissue feeders (61.95 per cent). *N. lugens* was a major pest (KAU, 1983) and *S. furcifera* established as a major problem in the rice ecosystem since 1997 in Kerala (Ambikadevi *et al.*, 1998). However very low population of *N. lugens* and *S. furcifera* and comparatively high population of *Nephotettix* spp. were observed in the present study. In the present investigation, the variety used was *Aiswarya* which is tolerant to plant hoppers. This could be attributed as the reason for the low population of plant hoppers. In general, wide spread cultivation of tolerant varieties suppresses the multiplication of these pests. A gradual increase in the population of *Nephotettix* spp. was reported from the major rice tracts of Kerala (KAU, 1995; Ambikadevi *et al.*, 1998; Premila, 2003).

Another interesting observation recorded from the observational fields was the negligible population of *S. incertulas* and the absence of *O. oryzae* and *N. depunctalis* (Fig. 2b), still considered as major pests and moderately high levels of *O. chinensis* and *H. philippina* reported as minor pests in the state (KAU, 2002; Nair, 1999). When a particular pest species is affected by specific interventions such as growing resistant varieties or application of insecticides, other species living in the same niche may become dominant due to lack of competition. Similar observations were made by Heong and Aquino (1990).

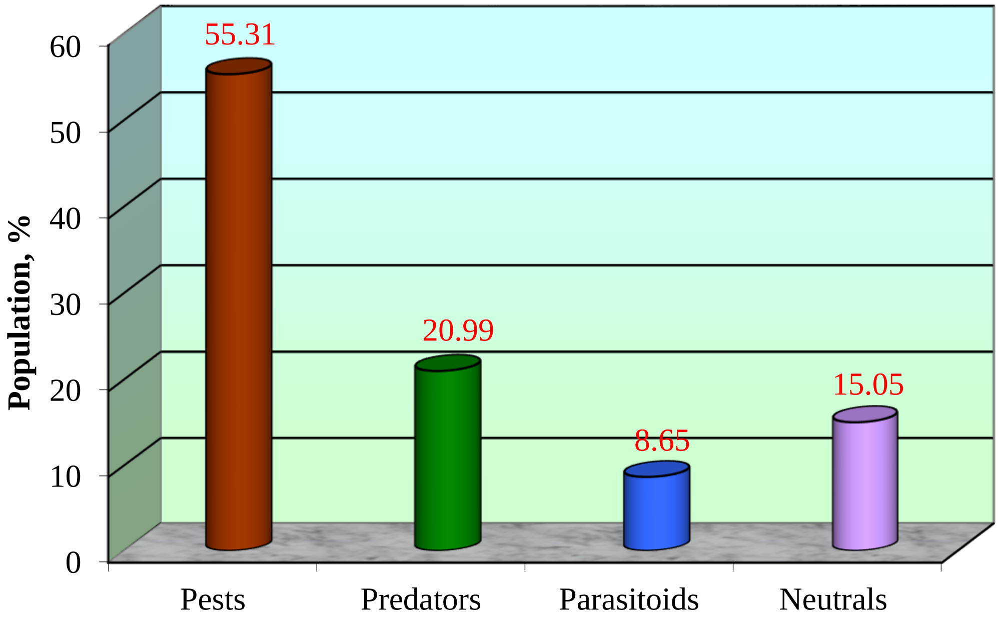


Fig. 2a. Percentage population of pests, predators, parasitoids and neutrals in rice ecosystem

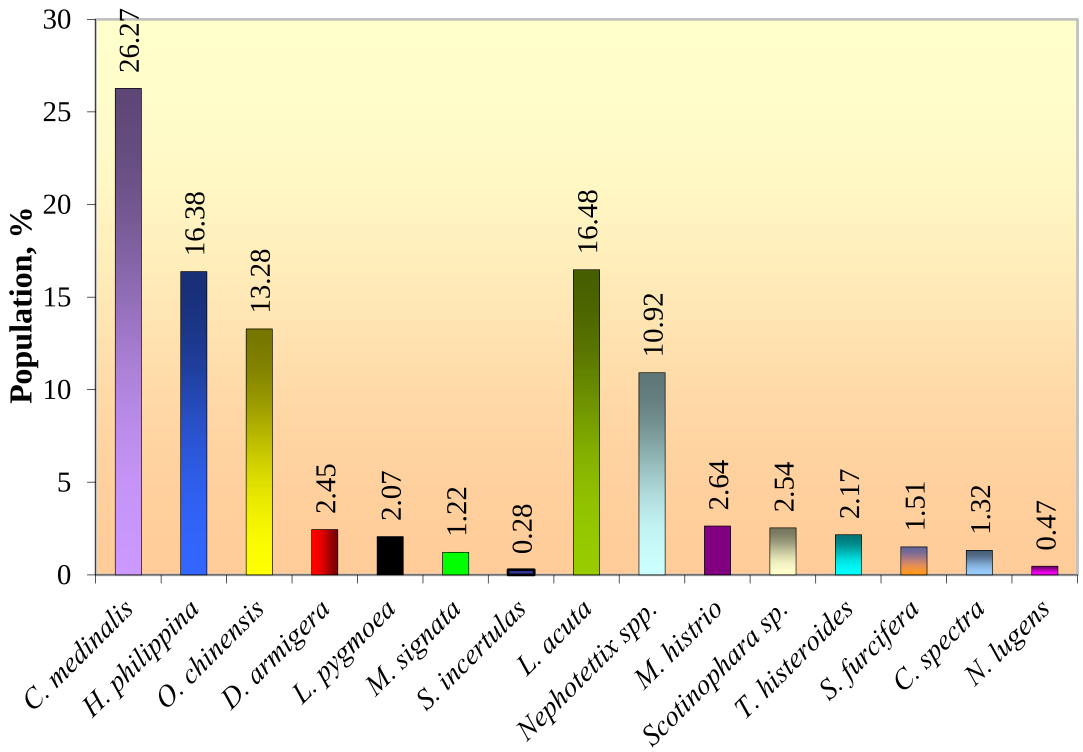


Fig. 2b. Percentage population of different pests in rice ecosystem

5.2 EVALUATION OF THE EFFECT OF INSECTICIDES ON ARTHROPOD COMMUNITY IN THE RICE ECOSYSTEM

An evaluation of the response of pests, predators, parasitoids and neutrals to insecticides is necessary for the better utilization of beneficials in pest management. As already stated, insecticides which are effective in controlling the pests without having much adverse effect on predators, parasitoids and neutrals are best suited for inclusion in IPM. In this context it has been emphasized that in the modern IPM, the arthropod community is to be assessed before taking decision on insecticide application (KAU, 2002).

Certain insecticides have a narrow spectrum of activity and are selective on individual pest species and natural enemies. It may be pointed out that such insecticides which are selective in pest suppression, having no adverse effect on predators, parasitoids and neutrals are suited for application in the vegetative phase, due to the presence of large number of beneficials in the rice ecosystem during the period. During the reproductive stage of rice crop, especially in the flowering time, effective and highly persistent insecticides are to be used for immediate and long lasting suppression of the pests as the beneficials are very low during that period. In the present study, analysis of the impact of various insecticides revealed that the insecticides tested differ in their effect on pests, predators, parasitoids and neutrals (Fig.3b). The persistent toxicity of most of the insecticides tested was less than their respective check treatments. They are effective against the pests; some are less toxic to natural enemies and neutrals when compared with check. The persistent toxicity of these insecticides on various groups of organisms vary very much. Immediate effect of these insecticides on pest was noticed in all treatments except in carbofuran.

In most of the locations, where rice is cultivated in large areas, many of the major and minor pests of rice have graminacious weeds as

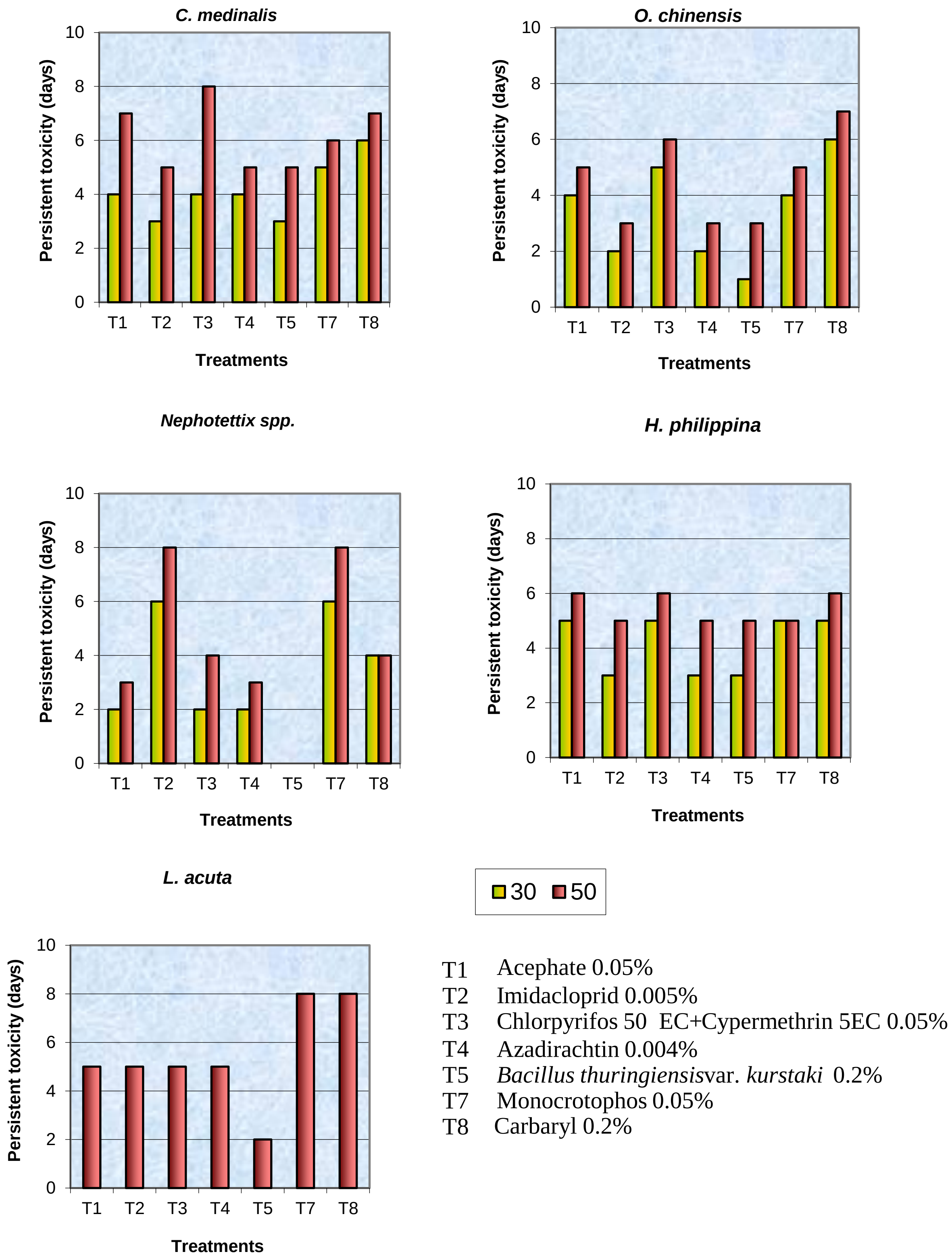
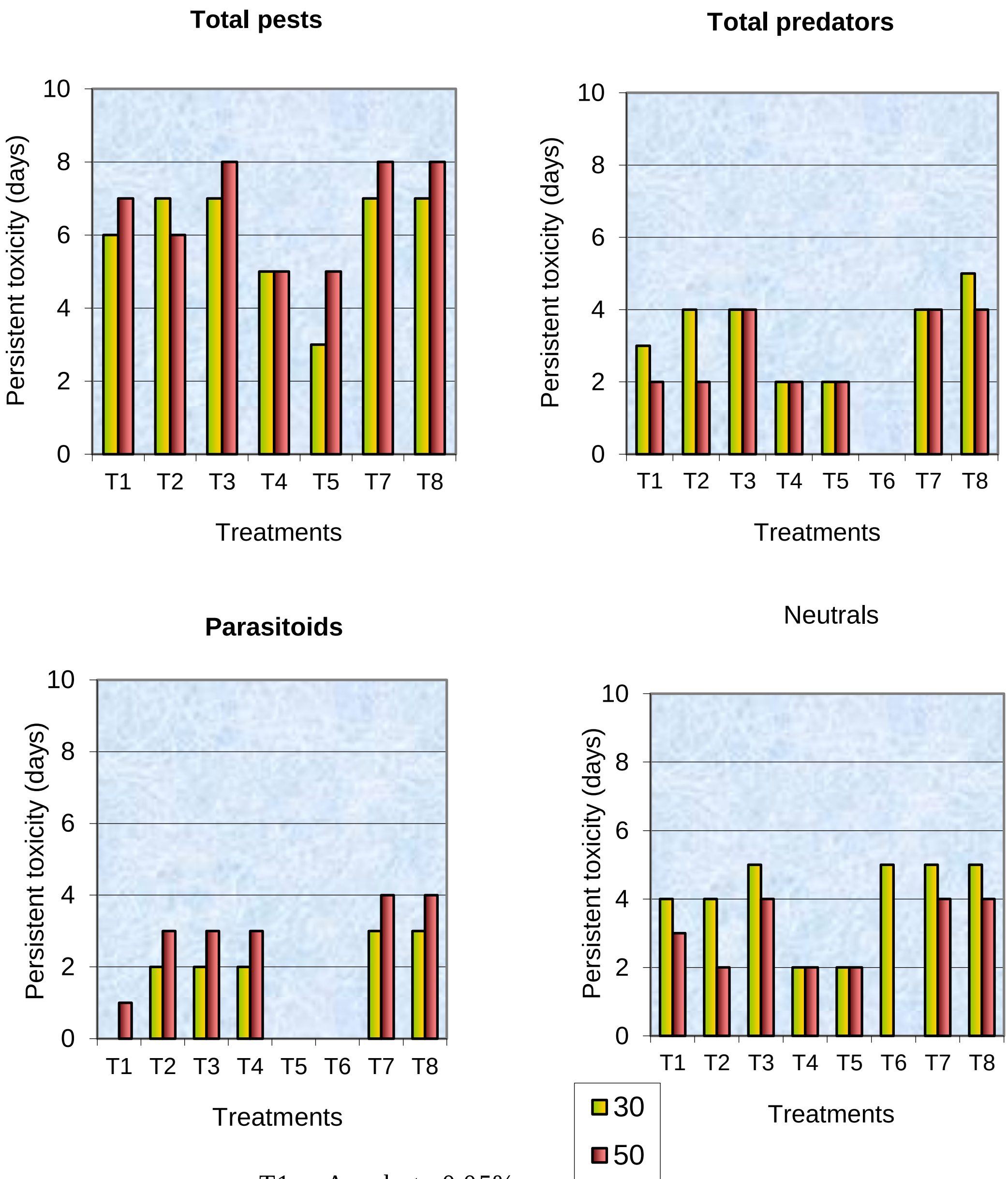


