IMPACT OF BOTANICALS ON PESTS AND DEFENDERS IN RICE ECOSYSTEM

By

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DECLARATION

I hereby declare that this thesis entitled **"Impact of botanicals on pests and defenders 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 to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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Certified that this thesis entitled **"Impact of botanicals on pests and defenders in rice ecosystem"** is a record of research work done independently by **Sri. C. AJAYAKUMAR** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

INTRODUCTION

Rice is the main staple food crop of half of world's population. As in the case of any other crop, pests have plagued rice ever since people began cultivation of this crop. Under favourable conditions, the population of pest increase to alarming proportions, leading to pest out breaks. Farmers, from time immemorial, have developed a wide range of methods to combat these pests, with varying degrees of success. However, the introduction of commercial pesticides in the 20th century has almost revolutionised pest control in the crop.

The large-scale use and misuse of toxic chemical pesticides has made our ecosystem highly unstable and resulted in the degradation of natural resources of land, water and air. The use of various types of modern pesticides has, however, created some of today's major environmental and health problems-reduction in the abundance and diversity of wild life, human health hazards (Pimbert, 1985; Gips, 1987; Conway and Pretty, 1991). About half of all pesticide poisoning of the people and 80 per cent of pesticide related deaths are occurring in developing countries where only 15-20 per cent of pesticides are consumed. Ambitious development plans are proposed world over to overcome these problems through attaining sustainability in agriculture. The concept of sustainable agriculture provides essential goals and criteria. In this context, it is necessary that strategies have to be formulated to sustain rice productivity through marginal adjustments in the cultivation practices, respecting the ecological principles of diversity by utilising traditional practices accumulated over centuries of experience by farmers. Last but not the least, adoption of such low cost technologies keeps away expensive, hazardous chemicals from cultivation.

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 plant products for managing pests, which are harmful to targeted species and safe to the defenders and the ecosystem.

One hectare of paddy field may have up to five to seven million parasitoids and predators that will contain the pests (Williamsettle, 1994). In spite of the high defender population, pest out breaks are reported, following pesticide application, probably on account of damage to the defenders (Kenmore, 1980; Heinrichs and Mochida, 1984; Ooi, 1988 and Kenmore, 1991). It is also a well established fact that rice crop is found to tolerate a certain level of pest infestation with out causing yield reduction under optimum field condition, with moderate level of defenders and climatic condition, without insecticide (Nalinakumari *et al.* 1996).

In rice fields, predator populations develop very early in the growing season, independently of plant feeding insect populations, by feeding on detritivores and filter feeders. This new hypothesis suggests that most rice fields are far more stable and resilient to influxes of rice pests because defender populations build up to high level during early season, before pest population develops (Williamsettle, 1994). Wide spread and indiscriminate use of pesticides results in more fragile system resulting in out break of pests. Under such a situation, insecticides of plant origin which are easily available, offer immense potentialities in reducing pest population, less harmful to defenders and the ecosystem play an important role. This calls for a detailed investigation on the effect of botanicals on major pests and defenders in rice ecosystem, in order to evolve an ecofriendly management strategy. Hence the present work was undertaken with the following objectives :-

1. To assess the population of pests and defenders in rice ecosystem and to identify the occurrence and distribution of major ones.
2. To screen various concentrations of easily available botanicals, the water extracts of leaves *Azadirachta indica* (A. Juss) and *Clerodendron infortunatum* (Linn.) and nimbecidine to identify the best product and the most effective concentration.
3. To evaluate the efficacy of botanicals on the population of pest and defenders in the field and to formulate a safe pest management strategy.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 Insect pests and defenders in rice ecosystem

Large number of reports on the occurrence and distribution of pests and defenders have been published from different rice growing tracts of the world. Recent literature in the various aspects is briefly reviewed here.

2.1.1 Pests reported from rice ecosystem.

Order and Common name	Scientific name	Citations
Important pests		
		IRRI (1983), KAU (1983)
		Pandey *et al.* (1983)
		Catling *et al.* (1984)
Lepidoptera		Murugesan & Chelliah (1984)
Leaf roller	*Cnaphalocrocis medinalis* (Guenee)	Dhaliwal (1985), Suresh *et al.* (1985)
Case worm	*Nymphula depunctalis* (Guenee)	Uthamaswamy *et al.* (1985)
Stem borer	*Scirpophaga incertulas* (Walker)	Heinrichs *et al.* (1986)
Army worm	*Spodoptera mauritia* (Boisduval)	Reissig *et al.* (1986), KAU (1987)
		Cruz *et al.* (1988)
		Arida & Shepard (1990), Nair (1990)
		Ghosh *et al.*(1992), Graf *et al.* (1992)
		KAU (1996),
		Mohankumar et al. (1996)
		Nadarajan (1996)

		Banerjee & Chatterjee (1982)
		Baskaran *et al.* (1983), IRRI (1983)
		KAU (1983), Abdulla (1984)
		Krishnakumar (1986),
		Reissig *et al.* (1986), KAU (1987)
Hemiptera		Thomas (1987), Heong *et al.* (1990)
Brown plant hopper	*Nilaparvata lugens* (Stal)	Nair (1990),
Rice bug	*Leptocorisa acuta* (Thunberg)	Rajendran & Devarajah (1990)
		Oka (1991), KAU (1996)
		Krishnakumar & Visalakshi (1996)
		Shanthi & Venugopal (1996)
		Velusamy *et al.* (1996)
		Rao *et al.* (1982), IRRI (1983)
		KAU (1983), Patnaik & Satpathy (1983)
		Prasad *et al.* (1983)
		Shukla & Kaushik (1983), Chiu (1984)
Diptera		Hidaka *et al.* (1984), Joshi *et al.* (1984)
Gallmidge	*Orseolia oryzae* (Wood-Mason)	Ukwung wu *et al.* (1984)
		Alam *et al.* (1985), Samalo (1985)
		Sundararaju (1985), Nair (1990)
		KAU (1996), Nadarajan (1996)

Coleoptera		Khan and Abedin (1982), IRRI (1983)
		Krishnaiah & Kalode (1983)
Rice hispa	*Dicladispa armigera* (Olivier)	Zafar (1984), Banerjee & Nath (1986)
		Reissig *et al.* (1986), Nair (1990)
		KAU (1996)

Other pests.