Fig. 3a Persistent toxicity of different insecticides applied at 30 and 50 DAT on pests of rice

alternate hosts, where the pests will survive during off seasons and when staggered cultivation is practiced either due to labour shortage or other reasons, there will be continuous multiplication of pests. This will result in the migration of these pests to new areas. Many of these pests can fly long distances and start fresh infestations (Reissig *et al.*, 1986). Under such situations, emphasis should be given to choose insecticides with long persistent toxicity for effective suppression of the pests. In the present study, insecticides with varying persistent toxicity were screened out.

General trend observed in the bioefficacy of insecticides on various groups of organisms has given a clear picture of variations in the persistent toxicity. The persistent toxicity of insecticides on pests and parasitoids was much pronounced in the reproductive stage of the crop than in the vegetative phase whereas that on predators and neutrals was more in the vegetative phase (Fig.3b). This variation in the persistence of these insecticides may be due to the variations in the comparative abundance of these organisms in a particular period (Fig.1). The persistent toxicity of total population of each group of organism is more than that of the individual species in that group in most of the cases. This supports the variation in the persistent toxicity of insecticides on the individual group of organisms in the vegetative as well as reproductive stage of the crop. In the present investigation the cultivation started at the end of monsoon period and there was rainfall during the vegetative phase of the crop (Fig.1). This also might have contributed to the comparatively low persistence of the insecticides on pests during the vegetative phase.

Among the different groups of insecticides tested, the insecticide mixture, chlorpyrifos 50 EC + cypermethrin 5 EC was found to be the most effective in suppressing the tissue feeders, *viz.*, *C. medinalis*, *O. chinensis* and *H. philippina*. It effectively suppressed *C. medinalis* and the persistent toxicity exceeded that of check treatments whereas the persistent toxicity of the chemical on *H. philippina* was same as that of



T1 Acephate 0.05%
T2 Imidacloprid 0.005%
T3 Chlorpyrifos 50 EC+ Cypermethrin 5EC 0.05%
T4 Azadirachtin 0.004%
T5 *Bacillus thuringiensis* var. *kurstaki* 0.2%
T6 Carbofuran 0.75 kg a. i./ha
T7 Monocrotophos 0.05%
T8 Carbaryl 0.2%

Fig. 3b Persistent toxicity of different insecticides applied at 30 and 50 DAT on total pests, total predators, parasitoids and neutrals in rice ecosystem

carbaryl and more than monocrotophos (Fig.3a). The percentage reduction in the population of *C. medinalis, O. chinensis* and *H. philippina* over control for a period of seven days was 54.45, 46.38 and 54.65 respectively in the reproductive stage of the crop (Fig.4a and b). Various workers supported the superiority of chlorpyrifos 50 EC + cypermethrin 5 EC in suppressing *C. medinalis* (Wakil *et al*., 2001; Krishnaiah *et al*., 2002). The insecticide was effective in reducing the population of *Nephotettix* spp. and *L. acuta* but persistence was comparatively low. The overall reduction in the population recorded over seven days was 40.85 per cent in *Nephotettix* spp. and 31.66 per cent in *L. acuta*. The effect of the insecticide showed varying trend in individual predators. It was found toxic to important groups of predators viz., O. *nigrofasciata*, spiders and *Agriocnemis* spp. and was safe to coccinellids. The safety of the insecticide to coccinellids was reported earlier (Kodandaram and Dhingra, 2003). The toxicity was found for longer period against spiders in particular and against predators in general (Fig.5b and c). The parasitoids and neutrals were also adversely affected by the insecticide (Fig.6). Chlorpyriphos 40 EC was reported to be toxic to parasitoids (Logiswaram *et al*., 1987).

Analysis of data on the effect of acephate also gave some what the same effect as that of chlorpyrifos 50 EC + cypermethrin 5 EC in effecting the suppression of tissue feeders, sap suckers and total population of the pests. Acephate and carbaryl exhibited longer toxic effect on *C. medinalis* and *H. philippina*. The insecticide effectively suppressed the population of *O. chinensis* and the persistence was for shorter period than its check. The chemical checked the total population of pests for about a week. The toxicity of the insecticide to *Nephotettix* spp. and *L. acuta* was comparatively for a lesser period (Fig.3a and b). The percentage suppression of *C. medinalis* over seven days was 21.32 and 50.00 in the first and second application of acephate respectively (Fig.4a), which is in agreement with 50.00 per cent (Korat *et al*., 1999) and 85.90 per cent

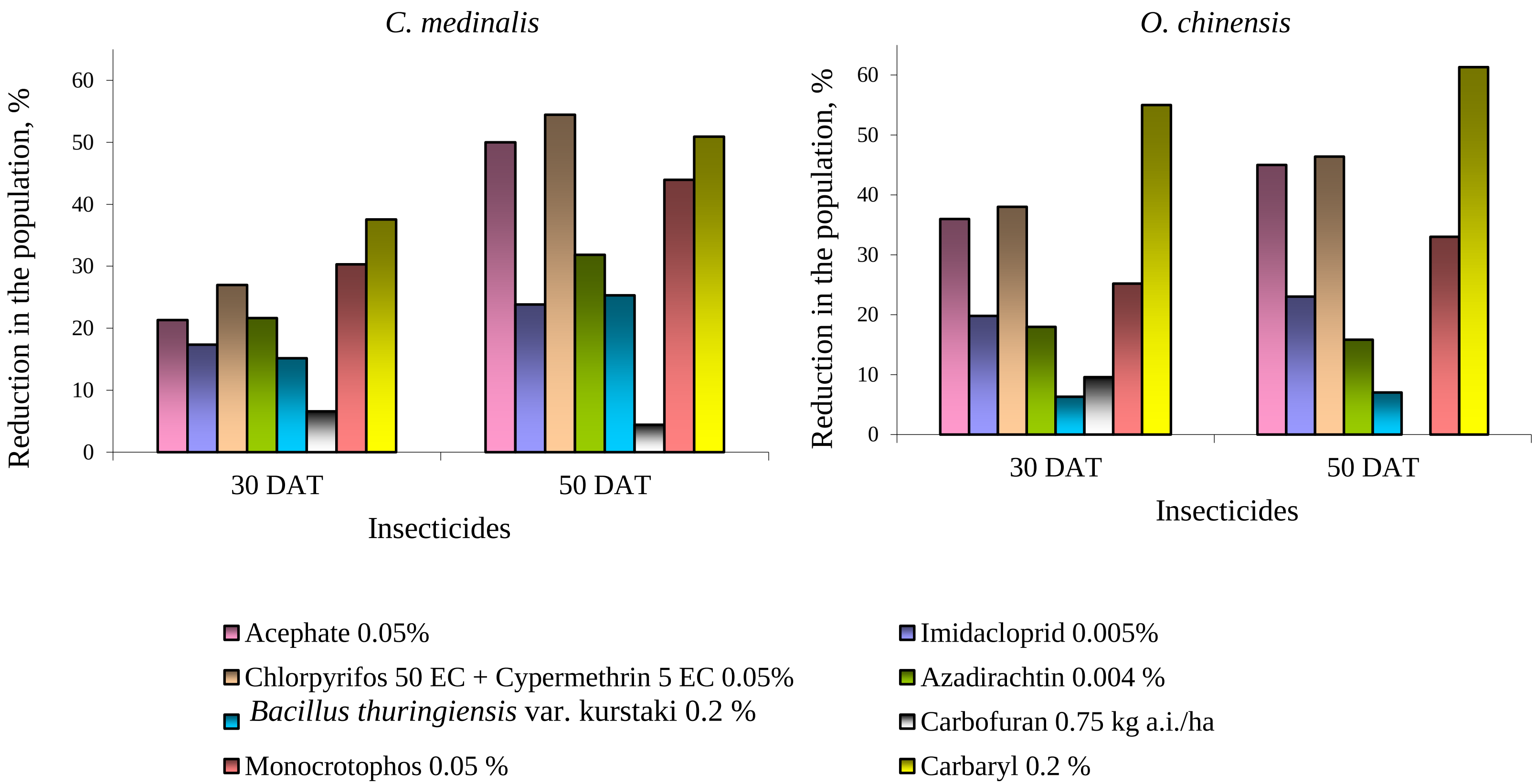


Fig. 4a Effect of different insecticides applied at 30 and 50 DAT on the population of pests observed over a period of seven days

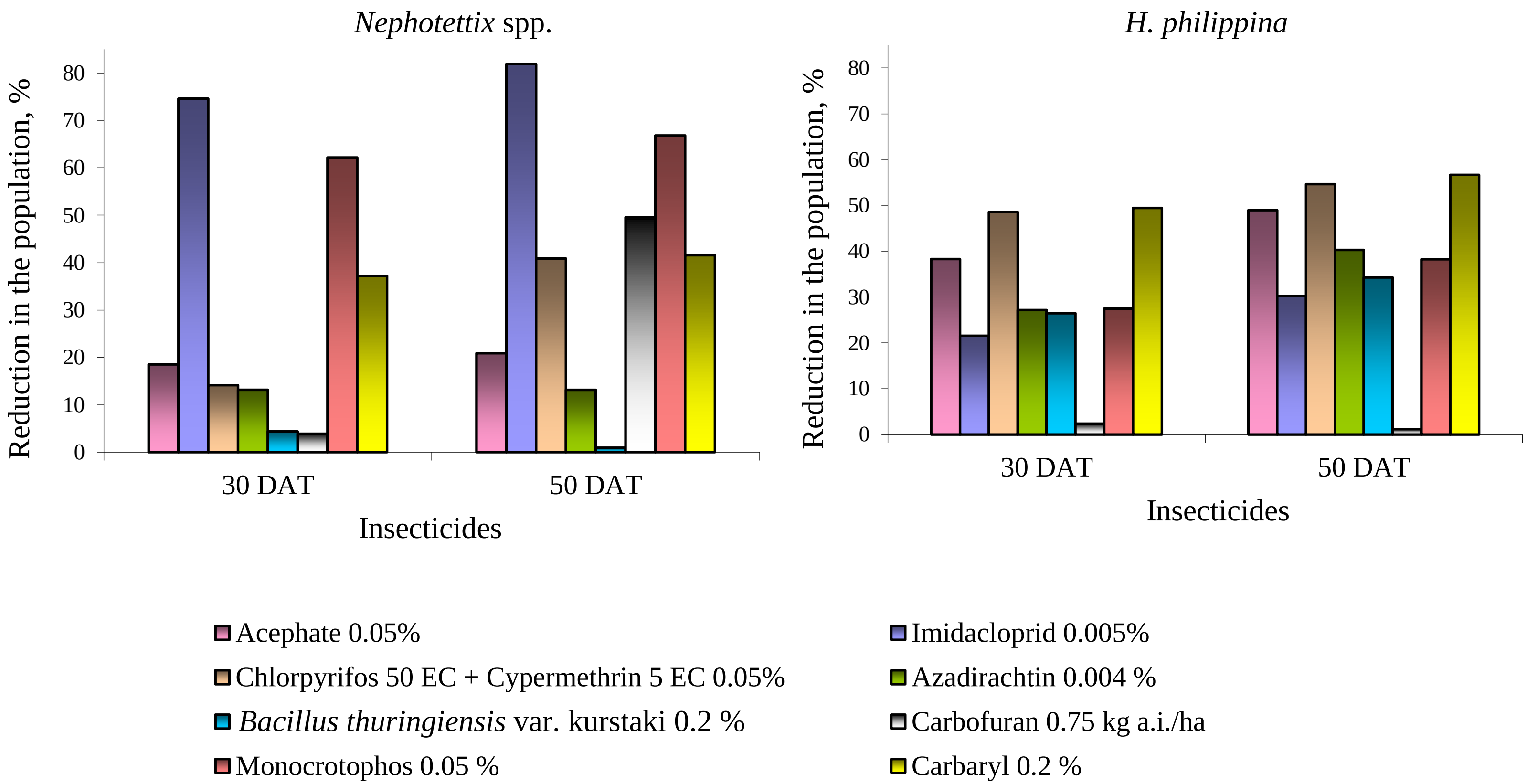


Fig. 4b Effect of different insecticides applied at 30 and 50 DAT on the population of pests observed over a period of seven days

(Zhong *et al*., 2002) reported earlier. The result obtained in the study on the effectiveness of acephate to *Nephotettix* spp. was supported by the report of Hsieh (1976), Mani and Jayaraj (1976b) and Kumar *et al*. (1988). Acephate 750 g a.i.ha^{-1} effected 100 per cent mortality of *L. acuta* (Kay *et al.*, 1993) as compared to 60 per cent mortality obtained in the study with 600 g a.i. ha^{-1}. Acephate was found to be toxic to predators and safe to parasitoids. Varying trend in the toxicity of the chemical to spiders was reported by different workers. Acephate was relatively safe (Chiu and Cheng, 1976; Kumar and Velusamy, 1996), less toxic (Fabellar and Heinrichs, 1984), reduced the growth and predation (Thang *et al*., 1987). Contradictory to the results obtained in the present study, it was reported as toxic to parasitoids (Singh *et al.*, 1994). The safety of the chemical observed in the earlier study (KAU, 1995) was in consonance with the present observation. Long lasting suppression of the neutrals by the toxicant was observed in the present study. Klass and Olson (1985) supported this result. However, Fei *et al.* (1999) found the development of resistance due to frequent use of the chemical.

Imidacloprid exhibited different trend on the pests in rice ecosystem. It was highly toxic to *Nephotettix* spp. and cent per cent suppression of the pest was recorded on third and fourth days after application, the effect being more than that of the check, monocrotophos. The toxicity of the chemical remained for one week as in the case of the check (Fig.3a). The percentage reduction in the population of the pests over seven days ranged from 74.59 to 81.89 (Fig. 4b) and the result was supported by the findings of Manjunatha and Shivanna (2001). The chemical effectively suppressed the population of *C. medinalis, H. philippina* and *L. acuta* and the toxicity against these pests remained for five days (Fig.3a). It was found effective against *O. chinensis* and the effectiveness was for a shorter period. Krishnaiah *et al.* (2002) reported that imidacloprid @ 25 g a.i. ha^{-1} was not very effective against *C. medinalis* whereas Lekha (2003) found it effective against the pest at 0.005 per cent.

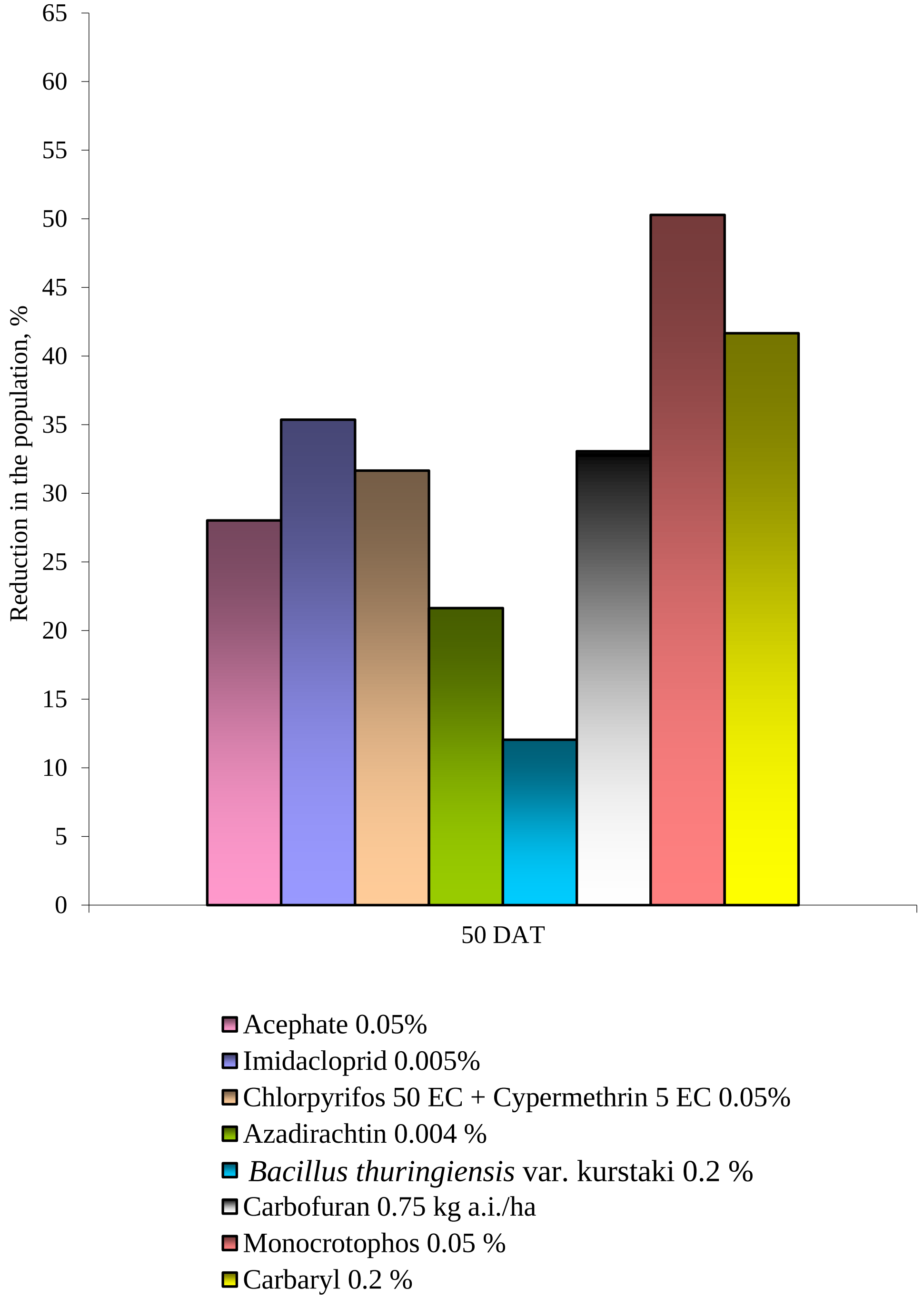


Fig. 4c Effect of different insecticides applied at 50 DAT on the population of *L. acuta*observed over a period of seven days