		Mochida *et al.* (1982)
Hemiptera		Xu (1982), IRRI (1983)
Green leaf hoppers	*Nephotettix virescens*(Distant)	Abdulla (1984)
	Nephotettix *nigropictus* (Stal)	Kushwaha & Singh (1986)
White backed hopper	*Sogatella furcifera* (Horvarth)	Reissig *et al.* (1986)
Black bug	*Scotinophara* spp.	Gubbaiah *et al.* (1987), Ajith (1990)
Red spotted bug	*Menida histrio* (Fb)	Heong *et al.* (1990), Nair (1990)
Striped bug	*Tetrodes histeroides* (Fb)	Rajendran & Devarajah (1990)
Thysanaptera		KAU (1996), Nalinakumari *et al.* (1996)
Rice thrips	*Baliothrips biformis* (Bagnall)	Ambikadevi (1998 a & b)
		Jacob & Remabai (1998)

Lepidoptera		
Green horned caterpillar	*Melanitis leda ismene* (Cramer)	
Rice skipper	*Pelopidas mathias* (Fabricius)	IRRI (1983),
Earcutting caterpillar	*Mythimna separata* (Walker)	Reissig *et al.* (1986)
Yellow hairy caterpiller	*Psalis pennatula* (Hb)	Nair (1990)
Rice semilooper	*Mocis frugalis* (Fb)	

2.1.2 Defenders reported from rice ecosystem.

Predators

		Sellammalmurugesan & Chelliah (1982)
		Reissig *et al.* (1986)
Araneae		Bhardwaj & Pawar (1987)
Wolf spider	*Lycosa pseudoannulata* (B and S)	Shepard *et al.* (1987)
Long jawed spider	*Tetragnatha maxillosa* (Thorell)	Vungsilabutr (1988)
Lynx spider	*Oxyopes javanus* (Thorell)	Heong *et al.* (1989)
Jumping spider	*Phidippus* sp.	Chakraborthy *et al.* (1990)
Dwarf spider	*Atypena formosana* (Oi)	Nair (1990), Reghunath *et al.* (1990)
Orb spider	*Araneus inustus* (L. koch)	Heong *et al.* (1991)
		Nalinakumari *et al.* (1996)
		Ambikadevi (1998 c)
		Nandakumar & Pramod (1998)
		Reissig *et al.* (1986)
		Bhardwaj and Pawar (1987)
		Kamal *et al.* (1987)
Coleoptera		Shepard *et al.* (1987)
Lady beetle	*Micraspis* spp.	Basilio and Heong (1990)
Ground bettle	*Ophionea* spp.	Chakraborthy *et al.* (1990), Nair (1990)
Hemiptera		Rajendran & Devarajah (1990)
Mirid bug	*Cyrtorhinus lividipennis*(Reuter)	Reghunath *et al.* (1990)
Odonata		Heong *et al.* (1991)
Damselfly	*Agriocnemis* spp.	Nalinakumari *et al.* (1996)
		Ambikadevi (1998 c)
		Nandakumar & Pramod (1998)

Parasites

Hymenoptera

Eulophid wasp	*Tetrastichus shoenbii* (Ferriere)	
Braconid wasp	*Cotesia* sp.	Reissig *et al.* (1986), Shepard *et al.* (1987)
Scelionid wasp	*Telenomus rowani* (Gahan)	Chandramohan & Chelliah (1990)
Ichneumonid wasps	*Itoplectis narangae* (Ashmead)	Nair (1990), Reghunath *et al.* (1990)
	Trichomma sp.	Nalinakumari et al. (1996), Ambikadevi (1998 c)
	Xanthopimpla flavolineata (Cameron)	Nandakumar & Pramod (1998)
	Charops sp.	
Elasmid wasp	*Elasmus* sp.	

2.2 Effect of plant products on pests of rice and their defenders.

2.2.1 Pests.

2.2.1.1 *Azadirachta indica* and its products

Rao and Rao (1979) reported that one per cent neem leaf extract gave high mortality of *N. lugens* 48 hours after application. According to Krishnaiah and Kalode (1984) neem oil has low acute and persistent toxicity against *N. lugens,* whereas, Saxena and Khan (1985), and Jayaraj (1991) observed that neem seed oil was highly effective in reducing the survival of *N. lugens*. The use of neem oil for the effective control of *N. lugens* was reported by Rajendran (1992).

Chiu (1985) reported antifeedant effect of neem seed oil on N. lugens. Krishnaiah and Kalode (1990) opined that neem oil affected the orientation, settling and disrupted growth and development of *N. lugens*. The repellent effect of neem on *N. lugens* was recorded by Telan *et al.* (1994). According to Krishnaiah *et al.* (1999) neem formulation with low and high azadirachtin content were effective against N. *lugens*. Maheshkumar *et al.* (1999) found that neem azal T/S (50 ppm azadirachtin) reduced the oviposition and the same product with 10 ppm azadirachtin reduced the reproduction of *N. lugens.*

Neem oil has low acute and persistent toxicity to *N. virescens* and caused disruption of growth and development of the pest (Krishnaiah and Kalode, 1984 and 1991). Heyde *et al.* (1985) recorded reduction in the growth of first instar nymphs of *Nephotettix sp* sprayed with neem oil or 100 mg/kg neem seed kernel extract. Adverse effect of neem on the growth, development and feeding behaviour of the nymphs of *Nephotettix sp* was reported by Lim (1991). According to Maheshkumar *et al.* (1999) neem azal T / S reduced the oviposition and reproduction of *N. virescens.*

Sontakke *et al.* (1994) reported that neem oil reduced the number of *S. furcifera.* According to Krishnaiah *et al.* (1999) neem formulations like achook, neemax, neemgold 4, rakshak, fortune aza, econeem and neem azal T/S were effective against *S. furcifera.* Maheshkumar *et al.* (1999) observed that neem azal T/S with 50 ppm azadirachtin reduced the oviposition and with 10 ppm azadirachtin reduced the reproduction of *S. furcifera.*

Chiu (1985) found that neem seed oil has strong oviposition deterrent effect on *O. oryzae.* Extract of neem leaf reduced the infestation of *M. separata* (ICRISAT, 1985). According to Jayaraj (1991), neem oil retarded growth and development of *C. medinalis.* Krishnaiah *et al.* (1999) reported that neem formulations with lower azadirachtin content (achook, neemax and neemgold 4) were more effective against *C. medinalis* as compared to water based formulation with high azadirachtin content. They also reported that rakshak and neem azal T/S were highly effective against *D. armigera.*

2.2.1.2 *Clerodendron infortunatum*

Van Beek and de Groot (1986) reported that clerodin isolated from *Clerodendron* spp. showed antifeedant activity. After a detailed bioassay of the leaf extracts of 20 plant species, Saradamma (1989) opined that *C. infortunatum* could be ranked above *A. indica*. Devakumar and Parmar (1993) observed the insect antifeedant activity of clerodanes.