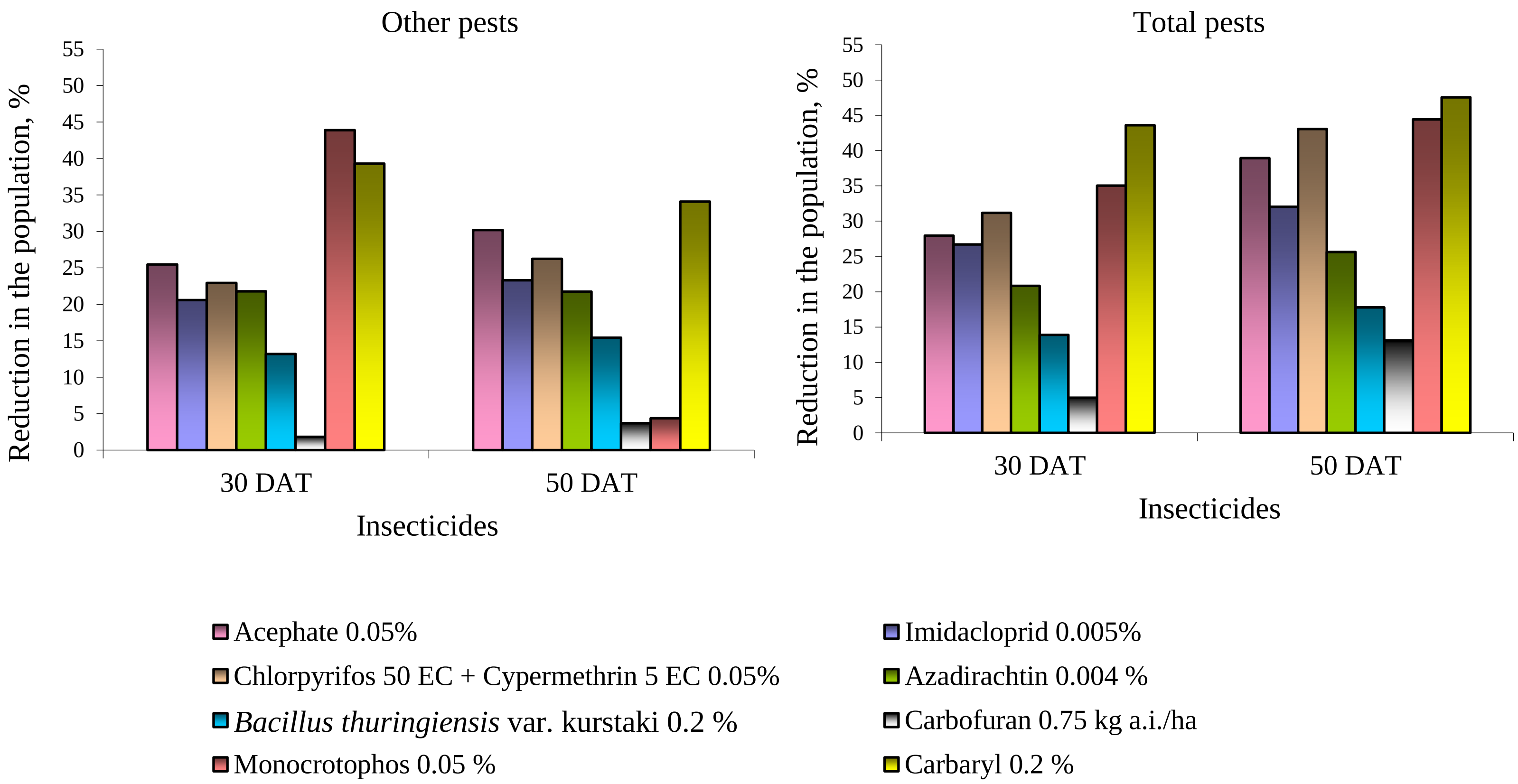


Fig. 4d Effect of different insecticides applied at 30 and 50 DAT on the population of pests observed over a period of seven days

Imidacloprid reduced the population of *L. acuta* upto 10 days (Misra, 2003) whereas suppression of the pest was observed only for five days in the present study. The variation in the persistence may be due to differences in the weather conditions in the place of study. Imidacloprid was found to be toxic to *O. nigrofasciata* and spiders and safer to *Agriocnemis* spp. and coccinellids in the study. This variation in the toxicity of the chemical was reported by several workers (Mao and Liang, 1995; Satheesan *et al.*, 2002; Lekha, 2003). Imidacloprid was found to be highly toxic to parasitoids and neutrals (Fig. 6). The toxic effect on parasitoids was contradicted by Kumar and Santharam (1999) and variation in the toxicity to different parasitoids was reported by Lekha (2003). According to Song and Brown (1998) varying levels of toxicity was observed in different species of culicids.

Carbofuran showed a different trend on its effect on the arthropod community in rice ecosystem. Carbofuran 0.75 kg a.i. ha^{-1} was applied at 30 DAT but immediate effect shown by the toxicant was only on neutrals and the toxicity lasted for five days (Fig.3b). The delayed toxic effect of the chemical was observed on *Nephotettix* spp., *L. acuta* and total population of the pests. The suppression of *Nephotettix* spp. was started from 15 days after application and it lasted up to 28 days. *L. acuta* population declined from 21^{st} to 28^{th} days after the application as the incidence of the pest was observed only during that period. Significant reduction in the total population of the pests was observed from seven to 28 days after application of the granule. The effective suppression of *Nephotettix* spp. by carbofuran was reported by various workers (Hsieh, 1976; Pillai, 1981; Kim *et al*., 1984; Krishnaiah *et al*., 2003). The ineffectiveness of carbofuran against *L. acuta* reported by Kay *et al.* (1993), was not in full agreement to the present result. This may be due to the variation in the time of application of the toxicant. Carbofuran did not produce any toxic effect on other pests and was found completely safe to predators and parasitoids.

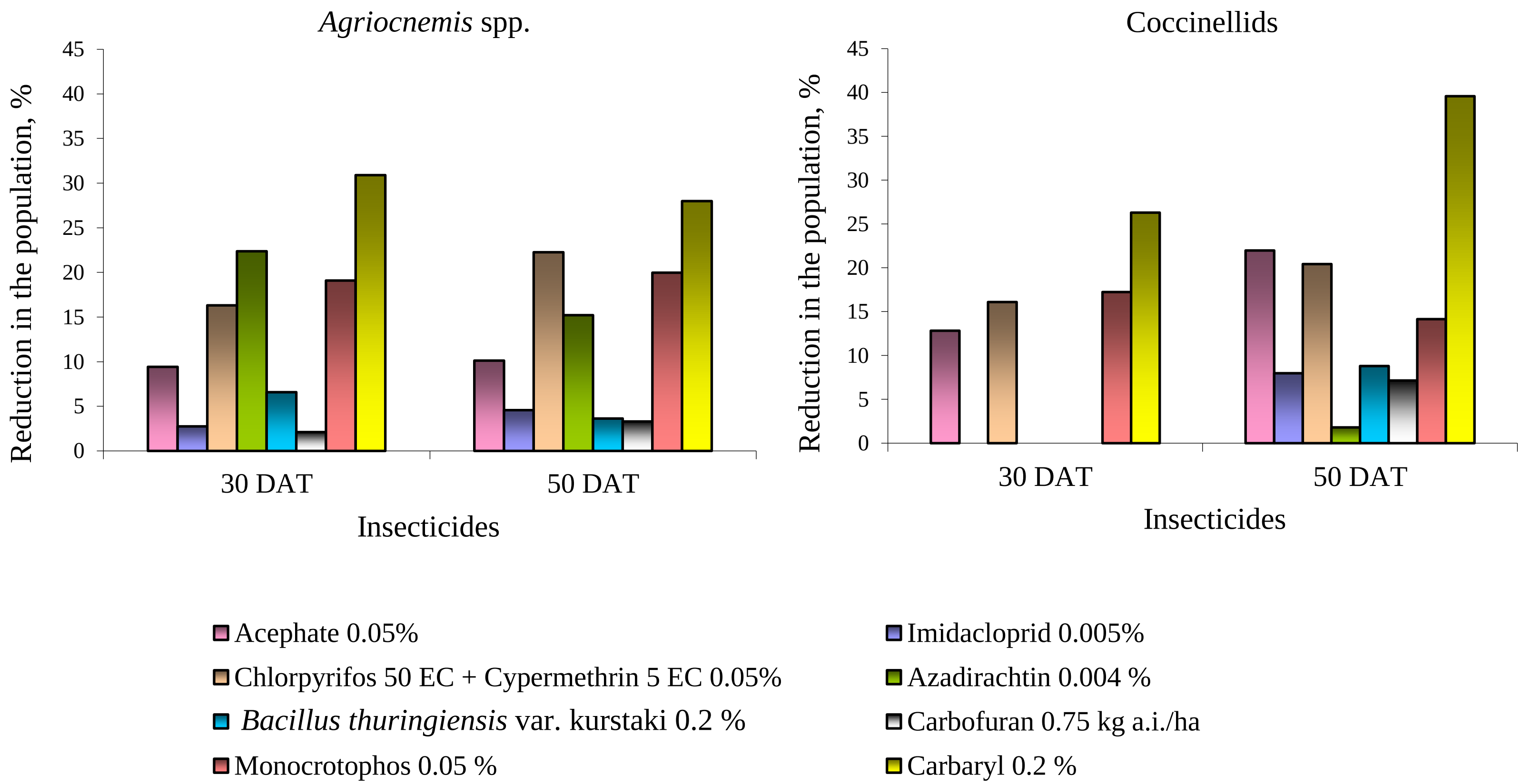


Fig. 5a Effect of different insecticides applied at 30 and 50 DATon the population of predators observed over a period of five days

Eventhough carbofuran was highly effective to sucking pests, and safer to predators and parasitoids, inclusion of the toxicant in IPM programmes is not advisable. The prophylactic application of any toxicant expecting the incidence of a pest is not recommended in IPM as it created a variety of problems. In addition to neutrals so many other beneficials present in the wet land soil may be destroyed.

The botanical pesticide, azadirachtin effectively suppressed the population of *C. medinalis*, *H. philippina*, *L. acuta* and total pests and its toxicity persisted for five days (Fig.3a). Percentage reduction in the population of these pests ranged from 20.00 to 40.00 per cent (Fig.4a, b and c). Immediate suppression of *O. chinensis* and *Nephotettix* spp. by azadirachtin was noticed but the effect was not for longer periods. Toxic effect of azadirachtin on *C. medinalis* was supported by various workers (Lingaiah *et al*., 1999; Lal, 2000; Ambikadevi and Satheesan, 2002; Dhaliwal *et al.*, 2002). Azadirachtin was found to be toxic to *Nephotettix* spp. by Maheshkumar *et al*. (1999) and Krishnaiah *et al*. (2001). Immediate suppression of *Nephotettix* spp. obtained in the present study was in corroborance with their view. Adverse effect of azadirachtin was observed on spiders specifically and total predators in general for two days after spraying (Fig. 3b). The maximum reduction in the population of *Agriocnemis* spp. and *O. nigrofasciata* (22.37 & 23.29 per cent respectively) was observed. The botanical pesticide was found to be safe to coccinellids (Fig.5a). Safety of azadirachtin to coccinellids, *O. nigrofasciata* and spiders was reported by Ajayakumar (2000). Azadirachtin was found to be toxic to parasitoids as well as neutrals. Percentage reduction was 22.14 for parasitoids and 15.63 for neutrals (Fig.6). Differing views on toxicity to parasitoids were reported by Lyons *et al*. (2003) and Markandeya and Divakar (1999). Toxicity of azadirachtin to neutrals was observed by Yun and Mulla (1998a).

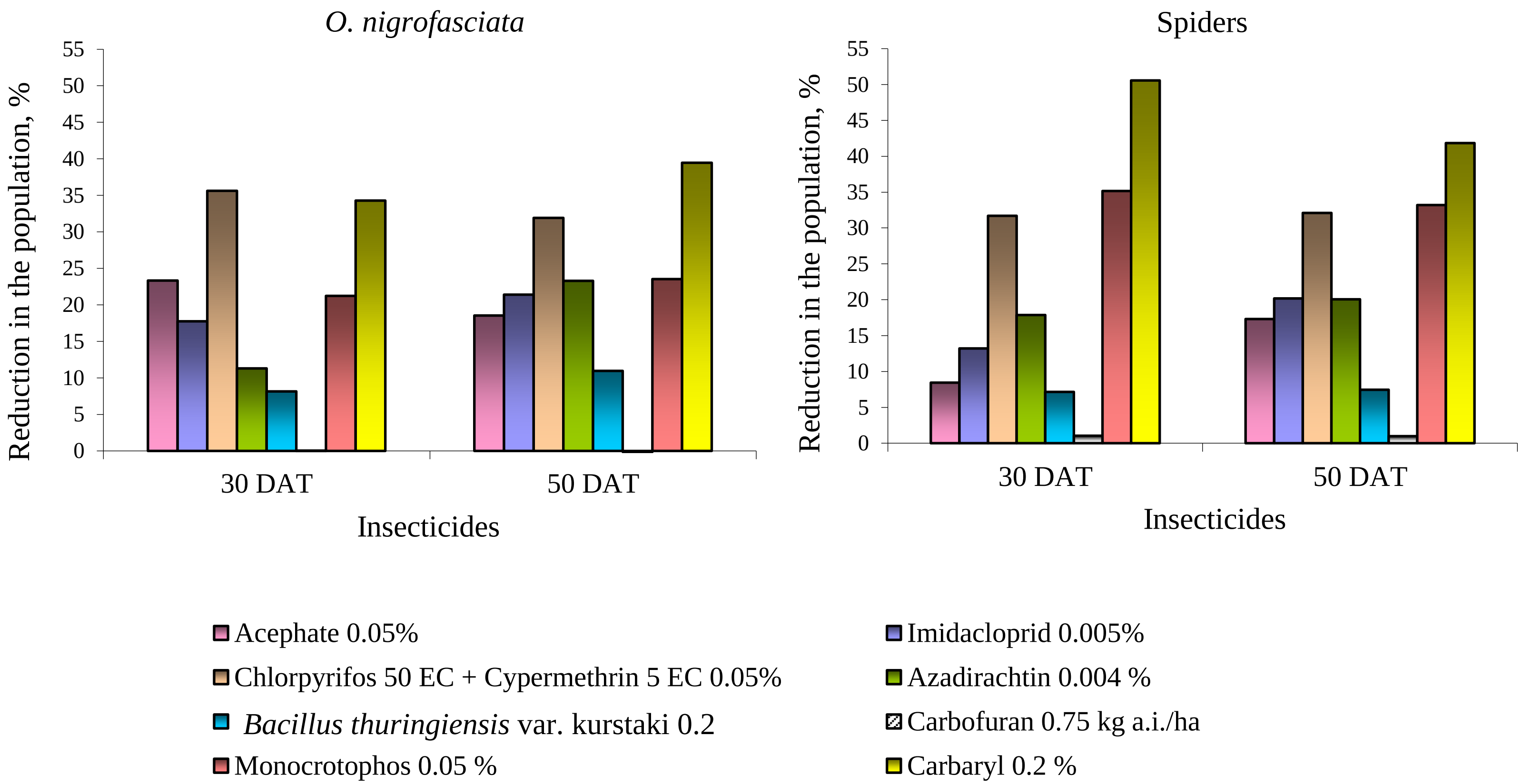


Fig. 5b Effect of different insecticides applied at 30 and 50 DAT on the population of predators observed over a period of five days

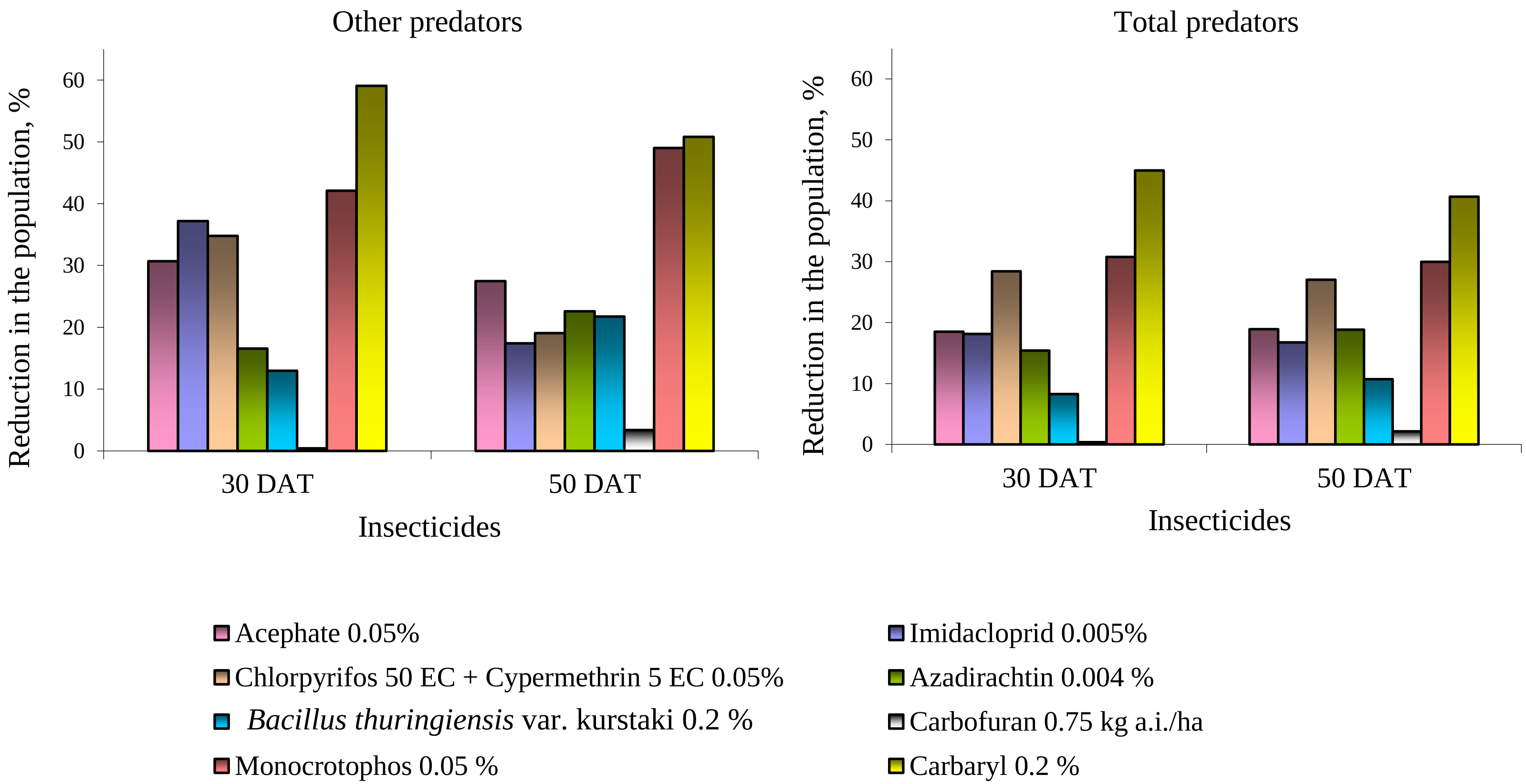


Fig. 5c Effect of different insecticides applied at 30 and 50 DAT on the population of predators observed over a period of five days

The microbial pesticide was found to be effective in suppressing the population of *C. medinalis, H. philippina, O. chinensis* and *L. acuta* and was not at all toxic to *Nephotettix* spp. Reasonably high toxicity was observed on *C. medinalis*, *H. philippina* and total population of pests and the percentage reduction over control for seven days was 25.31, 34.28 and 17.78 respectively (Fig. 4a, b, and d). According to Tripathy *et al*. (1999), Bt preparations were effective against lepidopteran pests. Various workers reported its effectiveness to *C. medinalis* (Panda *et al*., 1999; Lal, 2001; Sehrawat *et al*., 2002). In the present study, the insecticide gave immediate suppression of *C. medinalis*, *H. philippina*, *O. chinensis* and *L. acuta* and the toxicity persisted only on *C. medinalis* and *H. philippina*. Varying reports on the toxicity of Bt preparations on predators were published by many workers. Moderate toxicity (Rao and Singh, 2003), low toxicity (Mendoza, 1972) and safety (Latha *et al*., 1994) were reported earlier. The results of the present study supported the view of Mendoza (1972). Lower toxic effect on predators, higher toxic effect on neutrals and safety on parasitoids were noticed in the study. Lower toxic effect of the toxicant observed on parasitoids in this investigation was supported by Mendoza (1972) and Latha *et al*. (1994). The findings on the toxicity of the chemical to neutrals in the present study was in agreement with the finding of Lacey and Inmann (1985).

Results presented in 4.2.5 gave an overall picture of the impact of the insecticides on total population of different groups of arthropods in rice ecosystems. All the treatments suppressed the pest as well as the predator population where as acephate and *Bacillus thuringiensis* var. kurstaki were safe to parastoids. Azadirachtin and *Bacillus thuringiensis* var. kurstaki were lower in toxicity to neutrals when compared to other treatments.

5.3 EVALUATION OF THE EFFECT OF INSECTICIDE APPLICATION ON GRAIN AND STRAW YIELD.

The grain and straw yield obtained in the field experiment did not show any significant variation as compared to control even though the pests were significantly reduced in all the insecticide treated plots.

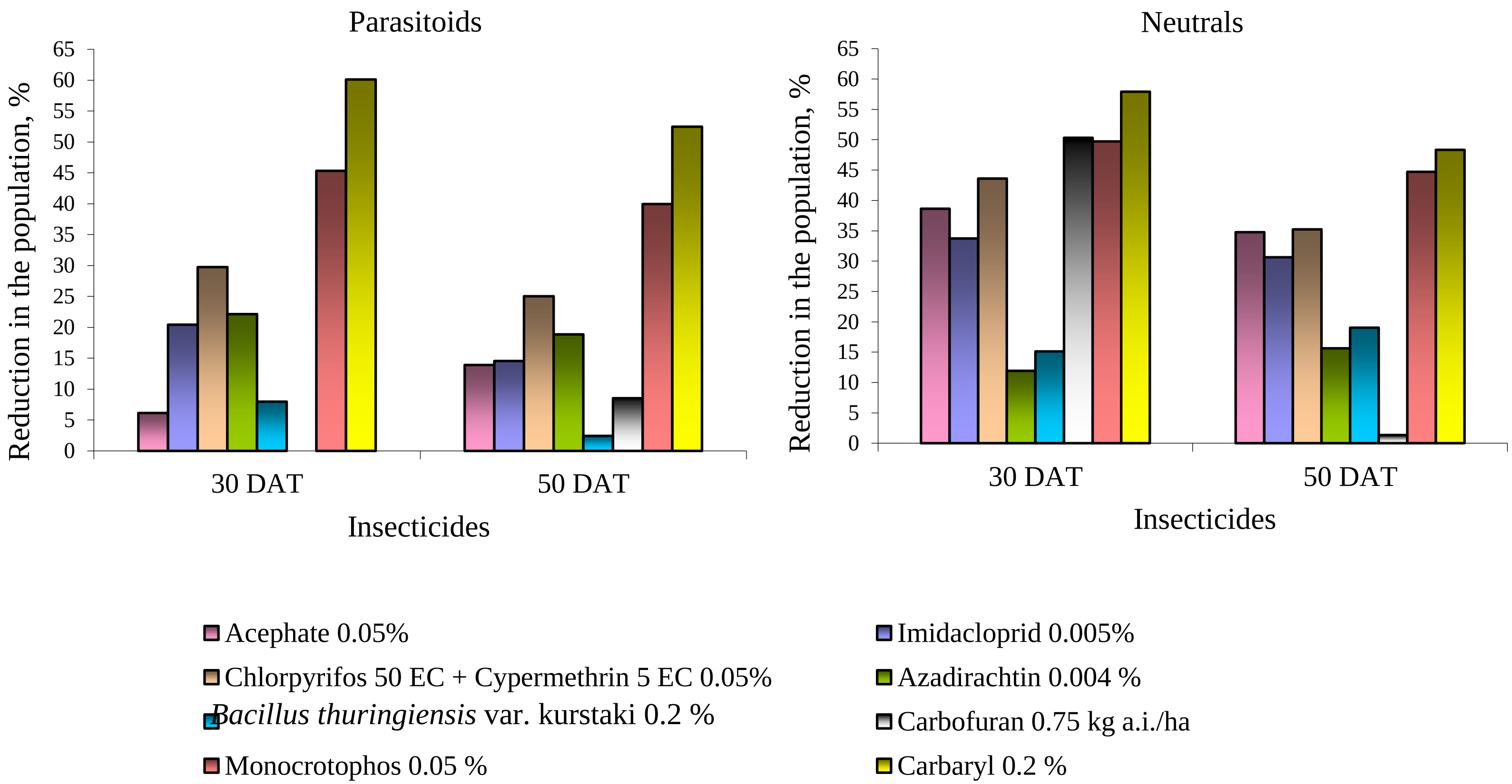


Fig. 6 Effect of different insecticides applied at 30 and 50 DAT on the population of parasitoids and neutrals observed over a period of five days

Deleterious effect of insecticides on arthropod community in rice ecosystem is well documented by Chelliah and Rajendran (1984). An interesting phenomenon noted in the present study was that all the insecticides tested which effectively suppressed the population of pests were equally harmful to predators. Insecticides which were highly toxic to pests were harmful to parasitoids and neutrals. On the other hand insecticides which were comparatively lesser in effectiveness and persistence against pests were less toxic to other organisms. The microbial insecticide, *Bacillus thuringiensis* var. kurstaki effective and less persistent chemical in most of the cases in suppressing the pests was found to be safe to neutrals and parasitoids. Acephate and azadirachtin were moderately effective for pest management. Acephate was less toxic to parasitoids whereas the same effect was shown by azadirachtin to neutrals.