2.2.1.3 Nimbecidine

The toxic effect of nimbecidine against *N. lugens* was recorded by Krishnaiah *et al.* (1999). Maheshkumar *et al.* (1999) observed that nimbecidine solution having 50 ppm azadirachtin reduced the oviposition of *N. lugens*. They also found that nimbecidine solution containing with 10 ppm azadirachtin reduced the reproduction of *N. lugens*.

Krishnaiah *et al.* (1999) observed that nimbecidine two per cent was toxic to *C. medinalis*, D. *armigera* , *S. furcifera* and *N. virescens*. Maheshkumar *et al.* (1999) found that nimbecidine solution with 50 ppm azadirachtin reduced the oviposition and 10 ppm azadirachtin reduced reproduction of *S. furcifera* and *N. virescens*.

2.2.1.4 Other products.

Chiu (1985) observed that petroleum ether extracts of the seed kernels of M*elia toosendan* and *M. azedarach* at six per cent had strong antifeedant effect on *N. lugens* and strong oviposition deterring effect on *O. oryzae*. Krishnaiah and Kalode (1990) opined that oils of *Brassica latifolia* and *Calophyllum ionophyllum* were highly toxic to nymphs of *N. lugens* on rice and both the oils disrupted growth and development in *N. lugens* and *N. virescens*. The repellent effect of *Annona reticulata* and *Tinospora rumphii* on *N. lugens* was observed by Telan *et al.* (1994).

2.2.2 Defenders

2.2.2.1 Predators

According to Saxena *et al.* (1980), Joshi *et al.* (1982) and Osman and Bradley (1993) neem and neem products were safe to predators of crop pests. Topical application of neem oil on *L. pseudoannulata* caused low mortality at a dose of 50 μg per spider (Saxena *et al.* 1984). Wu (1986) suggested that neem seed oil was safe to *L. pseudoannulata*. Neem products did not affect the population of *L. pseudoannulata* (Saxena, 1989) and *O. javanus* (TNAU, 1992).

Neem oil was found toxic to *C. lividipennis* (Saxena *et al.*, 1984). According to Saxena (1989) neem products did not affect the population of *C. lividipennis*. The safety of neemark to *Menochilus* sp. was reported by Patel and Yadav (1993).

Eucalyptus sp. and *Cartharanthus roseus*, even at high concentrations had very low toxicity against *Lycosa* spp. and *Cyrtorhinus* sp. (Shanthi and Janardhanan, 1991). The extracts of *Eucalyptus terticornis* and *Tagetes erecta* were toxic to *Microvelia atrolineata* but were comparatively safe to *T. maxillosa* spiderlings (Shanthi and Sundaram, 1992). Patel and Yadav (1993) reported that nicotine sulphate showed 100 per cent safety to *M. sexmaculatus*.

2.2.2.2 Parasites

Schmutterer *et al.* (1983) reported that growth and development of endoparasitic hymenopterans on the larvae of *C. medinalis* exposed to rice leaves treated with neem were unaffected. Wu (1986) reported safety of neem seed oil to *Apanteles cypris* of brown plant hopper. Neem seed kernel extract and neem oil 50 EC have been reported to be safe to *Trichogramma japonicum, Bracon sp* and *Apanteles sp* (TNAU, 1992). Patel and Yadav (1993) found that neemark was highly toxic to the adults of *Tetrastichus* sp.

Srinivasababu *et al.* (1993) observed that neemguard at lower concentrations was safe to *Trichogramma australicum* and *Tetrastichus israeli.* According to Markandeya and Divakar (1999) eggs of *T. chilonis* treated with margosom 1500 ppm offered 45 per cent parasitisation. Patel and Yadav (1993) reported that nicotine sulphate was highly toxic to the adults of *Tetrastichus* sp.

2.3 Impact of plant products on pests and defenders in rice ecosystem.

2.3.1 Pests of rice

2.3.1.1 *A.. indica* and its products.

According to Krishnaiah and Kalode (1990), soil incorporation of neem cake @ 150 kg/ha followed by spraying of three per cent neem oil after ten days was effective against *C. medinalis.* Lim (1991) opined that neem reduced leaf spinning and feeding in *C. medinalis.* Ambethgar (1996) reported that neem cake and neem seed kernel extract five per cent was superior to neem cake and neem leaf decoction five per cent in reducing the damage of rice leaves by *C. medinalis.* Raguraman and Rajasekharan (1996) observed that neem oil, three per cent and neem seed kernel extract five per cent were effective in checking *C. medinalis.*

Krishnaiah and Kalode (1984) reported that neem oil did not significantly reduce the damage caused by *S. incertulas.* Mahapatra *et al.* (1996) observed that the effectiveness of neem oil and neem seed extract (both at two per cent) as foliar spray at 20, 40 and 70 days after transplantation together with one spray of monocrotophos (0.4 kg ai/ha) at 40 DAT gave moderate effect. Raguraman and Rajasekharan (1996) reported that the incidence of *S. incertulas* was not reduced by the application of neem oil three per cent or neem seed kernel extract five per cent.

According to Rao and Rao (1979) two per cent neem leaf extract reduced the overall population of *N. lugens* by 40 per cent. Saxena and Khan (1984) observed that the duration of survival of *N. lugens* decreased markedly in rice seedlings that had been previously sprayed with neem oil. Fewer nymphs of *N. lugens* became adults on TN_1 rice seedlings raised from seeds treated with neem leaf extract was reported by Abdulkareem *et al.* (1989). Lim (1991) found that root dip treatment of neem reduced the oviposition of *N. lugens*. Mohan *et al.* (1991) found that high volume or low volume application of neem products were more effective than ultra low volume application in controlling *N. lugens*. High volume application of neem oil three per cent and neem seed kernel extract five per cent was found to be superior to monocrotophos in suppressing *N. lugens* was suggested by Raguraman and Rajasekharan (1996).

Durairaj and Venugopal (1993) observed that neem oil two per cent and neem seed kernel extract five per cent showed reduction in *L. acuta* incidence by 69 per cent and 39 per cent respectively. A very low incidence of the population of *Leptocorisa* spp. in plots treated with neem oil three per cent and neem seed kernel extract five per cent was suggested by Raguraman and Rajasekharan (1996).

Krishnaiah and Kalode (1984) reported that neem oil did not significantly reduce the damage caused by *O. oryzae*. Dash *et al.* (1994) also found that neem derivatives were not effective for the control of *O. oryzae*.

Krishnaiah and Kalode (1984) observed that neem oil did not significantly reduce the damage caused by *Hydrellia philippina*.