The data on the percentage of total population of the four groups of organisms (Fig. 7) indicated that there was not much variation in their abundance in treatments and control. The percentage population of pests, predators, parasitoids and neutrals varied from 56 to 59, 22 to 24, 8 to 9 and 9 to 12 respectively in treated plots as compared to 59, 22, 8 and 11 respectively in control. This clearly explains the reason for the lack of statistical difference in grain and straw yield in the treatments and control. The comparable yield obtained in control plots might be due to the tolerance of the variety *Aiswarya* to the population of pests there existed and proper utilization of the existing natural enemies and neutrals. According to Bottrell (1993), the use of tolerant variety and conservation of natural enemies in wetland rice ecosystem was reported to be the ‘best mix’ for rice pest management and for maintaining the yield. Various workers from Kerala (Nalinakumari *et al*., 1996; Nadarajan, 1999; Nalinakumari and Remamony, 1999; Nalinakumari *et al*., 2002) supported the above view.

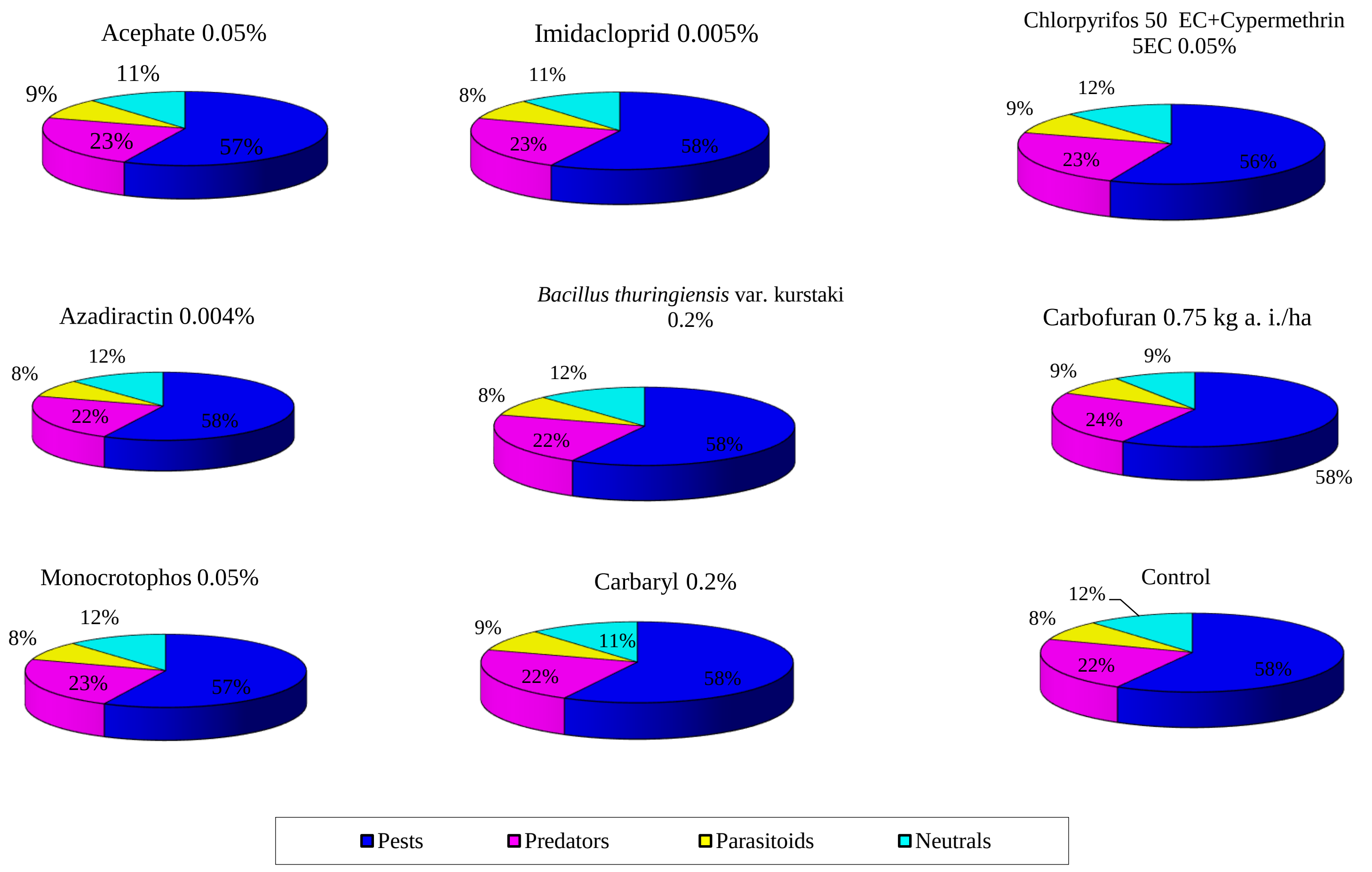


Fig. 7. Impact of different insecticides on percentage population of arthropod community in rice ecosystem

In conclusion, the study on the effect of insecticides on pests, predators, parasitoids and neutrals revealed that insecticides found to be toxic to pests were not safe to all groups of beneficials in rice ecosystem. It has to be emphasized in this context that in the modern IPM, application of insecticides on a crop should be decided only after thorough analysis of the ecosystem. The parameters to be analyzed are stage of the crop, nature and status of the pest, severity of attack and presence of beneficial organisms. As such acephate, azadirachtin and *Bacillus thuringiensis* var. kurstaki, which were found to be toxic to tissue feeders and comparatively safe to non target organisms, are suitable for application during vegetative phase of the crop. Chlorpyrifos 50 EC + cypermethrin 5 EC and imidacloprid which were highly toxic to all the pests and harmful to natural enemies but comparatively less persistent, could be recommended for pocket application in the reproductive stage of the crop. Carbofuran application should be avoided as it was not producing any immediate effect on the pests and prophylactic application of a toxicant expecting pest incidence is not recommended in IPM. Under normal conditions of pest status and climate as observed in the present study, cultivation of a tolerant variety and conservation of existing beneficial organisms are found to be equally good as insecticide protection in managing the pests and maintaining yield.

Summary

6. SUMMARY

Extensive cultivation of high yielding varieties, wide spread use of modern agronomic practices and use of synthetic pesticides over the past several decades have aggravated pest problems and changed the status of the pests. For the management of these pests, pocket application of insecticides is one of the steps recommended in IPM. Screening of insecticides is necessary to select the best insecticides, which could effectively suppress the pest population and at the same time spare the natural enemies and neutrals. The present investigation was carried out to assess the population status of pests, natural enemies and neutrals in the rice ecosystem and to evaluate the effect of some of the commonly used insecticides on these groups of organisms so as to integrate them in pest management. The major findings of the study are summarized here under.

Analysis of the arthropod community showed the dominance of pests, followed by predators, neutrals and parasitoids. Among the pests, tissue feeders were found to be more in number (61.95 per cent) than the sucking pests (38.05 per cent). The sizeable population of pests recorded was those of *C. medinalis*, *L. acuta*, *H. philippina*, *O. chinensis* and *Nephotettix* spp. Predators *viz.*, *Agriocnemis* spp., coccinellids, *O. nigrofaciata* and spiders were present in fairly good number. Parasitoids and neutrals were observed throughout the cropping period.

Population of pests, predators, parasitoids and neutrals showed fluctuating trend at different growth stages of the crop. Highest population of pests, predators, parasitoids and neutrals were recorded at 45, 30, 60 and 15 DAT respectively.

The insecticide mixture, chlorphyrifos 50 EC + cypermethrin 5 EC was found to be effective in suppressing *C. medinalis, O. chinensis, H. philippina, Nephotettix* spp. and *L. acuta.* It effectively reduced the population of

C. medinalis (54.45 per cent) against the check treatment carbaryl (50.91 per cent) with long persistent toxicity (eight days) than the check treatment (seven days). This mixture suppressed *O. chinensis* and *H. philippina* population for six days with a population reduction of 46.38 per cent and 54.65 per cent respectively. The reduction in population was lower in *Nephotettix* spp. (40.85 per cent) and *L. acuta* (31.66 per cent) and the toxicity remained at significant levels upto four days and five days respectively, compared to eight days in the check treatments. This insecticide mixture was toxic to predators and parasitoids and the persistent toxicity was less than that of carbaryl. The toxic and persistent effect of the insecticide mixture on the neutral population is the same as that of the check treatments.

Acephate showed almost the same effect as that of chlorpyriphos 50 EC + cypermethrin 5 EC in suppressing the tissue feeding and sap sucking pests in the study. The toxic effect of acephate on *C. medinalis* and *H. philippina* was highly persistent and the persistence was same as that of carbaryl (seven and six days respectively). The percentage suppression effected by the toxicant on *C. medinalis* and *H. philippina* over seven days was same as that observed in carbaryl. The insecticide showed comparatively less persistent toxicity on *O. chinensis* (five days) as compared to carbaryl (seven days). Among the sucking pests, *Nephotettix* spp. and *L. acuta* caused 20.88 and 28.03 per cent suppression respectively over seven days and significant reduction in their population for three and five days respectively. Acephate was observed to be toxic to predators and safe to parasitoids. Comparatively long lasting suppression of neutrals by the application of acephate was observed in the study.

Cent per cent suppression of *Nephotettix* spp. was observed with imidacloprid treatment which was found more effective than the check insecticide, monocrotophos. The persistent toxicity was same as that of the check (eight days). The percentage reduction in the population on *Nephotettix* spp. for seven days over control was 81.89. The insecticide significantly suppressed the population of *C. medinalis*, *H. philippina,* and *L. acuta* and the persistent toxicity of imidacloprid lasted for five days against all these pests. The insecticide showed lower persistent toxicity on *O. chinensis*. Imidacloprid was observed to be toxic to predators, parasitoids and neutrals but its toxicity on these organisms persisted for a shorter period as compared with both the check treatments.

Carbofuran showed immediate toxicity only to neutrals among the arthropod community in rice ecosystem and the toxicity lasted for five days. The toxic effect of the granule was observed only on *Nephotettix* spp. And *L. acuta* and persisted from 15 to 28 days and 21 to 28 days respectively after application. Carbofuran did not produce any toxic effect on tissue feeding pests and was safe to predators and parasitoids.

Application of azadirachtin effectively suppressed the population of *C.medinalis*, *H. philippina* and *L. acuta* for five days. It significantly reduced the population of *O. chinensis* and *Nephotettix* spp. only for three days. The toxicity of azadirachtin was found to be less persistent to predators, parasitoids and neutrals when compared to both the check treatments.

Among the insecticides tested, lower percentage mortality of the pests over a period of seven days was recorded with *Bacillus thuringiensis* var. kustaki. The mortality percentage ranged from 0.94 to 34.28. However, significant toxicity was shown by the microbial insecticide on *C. medinalis* and *H. philippina* which lasted for five days each. On *O. chinensis* and *L. acuta* toxicity lasted for three days and two days respectively. The toxicant was not at all toxic to *Nephotettix* spp. This was safe to parasitoids and comparatively lower in toxicity to predators and neutrals when compared to monocrotophos and carbaryl.

The overall picture on the effect of two applications of all the insecticides except carbofuran (applied only at 30 DAT) on the total population over a period of 40 days showed that all the insecticides evaluated suppressed the total population of pests as well as predators. Acephate and *Bacillus thuringiensis* var. kustaki were safe to parasitoids while azadirachtin and *Bacillus thuringiensis* var. kustaki showed lower toxicity to neutrals.

All the treatments including control recorded no significant variation in grain and straw yield. Analysis of the percentage of total population of pests, predators, parasitoids and neutrals indicated almost the same magnitude in treatments and in control which varied from 56 to 59, 22 to 24, 8 to 9 and 9 to 12 respectively.

The results of the study emphasized the need for periodical assessment of arthropod community in wetland ecosystem. Acephate, azadirachtin and *Bacillus thuringiensis* var. kustaki are suitable during the vegetative phase while chlorpyrifos 50 EC + cypermethrin 5 EC and imidacloprid can be recommended for pocket application in the reproductive stage of the crop. Carbofuran should be avoided from rice pest management. The study clearly indicated that the cultivation of tolerant varieties and conservation of existing beneficial organisms are essential for rice pest management and maintaining yield.

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*Original not seen

Appendices

APPENDIX – I

Weather parameters recorded during the growth season of the crop

(From 1 DAT to 75 DAT)

Date	Relative humidity (%)		Temperature (°C)		Rainfall (mm)
	Morning	Evening	Maximum	Minimum	
16.10.2003	93	70	31.0	24.0	0
17.10.2003	92	70	31.2	24.0	0
18.10.2003	97	74	31.0	24.2	9.8
19.10.2003	95	71	31.1	24.0	0
20.10.2003	95	63	31.2	24.5	6.2
21.10.2003	96	92	27.0	23.2	56.8
22.10.2003	96	77	28.8	23.0	16.3
23.10.2003	92	72	30.6	23.0	4.6
24.10.2003	98	87	27.1	22.8	177.0
25.10.2003	91	77	30.2	22.2	3.2
26.10.2003	92	74	31.0	23.5	0
27.10.2003	95	74	31.5	23.2	0
28.10.2003	93	69	32.0	23.2	0
29.10.2003	90	64	31.0	23.2	0
30.10.2003	85	73	31.8	23.5	0
31.10.2003	92	85	30.0	23.8	0

APPENDIX – I Continued

Date	Relative humidity (%)		Temperature (°C)		Rainfall (mm)
	Morning	Evening	Maximum	Minimum	
01.11.2003	95	80	29.8	22.5	3.0
02.11.2003	95	80	30.5	23.0	5.6
03.11.2003	92	79	30.5	23.0	15.0
04.11.2003	93	61	30.6	22.0	0.4
05.11.2003	95	79	29.8	23.2	12.0
06.11.2003	96	62	30.5	23.0	52.2
07.11.2003	96	83	28.5	22.5	35.5
08.11.2003	96	90	28.5	23.2	5.0
09.11.2003	92	71	30.2	23.0	15.0
10.11.2003	95	69	30.8	22.5	0
11.11.2003	87	68	31.4	22.9	0
12.11.2003	95	68	31.0	23.0	0
13.11.2003	95	65	31.8	23.2	3.2
14.11.2003	89	78	30.3	24.5	0
15.11.2003	95	73	29.0	24.0	19.0
16.11.2003	95	71	31.4	22.5	0.6
17.11.2003	95	68	31.1	23.0	0.4
18.11.2003	92	66	32.0	24.0	0
19.11.2003	92	74	31.0	24.0	0
20.11.2003	95	66	30.8	23.0	0
21.11.2003	90	62	31.4	23.2	0
22.11.2003	92	71	31.5	23.8	0
23.11.2003	97	78	29.4	24.8	0
24.11.2003	98	61	30.8	22.8	1.7
25.11.2003	91	63	31.0	22.5	0
26.11.2003	92	65	31.2	24.4	0
27.11.2003	95	69	31.0	23.5	0
28.11.2003	90	70	30.0	23.0	0
29.11.2003	95	75	29.6	24.0	0
30.11.2003	95	70	30.5	23.5	0.8

APPENDIX – I Continued

Date	Relative humidity (%)		Temperature (°C)		Rainfall (mm)
	Morning	Evening	Maximum	Minimum	
01.12.2003	95	71	31.6	23.5	0
02.12.2003	96	66	31.2	22.5	0
03.12.2003	93	59	31.6	22.0	0
04.12.2003	93	67	31.0	21.0	0
05.12.2003	96	64	31.0	22.5	0
06.12.2003	93	62	31.5	22.0	0
07.12.2003	95	63	31.0	22.5	0
08.12.2003	87	43	31.8	19.0	0
09.12.2003	91	59	31.0	20.0	0
10.12.2003	96	54	30.8	19.5	0
11.12.2003	94	45	31.1	18.5	0
12.12.2003	96	61	30.4	20.4	0
13.12.2003	95	63	31.0	21.8	0
14.12.2003	95	61	31.4	21.5	0
15.12.2003	95	53	32.0	22.5	0
16.12.2003	95	65	30.5	21.0	0
17.12.2003	95	66	30.6	22.0	0
18.12.2003	93	65	31.0	23.0	0
19.12.2003	88	66	31.2	24.0	0
20.12.2003	91	64	31.0	22.5	0
21.12.2003	86	52	31.8	21.8	0
22.12.2003	95	50	31.4	20.8	0
23.12.2003	96	61	31.0	20.4	0
24.12.2003	95	65	31.0	21.0	0
25.12.2003	95	67	30.6	21.5	0
26.12.2003	95	56	31.4	22.0	0
27.12.2003	95	65	31.5	22.5	0
28.12.2003	96	60	31.2	22.5	0
29.12.2003	96	66	32.0	22.8	0
30.12.2003	93	60	32.0	22.0	0
31.12.2003	95	59	31.5	22.2	0

APPENDIX – I Continued

Date	Relative humidity (%)		Temperature (°C)		Rainfall (mm)
	Morning	Evening	Maximum	Minimum	
01.01.2004	91	61	31.8	21.8	0
02.01.2004	96	61	31.6	22.5	0
03.01.2004	93	60	31.8	22.2	0
04.01.2004	93	60	31.5	22.2	0
05.01.2004	96	62	31.8	22.2	0
06.01.2004	93	65	31.5	22.5	0
07.01.2004	96	58	32.0	22.5	0
08.01.2004	93	54	32.0	21.5	0
09.01.2004	91	58	31.5	20.5	0
10.01.2004	95	59	32.0	22.0	0
11.01.2004	93	51	32.0	21.8	0
12.01.2004	91	52	31.6	20.2	0
13.01.2004	94	61	30.6	19.8	0
14.01.2004	96	62	30.5	20.8	0
15.01.2004	96	62	30.2	19.6	0
16.01.2004	96	53	31.0	19.5	0
17.01.2004	96	65	31.0	19.5	0
18.01.2004	96	60	30.5	21.0	0
19.01.2004	94	61	30.5	20.8	0
20.01.2004	95	65	30.5	21.5	0
21.01.2004	96	50	31.8	21.5	0
22.01.2004	93	54	31.8	21.0	0
23.01.2004	93	60	31.5	21.8	0
24.01.2004	95	59	32.0	22.0	0
25.01.2004	93	61	32.2	23.0	0
26.01.2004	95	62	32.4	23.5	0
27.01.2004	95	61	31.2	22.0	0
28.01.2004	95	64	31.5	23.0	0
29.01.2004	95	61	32.2	22.8	0
30.01.2004	95	65	31.8	23.2	0
31.01.2004	96	57	32.0	23.0	6.8

APPENDIX – II

Mean population of total pest recorded at 11 to 20 days after two sprayings (41 – 50 and 61 – 70 DAT)

Days after 1st spraying	Treatments								
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
11	74.33	75.67	78.00	82.33	78.00	61.67	77.33	78.33	79.70
12	73.33	78.33	79.33	77.67	79.33	62.67	81.67	80.33	84.33
13	84.00	85.67	80.00	83.67	83.67	67.67	86.33	86.67	88.33
14	86.67	86.67	85.33	83.00	86.00	68.33	85.00	89.67	93.00
15	89.33	93.67	89.67	92.00	91.33	72.00	87.67	92.00	96.00
16	92.33	97.00	92.00	97.00	99.00	75.00	94.67	98.33	99.67
17	95.67	103.67	97.33	102.67	102.67	82.33	97.67	103.67	103.67
18	101.00	109.00	102.00	108.00	111.00	85.00	13.00	107.00	104.00
19	106.00	113.33	105.67	111.33	116.33	89.33	107.00	111.00	108.33
20	112.67	118.67	107.00	114.67	120.33	90.67	114.67	111.67	111.67
2nd spraying									
11	121.67	123.33	123.33	120.00	125.00	123.33	119.67	121.67	124.33
12	111.00	115.33	115.33	115.67	119.33	119.00	114.67	115.00	118.00
13	104.67	114.67	105.00	108.33	107.67	107.67	110.33	107.33	106.67
14	98.00	100.00	107.33	104.00	103.33	103.33	102.00	100.33	103.00
15	97.33	98.67	97.33	97.00	100.33	97.00	67.67	97.33	96.33
16	91.00	95.00	93.67	90.67	90.67	94.00	92.00	93.67	93.00
17	89.33	84.33	88.33	84.33	90.00	87.33	91.67	87.00	87.67
18	81.33	77.33	82.33	81.67	80.00	81.33	87.00	83.67	82.33
19	80.67	74.00	72.33	77.33	72.33	76.33	85.00	80.67	77.67
20	81.00	74.67	68.67	72.67	73.33	73.67	81.67	77.33	74.33

APPENDIX – III

Mean population of total predators recorded at 6 – 20 days after two sprayings (36-50 and 56 – 70 DAT)

Days after 1st spraying	Treatments								
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
6	46.33	47.33	44.00	47.33	46.33	46.00	45.67	43.00	48.33
7	45.00	45.00	43.33	46.00	44.00	44.00	46.33	44.33	45.67
8	46.67	44.33	46.00	44.33	42.00	43.33	45.00	43.00	47.33
9	44.67	45.33	42.67	45.67	44.00	42.33	43.67	42.67	45.67
10	44.67	45.00	45.00	47.33	45.33	41.67	46.33	41.67	48.33
11	45.00	43.33	48.00	48.33	44.33	39.33	45.67	44.67	47.33
12	43.67	42.67	46.00	46.67	40.33	38.67	42.33	43.00	47.33
13	42.33	44.33	45.33	44.67	44.33	40.67	43.67	42.67	46.00
14	44.00	44.00	43.00	45.00	42.00	39.00	40.33	44.00	46.33
15	43.00	42.33	43.33	43.33	41.00	43.00	44.33	42.00	39.33
16	40.33	40.00	41.00	40.00	38.00	44.67	42.33	41.67	42.33
17	38.33	39.00	38.00	41.00	39.67	40.00	40.33	39.67	44.00
18	36.00	41.00	43.00	38.67	37.67	38.00	38.33	41.00	41.00
19	34.00	38.00	40.00	36.33	38.33	39.00	39.67	40.00	39.33
20	34.67	38.33	39.33	35.67	37.00	39.33	39.67	42.33	40.33
2nd spraying									
6	39.00	40.33	39.67	43.67	44.33	39.00	39.67	39.00	40.00
7	35.00	37.67	40.67	39.67	37.00	37.67	40.33	37.67	39.33
8	33.00	35.00	38.00	36.33	40.00	35.67	38.33	34.67	35.67
9	32.00	35.00	34.33	33.67	28.67	33.33	35.00	31.67	35.00
10	28.00	28.00	32.67	29.33	33.33	31.33	33.67	29.67	27.67
11	29.00	24.33	30.33	26.67	27.00	28.00	30.67	28.00	32.33
12	25.00	27.33	26.00	24.67	27.67	24.67	27.33	25.00	27.00
13	20.33	21.67	24.33	26.33	18.33	21.00	21.33	22.33	24.00
14	18.67	16.33	23.00	17.33	16.67	18.67	16.33	19.67	22.33
15	18.33	16.67	19.67	19.00	16.33	18.33	17.00	18.00	18.33
16	14.33	17.33	15.67	13.33	15.00	16.33	15.33	15.00	14.67
17	13.00	15.33	15.33	12.00	15.33	17.33	12.33	13.33	17.67
18	13.67	15.67	13.33	15.33	13.67	15.33	12.67	14.33	16.33
19	13.33	15.33	13.00	14.00	13.67	14.33	13.33	16.67	14.67
20	14.00	15.00	14.33	15.67	14.33	13.67	15.00	15.67	14.33