Rice seedlings grown in soil treated with neem seed cake @ 150 kg/ha had significantly reduced the incidence of rice tungro virus transmitted by *N. virescens* than did untreated seedlings (Saxena *et al.* 1987). Abdulkareem *et al.* (1989) found that with treated seedlings, fewer first instar *N. virescens* nymphs reached the adult stages on TN-1 rice seedlings raised from seeds treated before sowing with ≥ 2.5 per cent neem kernel extract or with two per cent neem cake. Jayaraj (1991) and Lim (1991) reported that neem oil was effective in controlling *Nephotettix spp.*

Sontakke (1993) opined that chlorpyrifos alone and in combination with neem oil suppressed the population of *S. furcifera*. Sontakke and co – workers (1994) reported reduction in the population of *S. furcifera* on application of neem oil. Sasmal *et al.* (1995) observed that neem based products were less effective as compared to monocrotophos sprays 0.4 kg ai / ha against pests of rice.

2.3.1.2 Other products

Mariappan and Saxena (1984) reported that sprays of mixtures of seed oils of *Annona squamosa* and *A. indica* in 1:1, 1:2 and 1:4 proportion (V/V) at five, 10 or 20 per cent concentrations were significantly more effective in reducing the survival of *N. virescens* than sprays of the individual oils. Saxena (1986) found that 1:4 mixture of *A. squamosa* and neem seed oil at 50 per cent were effective in controlling *N. virescens* and rice tungro virus on the variety IR. 42.

2.3.2 Defenders of pests of rice

2.3.2.1 Predators

Application of neem oil in rice fields was harmless to predators of leaf hoppers and plant hoppers (Saxena *et al.*, 1981 a). Lim (1991) reported that the predators *Paradosa pseudoannulata* and *Cyrtorhinus lividipennis* were unaffected by neem application. Mohan *et al.* (1991) found that though there was an initial reduction in number of *L. pseudoannulata* and *C. lividipennis* in neem treated plots, recolonisation was better than in plots treated with monocrotophos. Better recolonization of

L. pseudoannulata in neem treatments was also reported by Raguraman and Rajasekharan (1996).

2.3.2.2 Parasites

According to Saxena *et al* (1981a) neem oil application in rice field was harmless to parasites of plant hoppers. This also augmented parasitisation of leaf folder larvae by the ichneumonid, encyrtid and braconid parasitoids since neem oil prevented the larva from folding rice leaves and exposed the larvae to easy parasitisation (Saxena *et al.* 1981 b). Dash *et al.* (1994) observed that attack by the parasitoid, *Platygaster oryzae* was not adversely affected by neem derivatives.

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 Assessment of the population of pests and defenders in the rice ecosystem of Thiruvananthapuram district.

The occurrence and distribution of pests and defenders in the rice ecosystem in Neyyattinkara, Nedumangad and Chirayinkil taluks of Thiruvananthapuram district were assessed through a survey conducted during *virippu* season of 1998. Three plots were selected from each taluk. The survey was carried out at 20, 40 and 60 days after transplanting of the crop.

The pests of rice and their defenders were collected from rice fields by the method followed by Reissig *et al.* (1986). The pests and defenders found on upper parts of plants and inside the leaf canopy were collected by sweep nets diagonal to the plots. The symptoms of pest attack with live stages of the pests and defenders present at the base of the plant were counted and recorded by examining the leaf and stem of plants from randomly selected ten hills, by moving from one corner to the opposite corner of the plot. The collection by sweep nets was made by moving the net to-and-fro with full stretched hand in one sweep.

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

3.1.1 Observations

The pests and defenders present in each bag brought to the laboratory were separated and counted. The number of adults and immature stages of each insect were counted. The number of each pest and defender recorded from randomly selected ten hills in each plot was added to the sweep net count of the same plot. This was treated as the population count of each plot during the period of observation.

3.2 Screening of botanicals using synthetic pesticides as check

Water extracts of the leaves of *A. indica* and *C. infortunatum,* and nimbecidine (a commercial formulation of *A. indica)* were tested by applying different concentrations of these botanicals on rice seedlings against the larvae of *C. medinalis* and *N. depunctalis*, for their toxic and antifeedant effect, adults of *N. lugens* and *L. acuta* for their deterrent and toxic effect, adults of *L. pseudoannulata* and *O. nigrofasciata* for their toxic and predatory efficiency, taking carbaryl and monocrotophos as check. The study was carried out with a view to select the best dose of these botanicals for pest management trial and to protect the defenders in rice ecosystem.

3.2.1 Maintenance of rice field for pests, defenders and seedlings.

For study of pests and defenders, rice variety *Jyothi* was raised in the wet lands of Instructional Farm, College of Agriculture, Vellayani. Sprouted seeds were sown in 160 sq.m of land at monthly intervals thrice utilising 480 sq.m of land, to get all stages of rice for natural multiplication of pests and defenders. These pests and defenders were collected and utilised for screening the bioefficacy of botanicals in the laboratory.

One hundred and twenty sq.m of land was utilised for growing rice seedlings for laboratory studies. Sprouted seeds of the variety *Jyothi* were sown in 40 sq.m of land at fortnightly intervals for six times to get continuous supply of one-month old seedlings for three months.

3.2.2 Preparation of seedlings for rearing pests and defenders.

Earthen pots (23 x 15 cm) filled two-third with clayey soil was used for growing seedlings for the rearing of pests and defenders. Ten, one-month old seedlings were planted in one earthen pot and were watered daily. They were kept undisturbed for one week in the insectary.

3.2.3 Preparation of seedlings for laboratory studies.

Ice cream cups (8 x 5.5 cm) were used for raising seedlings for laboratory studies. They were filled two-third with clayey soil and two numbers of one-month old seedlings were planted in each cup. They were kept in the insectary undisturbed for one week and watered daily.

3.2.4 Rearing of insects

3.2.4.1 Rearing *C. medinalis*

Adults of *C. medinalis* were collected from the field in specimen tubes (10 x 2.5 cm) using a camel hair brush. These insects were brought to the laboratory and ten insects were transferred to seedlings planted in each pot as described in 3.2.2. The pot was closed with metal cage (30 x 23 cm) covered with polythene sheets on the sides and moistened muslin cloth on the top. Twenty- four hours after the release of the moth, they were removed from the cage. The plants with the egg laid by the moth were kept undisturbed and watered daily. On the ninth day after release of the moth, the required number of larvae were collected from the plants treating them as freshly emerged second instar larvae for experimental purpose. The remaining larvae were retained up to emergence of the adults. These adults were used for the further multiplication of the pest.