APPENDIX – IV

Mean population of total parasitoids recorded at 6 – 20 days after two sprayings (36-50 and 56 – 70 DAT)

Days after 1st spraying	Treatments								
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
6	7.00	6.33	7.33	6.33	5.33	7.00	7.33	7.33	7.33
7	6.00	7.33	6.00	6.67	5.67	6.00	7.33	7.67	6.33
8	5.33	5.67	5.67	7.00	7.33	5.67	6.67	7.67	6.00
9	7.67	7.00	8.33	6.33	8.33	5.33	8.33	6.33	6.67
10	5.67	8.00	6.00	6.00	7.67	4.67	7.67	9.00	7.67
11	9.00	8.00	9.00	8.00	7.67	5.00	8.33	9.67	9.33
12	8.33	10.33	11.33	9.00	12.33	6.67	10.00	9.67	10.33
13	11.33	9.67	12.33	11.33	11.67	7.67	10.33	9.67	12.67
14	11.33	9.67	11.67	11.33	12.00	9.00	12.33	10.33	12.00
15	13.67	12.00	12.67	13.33	13.33	10.67	13.33	12.67	14.00
16	14.67	13.00	14.33	14.33	14.00	13.00	13.33	15.33	15.00
17	16.67	14.67	15.67	14.33	16.33	12.00	14.00	16.00	16.00
18	18.00	16.33	16.00	16.00	18.00	13.67	15.00	18.00	16.67
19	19.67	17.00	15.33	14.00	19.67	14.00	15.67	19.00	17.67
20	20.67	18.00	16.00	17.67	19.33	14.33	16.33	20.00	18.67
2nd spraying									
6	22.33	22.67	21.67	21.33	20.00	23.00	21.00	20.33	20.00
7	19.00	22.00	20.33	20.0	20.67	22.67	20.33	21.33	23.33
8	19.67	19.33	22.33	22.67	20.67	21.67	21.00	21.67	18.67
9	21.33	20.33	20.67	20.00	22.00	23.00	19.33	22.33	19.33
10	20.33	22.00	23.33	23.67	21.00	21.33	22.33	21.33	19.67
11	20.00	21.00	22.00	21.33	23.33	22.33	21.33	23.00	22.33
12	21.67	22.67	21.67	21.67	22.33	20.67	21.67	21.67	21.67
13	20.00	20.67	20.67	19.00	23.33	19.00	20.67	20.33	20.00
14	18.67	18.33	17.67	18.33	17.00	19.00	17.67	20.33	16.67
15	17.33	15.67	18.33	13.33	14.67	15.67	17.00	18.67	13.33
16	12.00	11.67	10.00	8.33	9.33	9.00	10.67	9.67	11.00
17	9.67	9.67	9.00	10.00	8.67	9.33	10.00	9.33	9.67
18	8.33	8.67	9.33	9.33	8.67	10.33	9.67	9.00	10.33
19	8.33	7.33	9.33	9.67	8.33	8.33	8.00	8.67	10.33
20	7.00	6.67	7.33	8.33	6.33	7.33	8.30	6.67	8.67

APPENDIX – V

Mean population of total neutrals recorded at 6 – 20 days after two sprayings (36-50 and 56 – 70 DAT)

Days after 1st spraying	Treatments								
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
6	30.00	29.00	32.00	33.00	32.67	8.67	31.33	31.33	29.00
7	31.00	31.67	31.33	32.00	33.67	10.67	29.67	32.67	32.67
8	31.67	31.33	31.33	31.67	32.67	12.67	31.33	31.33	31.67
9	30.00	30.67	32.33	32.33	31.33	15.33	31.33	33.00	31.33
10	29.33	28.33	32.67	30.00	30.67	16.33	29.33	30.00	29.67
11	29.67	29.00	30.33	28.67	28.67	17.67	28.00	29.00	27.67
12	28.33	27.67	29.33	24.00	28.00	18.67	25.67	26.67	26.67
13	26.67	26.67	24.00	25.00	26.66	22.00	25.33	24.00	25.67
14	24.00	24.00	25.67	23.33	25.67	21.00	23.67	23.00	24.00
15	21.00	22.00	24.33	24.33	24.00	20.00	22.33	20.67	22.33
16	19.67	20.00	20.33	20.33	22.33	17.00	20.33	20.00	22.67
17	16.33	20.33	19.67	20.33	19.33	17.33	20.3	19.00	20.33
18	14.67	19.33	17.00	17.67	17.67	16.67	19.33	18.67	18.67
19	14.00	14.67	15.67	15.67	15.33	16.00	18.67	17.00	15.33
20	14.67	14.00	13.67	14.00	14.00	14.00	18.00	15.00	13.00
2nd spraying									
6	12.33	13.00	12.67	13.67	12.67	13.33	14.33	12.00	12.33
7	10.67	9.67	11.67	11.00	13.67	11.00	12.33	1.00	14.00
8	9.33	11.00	11.67	12.0	15.67	10.33	12.67	14.00	11.33
9	12.33	11.33	12.00	13.00	13.67	14.67	11.37	10.00	12.67
10	10.67	11.67	13.33	14.00	14.67	13.33	14.33	13.67	11.67
11	12.00	11.67	11.00	12.33	12.33	11.67	12.00	13.67	11.33
12	10.67	11.67	11.33	11.33	12.33	12.67	11.00	11.67	12.67
13	12.67	11.33	10.33	11.67	10.67	12.00	12.00	10.33	12.00
14	14.00	9.00	11.00	10.33	12.33	11.00	10.33	10.67	10.00
15	10.00	11.00	10.67	13.00	12.00	8.67	10.33	10.67	10.67
16	11.67	11.00	8.00	12.00	11.00	8.67	13.33	10.00	10.33
17	8.33	8.33	10.67	9.00	11.00	9.67	11.33	10.33	10.00
18	10.33	9.00	9.00	11.00	10.33	11.67	10.00	10.00	9.00
19	9.33	8.33	9.67	9.67	9.00	10.00	9.67	10.33	8.33
20	10.33	10.00	10.00	11.00	11.67	9.33	10.67	11.00	8.33

APPENDIX-VI

Mean population of *Nephotettix* spp. recorded at 11 to 20 days after first spraying (41-50 DAT)

Days after spraying	Treatments								
	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
11	7.61	8.29	11.27	9.24	8.59	6.64	9.55	8.77	9.93
12	8.29	8.83	9.22	8.21	9.76	6.90	10.97	9.24	10.30
13	9.24	9.15	9.89	7.80	8.29	6.61	9.22	8.88	9.63
14	10.56	11.31	8.88	8.14	9.39	6.63	8.23	9.93	10.63
15	10.53	10.56	11.57	9.63	9.25	5.97	7.92	10.31	10.33
16	10.60	9.93	12.33	8.95	8.98	5.53	8.98	9.93	9.93
17	10.98	10.89	10.60	9.22	8.66	5.32	8.92	8.98	9.98
18	10.56	9.33	9.93	9.63	9.98	5.17	9.93	10.66	10.98
19	10.95	11.27	9.95	10.30	9.31	4.97	10.33	10.63	10.94
20	9.20	10.56	10.98	9.93	9.93	3.32	11.63	10.56	12.64

IMPACT OF DIFFERENT INSECTICIDES ON PEST, NATURAL ENEMY AND NEUTRAL COMPLEX IN RICE ECOSYSTEM

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ABSTRACT

Investigations were carried out during the second crop season of 2003-2004 at CSRC, Karamana, to assess the status of pests, natural enemies and neutrals in the rice ecosystem and to evaluate the efficacy of different insecticides on these organisms.

The results revealed that pests dominated in the rice ecosystem followed by predators, neutrals and parasitoids. The sizeable population of pests recorded were *Cnaphalocrocis medinalis* (Guenee), *Leptocorisa acuta* (Thunberg), *Hydrellia philippina* Ferino, *Oxya chinensis* (Thunberg) and *Nephotettix* spp. Predators were present in fairly good number. Parasitoids and neutrals were comparatively less. The neutrals observed in the study came under the family Chironomidae, Culicidae, Tanyderidae, Otitidae and Sciomyzidae. Arthropod population showed a fluctuating trend and the highest population of pests, predators, parasitoids and neutrals were at 45, 30, 60 and 15 DAT respectively.

Chlorpyrifos 50 EC + cypermethrin 5 EC was the most effective and persistent insecticide in suppressing *C. medinalis*. It effectively suppressed the other pests also and the persistent toxicity against them was comparatively less. It was toxic to the beneficial organisms; with shorter persistence on predators and parasitoids and the effect on neutrals was same as in carbaryl and monocrotophos.

Acephate was found to be equally effective as carbaryl against *C. medinalis* and *H. philippina*. The other pests were also suppressed with the insecticide but the persistent toxicity was less. The insecticide was observed to be toxic to predators and neutrals and safe to parasitoids.

Highest toxicity of imidacloprid was observed on *Nephotettix* spp., and was same as that of monocrotophos. The insecticide was found to be equally toxic to *C. medinalis*, *H. philippina* and *L. acuta* and the toxicity

was less persistent on *O. chinensis*. It was toxic to all the three groups of beneficial organisms and toxicity was for a shorter period. Carbofuran granule showed immediate toxic effect only to neutrals and the delayed toxicity was exhibited on *Nephotettix* spp. and *L. acuta*. The granule was observed to be safe to predators and parasitoids.

Azadirachtin suppressed the population of pests effectively and the effect was for a shorter period. This botanical insecticide was comparatively lower in toxicity to predators, parasitoids and neutrals. Among the insecticides tested, *Bacillus thuringiensis* var. kurstaki showed lower percentage mortality of *C. medinalis, H. philippina, O. chinensis* and *L. acuta* and no toxic effect on *Nephotettix* spp. This insecticide was safe to parasitoids and less toxic to predators and neutrals.

The overall effect of these insecticides on the total population of four groups of arthropods showed that all the insecticides significantly suppressed the population of pests and predators. Acephate and *Bacillus thuringiensis* var. kurstaki were safe to parasitoids while azadirachtin and *Bacillus thuringiensis* var. kurstaki were less toxic to neutrals.

The grain and straw yield recorded and the percentage abundance of the total population of four groups of arthropods were same in all treatments including control.

The study emphasizes the need for cultivation of tolerant varieties and periodical field assessment of arthropod community. If the pest population is high and beneficial organisms are very low, pocket application of appropriate insecticides can be resorted to. The study once again asserts that insecticidal interventions are rarely needed and the four groups of arthropods regulate themselves and manage the pests and maintain the yield.