3.2.4.2 Rearing *N. depunctalis*

Adults of *N. depunctalis* were collected from the field and released to the plants, raised on pots as described in 3.2.2 and 3.2.4. Water was retained in the pot one inch below the rim of the pot so that the larvae could survive in the caged plants by taking oxygen from water. The required numbers of larvae, with the cases were collected, nine days after release of the moth. The remaining larvae were allowed to grow as adults for further multiplication.

3.2.4.3 Rearing *N. lugens*

Fifth instar nymphs *N. lugens* were collected from the field using aspirator. They were transferred to potted plants and covered with metal cage as described in 3.2.4. Three days after the release of the nymphs, the adults present in the pots were removed carefully. Next day onwards the adults emerged were collected treating them as one day old adults for experimental purpose.

3.2.4.4 Rearing *L. acuta*

Rearing of *L. acuta* was done as described in the case of *N. lugens* (3.2.4.3).

3.2.5 Collection of *L. pseudoannulata* and *O. nigrofasciata* from rice field.

L. pseudoannulata was collected from the rice field maintained as given in 3.2.1. Sufficient number of the adults of *L. pseudoannulata* were collected from the field one in each specimen tube to avoid any mechanical injury and the tubes were closed with cotton plug. These spiders were used for experimental purpose.

The required number of *O. nigrofasciata* was collected from the field in specimen tubes and closed with cotton plug. They were brought to the laboratory and used as test insect.

3.2.6 Preparation of plant extracts

3.2.6.1 *A. indica*

The leaves of A. *indica* plants were collected from Instructional Farm, Vellayani for extraction. Samples, 50 g each, were chopped and finely ground in mixer grinder using 200 ml water. The finely ground leaves were then extracted with 50ml water. The extract was filtered using a fine muslin cloth and transferred to 250ml volumetric flask and the volume was made up with water. Thus a 20 per cent stock solution was obtained. The extract was further diluted with water containing one per cent teepol as emulsifier for obtaining two, five and ten per cent concentrations required for the experiment.

3.2.6.2 *C. infortunatum*

The water extract of the leaves of *C. infortunatum* was prepared as described for *A. indica* (3.2.6.1). While collecting leaves, the older leaves at the base of the plant were not included.

3.2.6.3 Nimbecidine

A commercial botanical pesticide containing azadirachtin 0.03 per cent supplied by M/S T. Stanes and Co., Coimbatore, was used for the experiment. Nimbecidine, 4.0, 2.0 and 1.0 per cent was obtained by separately dissolving 4, 2 and 1 ml of nimbecidine respectively in 100 ml water.

3.2.7 Estimation of antifeedant action of botanicals on pests.

Rice seedlings prepared as given in 3.2.3. and *C. medinalis* and *N. depunctalis* as described in 3.2.4. were used for the study.

Water extract of leaves of *A. indica* (ten, five and two per cent), *C. infortunatum* (ten, five and two per cent) and Nimbecidine (four, two and one per cent) were sprayed on the rice seedlings planted in ice cream cups using an atomizer. Altogether there were ten treatments, three times of release and four replications for each pest.

Single, second instar larva of *C. medinalis* was transferred to the leaves of treated plant immediately after spraying, one day and three days after spraying. The ice cream cup with the treated plants and the larva was placed inside a trough (23 x 12 cm) and was covered over by metal cage (30 x 23 cm) the sides of which were covered with polythene sheet and the top with moistened muslin cloth. This served as one replication. Second instar larva released on untreated plants served as control.

Antifeedant action of *N. depunctalis* was studied by using plants raised in ice cream cups sprayed with different concentrations of botanicals. Ice cream cup with plants was placed inside a trough filled with water to 10cm height. This was done for utilising water-dissolved oxygen for respiration of *N. depunctalis* larva. One-second instar larva with its case was introduced into each treated plant immediately after spraying, one day and three days after spraying. Treated plants with the larvae were kept undisturbed.

The total area of the leaf and the area of leaf consumed by the larva, two, four and twenty four hours after release were recorded on a graph paper. The percentage of leaf protected by the extracts was estimated as A-B/A x 100, where A - the total area of the leaf and B - the area of the leaf consumed by the larva. The data was statistically analyzed and the results were interpreted.

3.2.8 Estimation of deterrent action of botanicals on pests.

Deterrent action of different concentration of various botanicals was studied by using *N. lugens* and *L. acuta* as test insects. Two ice cream cups with the seedlings, one sprayed and another unsprayed, were placed side by side inside a trough. Ten one-day old adults of *N. lugens* or *L. acuta* were transferred to the treated plant. The trough with the seedlings and insects was covered with metal cage. This served as one replication. Control was set up by releasing ten one-day old adults of *N. lugens* or *L. acuta* on untreated plants, separately. There were ten treatments, two insects, three times of applications and three replications. The insects were released at the time of spraying, one day and three days after spraying. The treated plants with the adult insects were kept undisturbed. The number of insects settled on the treated and untreated plants were recorded two, four and twenty four hours after release. The percentage deterrent effect was worked out by using the formula A-B/A x 100, where A – total number of insects released and B – number of insects congregated on the treated plant.

3.2.9 Evaluation of the toxicity of botanicals to pests.

The trial was conducted in the laboratory using second instar larvae of *C. medinalis* and *N. depunctalis* and one day old adults of *N. lugens* and *L. acuta.* Different concentrations of botanicals (as given in 3.2.6.1) were used for the trial. Ten insects each were taken in petridish and were sprayed with different concentrations of botanicals using an atomizer. There were 10 treatments, four insects and two replications. The number of adults dead and surviving, 24 h and 48 h after spraying, were observed. Percentage mortality in two replications for each treatment was worked out.

3.2.10 Evaluation of the bioefficacy of botanicals on defenders.

A laboratory study was conducted using *L. pseudoannulata* and *O. nigrofasciata* as test organisms, to evaluate the toxic effect of various botanicals. Five numbers of the test organisms were transferred to each petridish. Different concentrations of botanicals were sprayed on the test organism. The mortality was recorded twenty-four hours and forty-eight hours after release from the three replications of all the treatments.

Another trial was conducted to study the feeding efficiency of defenders on treated insects. Ten numbers of second instar larvae of *C. medinalis* and adults of *N. lugens* were taken in each petridish and treated with different concentrations of botanicals. *O. nigrofasciata* and *L. pseudoannulata* which were starved for twenty four hours were collected from culture maintained in the laboratory. Five adults of *O. nigrofasciata* were released in each petridish containing treated larvae of *C. medinalis* and five adults of *L. pseudoannulata* were transferred to each dish with treated *N. lugens*. Starved adults of *O. nigrofasciata* and *L. pseudoannulata* were released on fresh insects kept in petridishes served as control. The number of insects fed by the defenders and the mode of feeding were observed in control and in treatments.

3.3 Field evaluation.

A trial was conducted from October 1998 to January 1999 in the State Seed Farm, Ulloor, Thiruvananthapuram district to evaluate the efficacy of water extracts of the leaves of *A. indica,* and *C. infortunatum* and nimbecidine in suppressing the pests of rice under field conditions. The effects were compared with carbaryl and monocrotophos as check.

3.3.1 Layout of the experiment.

The experiment was laid out in randomized block design. Plots of 25 x 8 m were used for the study. Seedlings of rice variety, *Jyothi* were transplanted at a spacing of 10 x 15 cm and at the rate of three seedlings per hill. There were six treatments and four replications. The treatments included in the experiments were, T1 – Water extract of leaves of *A. indica* (5%)

T2 – Water extract of leaves of *C. infortunatum* (5%)

T3 – Nimbecidine (2%)

T4 – Carbaryl (0.2%)

T5 – Monocrotophos (0.05%)

T6 – Control

Application of fertilizer and other crop husbandry practices recommended in the package of practices of Kerala Agricultural University (KAU, 1996) were adopted excluding the plant protection measures.

3.3.2 Application of plant extracts.

The plant extracts were applied in the respective plots with pneumatic knapsack sprayer at 20, 40 and 60 days after transplanting.

3.3.3 Assessment of results.

Pre-treatment and post treatment counts of the population of pests and defenders were recorded as explained in 3.1. Post treatment counts were taken at one, three and seven days after each spraying. The data of individual pest and defender population was recorded. Pest defender ratio was worked by dividing the total population of pests by total population of defenders. The data on the pest and defender population were statistically analysed using analysis of co-variance, taking pre-count as the co-variate. At harvest the weight of grain was recorded after drying and winnowing and straw after drying. The data were subjected to statistical analysis.

RESULTS

RESULTS

4.1 Occurrence and distribution of pests and defenders in rice ecosystem in different taluks of Thiruvananthapuram district

The pests recorded in the survey were *Cnaphalocrocis medinalis* (Guenee), *Nymphula depunctalis* (Guenee), *Scirpophaga incertulas* (Walker), *Nilaparvata lugens* (Stal), *Leptocorisa acuta* (Thunberg), *Nephotettix spp* and *Oxya chinensis* (Thunberg) and the defenders were *Agriocnemis* sp, *Crocothemis* sp., *Lycosa pseudoannulata* (Boesenberg and Strand), *Tetragnatha maxillosa* (Boesenberg & Strand), *Micraspis crocea* (Mulsant), *Ophionea nigrofasciata* (Schmidt-Goebel), *Cyrtorhinus lividipennis* (Reuter), *Cotesia flavipes* (Cameron) and *Tetrastichus schoenobii* (Ferriere).

The results of the survey conducted to study the magnitude of distribution caused by insect pests of rice and their defenders in the rice ecosystem are presented in Table 1.

4.1.1 Pests

4.1.1.1 *C. medinalis*

The highest mean population of this pest was noticed in Chirayinkil (1.55) and the population at Neyyattinkara (1.22) followed it. The least incidence was observed in Nedumangad (0.33).

The mean population of the pest was highest at 20 days after transplanting (DAT) and remain the same low level (1.0) at 40 and 60 DAT at Neyyattinkara taluk. At Nedumangad the insect was recorded only at 40 DAT (1.00). High population of 3.33 was observed at 40 DAT in Chirayinkil taluk and at 20 DAT (1.33) and no population observed at 60 DAT.

Table 1. **Occurrence and distribution of pests and defenders in the rice ecosystem of different taluks in Thiruvananthapuram district, as observed in a survey**

Pests and defenders observed	Mean number of Pests and Defenders present in each locations.											
	Neyyattinkara Taluk				Nedumangad Taluk				Chirayinkil Taluk			
	20 DAT	40 DAT	60 DAT	Mean	20 DAT	40 DAT	60 DAT	Mean	20 DAT	40 DAT	60 DAT	Mean
Pests												
C. medinalis	1.67	1.00	1.00	1.22	0.00	1.00	0.00	0.33	1.33	3.33	0.00	1.55
N. depunctalis	0.00	0.00	0.00	0.00	5.00	2.33	0.00	2.44	0.00	0.00	0.00	0.00
S. incertulas	2.33	1.33	0.00	1.22	2.33	3.33	0.00	1.89	0.00	1.00	0.00	0.33
N. lugens	0.00	50.67	0.00	16.89	0.00	45.33	2.33	15.89	0.00	44.33	0.00	14.78
L. acuta	0.00	5.33	16.67	7.33	0.00	0.67	13.33	4.67	0.33	0.67	16.67	5.89
Nephotettix spp.	41.67	11.67	2.33	18.56	46.67	10.67	6.67	21.34	36.67	5.67	7.33	16.56
O. chinensis	2.33	3.00	0.00	1.78	0.33	3.00	0.00	1.11	3.67	1.33	0.00	1.67
Total	48.00	73.00	20.00		54.33	66.33	22.33		42.00	56.33	24.00	
Defenders												
Agriocnemis sp.	5.00	7.00	6.00	6.00	4.00	5.00	7.00	5.33	6.00	3.00	2.00	3.67
Crocothemis sp.	3.33	2.00	2.67	2.67	0.00	3.00	6.00	3.00	5.00	5.00	5.33	5.11
L. pseudoannulata	3.33	4.00	3.00	3.44	3.33	4.00	5.00	4.11	1.33	3.00	3.00	2.44
T. maxillosa	2.33	3.33	2.33	2.66	4.66	2.00	2.33	3.00	5.00	1.33	1.67	2.67
M. crocea	0.00	0.00	0.00	0.00	0.00	0.00	1.67	0.56	0.00	4.00	0.00	1.33
O. nigrofasciata	0.00	0.00	0.00	0.00	0.00	0.67	0.00	0.22	0.00	0.00	1.67	0.56
C. Lividipennis	0.00	8.00	0.00	2.67	0.00	7.00	0.00	2.33	0.00	7.33	0.00	2.44
C. flavipes	0.00	0.00	12.67	4.22	0.33	5.00	9.00	4.78	3.33	6.67	14.00	8.00
T. schoenobii	0.00	0.00	10.33	3.44	0.00	2.00	6.33	2.78	0.67	5.00	8.00	4.56
Total	13.99	24.33	37.00		12.32	28.67	37.33		21.33	35.33	35.67	

4.1.1.2 *N. depunctalis*

The population of *N. depunctalis* was observed in the fields of Nedumangad alone and that too at 20 DAT (5.0) and 40 DAT (2.33).

4.1.1.3 *S. incertulas*

The highest mean population of *S. incertulas* was recorded at Nedumangad (1.89) followed by Neyyattinkara (1.22) and lowest in Chirayinkil (0.33). At Neyyattinkara the mean population at 20, 40 and 60 DAT ranged from 0 to 2.33, at Nedumangad 0 to 3.33 and at Chirayinkil 0.0 –1.0.

4.1.1.4 *N. lugens*

The mean population of *N. lugens* recorded in three observations in the three locations remained identical and ranged from 14.78 to 16.89. The pest was observed only at 40 DAT in Neyyattinkara taluk (50.67) and in Chirayinkil taluk (44.33) whereas in Nedumangad taluk, the pest was recorded at 40 DAT (45.33) and at 60 DAT (2.33).

4.1.1.5 *L. acuta*

The mean population of *L. acuta* observed in Neyyattinkara, Nedumangad and Chirayinkil taluks was 7.33, 4.67 and 5.89 respectively. *L. acuta* was not observed at 20 DAT in Neyyattinkara and Nedumangad taluks but a low mean population of 0.33 was noticed in Chirayinkil taluk. The mean population of the insect seen at 40 DAT was 5.33 in Neyyattinkara and that in the other two taluks was 0.67. Maximum population was recorded at 60 DAT in three taluks surveyed, which ranged from 13.33 to 16.67.

4.1.1.6 ***Nephotettix* spp.**

Among the insect pests observed in the survey in the three taluks, the population of *Nephotettix* spp. was the highest. This insect was present through out the cropping season and the highest population was noticed at 20 DAT. The highest population of 46.67 was recorded from Nedumangad followed by Neyyattinkara (41.67) and Chirayinkil (36.67). In the other two observations, the population ranged from 2.33 to 11.67 in the three locations.

4.1.1.6 ***O. chinensis***

Low population of *O. chinensis* was recorded from the three locations and the mean ranged from 1.11 to 1.78. In the three taluks, the population of the insects observed at 20 and 40 DAT was 2.33 and 3.00, 0.33 and 3.00, and 3.67 and 1.33 at Neyyattinkara, Nedumangad and Chirayinkil taluks respectively. No pest was recorded 60 DAT in any of the locations.

4.1.2 Defenders

4.1.2.1 ***Agriocnemis*** **sp.**

The highest mean population of *Agriocnemis* sp. was recorded in Neyyattinkara (6.0) followed by Nedumangad 5.33 and Chirayinkil 3.67. The population of the insect observed was 5.0, 7.0 and 6.0; 4.0, 5.0 and 7.0 and 6.0, 3.0 and 2.0 in Neyyattinkara, Nedumangad and Chirayinkil respectively at 20, 40 and 60 DAT.

4.1.2.2 *Crocothemis* sp.

The lowest mean population of the insect was recorded from Neyyattinkara (2.67) followed by Nedumangad (3.0) and the highest in Chirayinkil (5.11). In all the three locations the pest was present with a population range of 2.0 to 6.0, except in Nedumangad at 20 DAT where no insect was observed.

4.1.2.3 *L. pseudoannulata*

L. pseudoannulata was present in the three locations surveyed. The highest mean population was recorded in Nedumangad (4.11), followed by the population in Neyyattinkara (3.44) and lowest mean population of 2.44 was recorded in Chirayinkil taluk. In Neyyattinkara low population of *L. pseudoannulata* was observed at 60 DAT (3.0) with a slight increase in population at 20 DAT (3.3) and 4.0 at 40 DAT. Whereas, in Nedumangad and Chirayinkil, the lowest population recorded was 3.3 and 1.33 at 20 DAT. There was a gradual increase in the population in Nedumangad at 40 DAT (4.0) , and at 60 DAT (5.0). The population of *L.pseudoannulata* recorded in Chirayinkil was 3.0 at 40 and 60 DAT.

4.1.2.4 *T. maxillosa*

The mean population of 2.66 was recorded from Neyyattinkara and Chirayinkil and a slight increase in the mean population of 3.0 was observed at Nedumangad. The population of *T. maxillosa* in different growth stages of the crop in Neyyattinkara was 2.33, 3.33 and 2.33, in Nedumangad 4.66, 2.0 and 2.33 and in Chirayinkil 5.0, 1.33 and 1.67 at 20, 40 and 60 DAT respectively.

4.1.2.5 *M. crocea*

Low mean population of *Micraspis crocea* was observed in three locations, mean population being 0, 0.56 and 1.33. The population of the defender in Nedumangad at 60 DAT was 1.67 and in Chirayinkil, at 40 DAT it was 4.0. No insects were recorded in any other observations.

4.1.2.6 *O. nigrofasciata*

A mean population of 0.22 and 0.56 was observed in Nedumangad and Chirayinkil talüks respectively. This defender was not present in any of the observations recorded at Neyyattinkara, whereas the same was present at 40 DAT (0.67) and at 60 DAT (1.67) in Nedumangad and Chirayinkil taluk respectively.

4.1.2.7 *C. lividipennis*

Mean population of *C. lividipennis* recorded from three locations ranged from 2.33 to 2.67. In all the three locations the insect was present only at 40 DAT with a population of 8.0, 7.0, 7.33 in Neyyattinkara, Nedumangad and Chirayinkil respectively.

4.1.2.8 *C. flavipes*

The highest mean population of 8.0 was recorded in Chirayinkil followed by 4.78 in Nedumangad and lowest population of 4.22 in Neyyattinkara. The population of *C. flavipes (12.67)* was recorded only at 60 DAT from Neyyattinkara. *C. flavipes* was recorded in the three observations from Nedumangad and Chirayinkil, the population ranged from 0.33 to 9.0 and 3.33 to 14 respectively.

4.1.2.9 *T. schoenobii*

The mean population of 3.44, 2.78 and 4.56 was noticed from Neyyattinkara, Nedumangad and Chirayinkil respectively. The parasite population was recorded only at 60 DAT (10.33) in Neyyattinkara, 40 DAT (2.0) and 60 DAT (6.33) in Nedumangad and a population range 0.67 to 8.0 in Chirayinkil.

The total population of pests and defenders recorded from the three locations at various growth stages of the crop were presented in Fig. 1. The data showed that defenders were present through out the cropping period along with pest in the three locations.

The total population of pest recorded from Neyyattinkara at 20 DAT was 48.0 and that of the defender were 14.0. The highest total population of pest was observed at 40 DAT (73.0) and the defender population was 24.33. The lowest population of pest (20) and the highest population of defender (37) were recorded at 60 DAT. The same trend was observed in Nedumangad and Chirayinkil. The total population of pests ranged from 22.33 to 66.33 and that of defenders varied from 12.32 to 37.33 at 20,40 and 60 DAT from Nedumangad. In Chirayinkil, the highest total population of pest was recorded at 40 DAT (56.33) followed by 42.0 at 20 DAT and the lowest population of 24.0 at 60 DAT. The values of defenders were 21.33, 35.33 and 35.67 at 20,40 and 60 DAT respectively.

4.2 Antifeedant action of various plant products on different test insects

4.2.1 *C. medinalis*

Antifeedant activity of water extracts of the leaves of *A. indica*, *C. infortunatum* and nimbecidine assessed in terms of percentages of leaf protection are presented in Table.2.

Fig. 1. Total population of pests and defenders recorded from different locations at various growth stages of the crop.

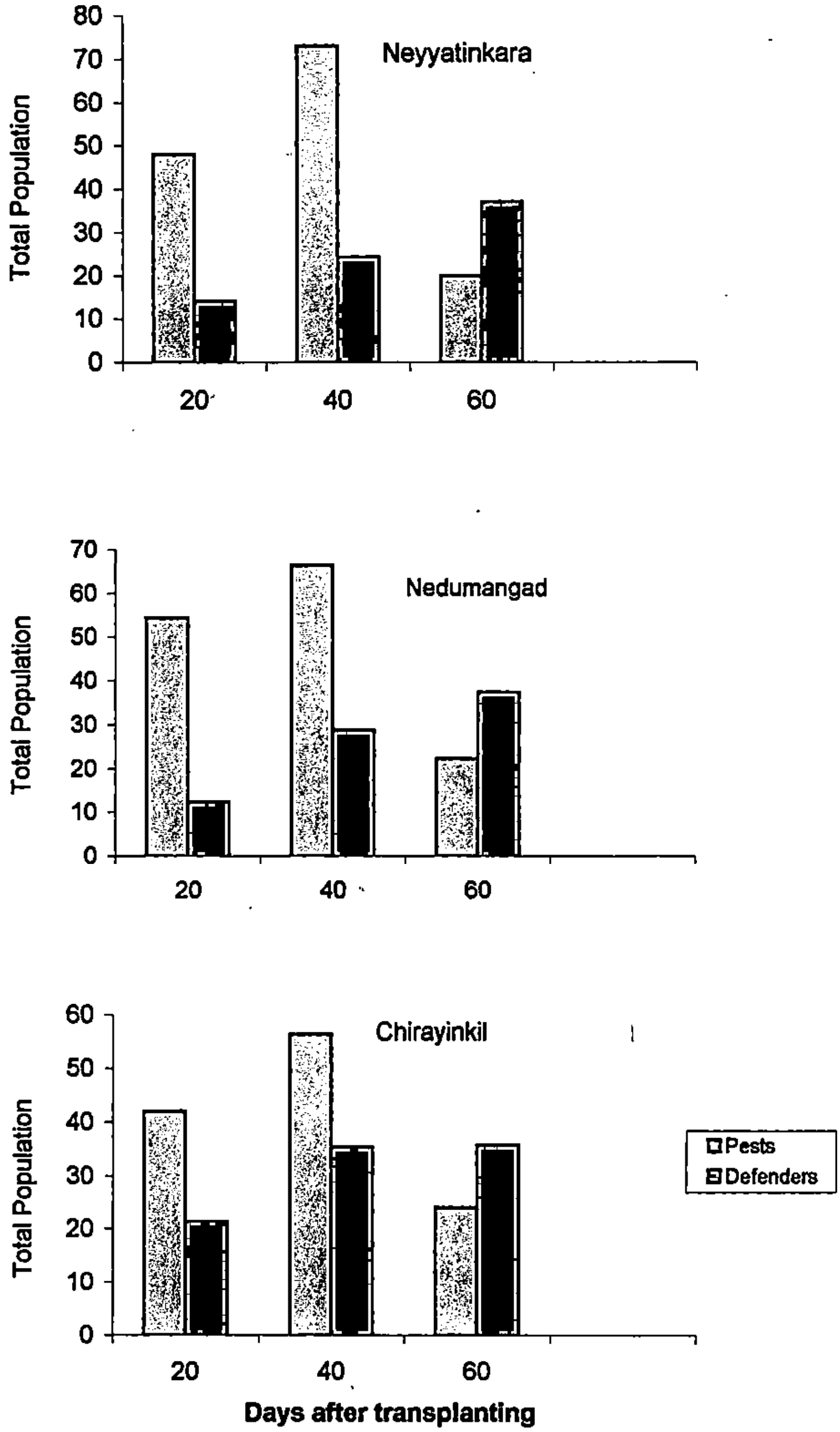


Table 2. Antifeedant action of leaf extracts of *A indica* and *C. .infortunatum* and Nimbecidine on second instar larvae of *C. medinalis* and *N. depunctalis* released at different intervals after application

Treatments	Percentage of leaf area protected (24 hours after release)							
	C. medinalis				*N. depunctalis*			
	At the time of application	One day after application	Three days after application	Mean	At the time of application	One day after application	Three days after application	Mean
Leaf extract of *A. indica* 2%	87.63 (69.38)	78.69 (62.49)	81.64 (64.60)	82.65(65.49)	74.97 (59.96)	81.59 (64.57)	74.45 (59.61)	77.00(61.38)
" 5%	91.11 (72.62)	77.02 (61.33)	80.89 (64.05)	83.01(66.00)	81.18 (64.26)	80.10 (63.48)	80.66 (63.88)	80.65(63.88)
" 10%	95.12 (77.21)	86.43 (68.35)	84.98 (67.17)	88.84(70.90)	94.80 (76.79)	84.54 (66.82)	81.84 (64.75)	87.06(69.46)
Leaf extract of *C. infortunatum* 2%	81.23 (64.30)	72.26 (58.19)	64.46 (53.38)	72.65(58.63)	66.88 (54.84)	76.76 (61.15)	77.68 (61.78)	73.77(59.26)
" 5%	95.06 (77.12)	83.68 (66.15)	75.82 (60.52)	84.85(67.93)	77.36 (61.57)	83.30 (65.86)	76.05 (60.68)	78.90(62.70)
" 10%	94.96 (76.99)	87.65 (69.40)	80.96 (64.10)	87.86(70.16)	72.33 (58.24)	84.77 (67.00)	80.19 (63.55)	79.10(62.93)
Nimbecidine 1%	89.55 (71.11)	82.79 (65.47)	63.29 (52.69)	78.54(63.09)	73.05 (58.70)	79.91 (63.34)	79.30 (62.91)	77.42(61.65)
" 2%	93.40 (75.08)	91.61 (73.13)	86.82 (68.68)	90.61(72.30)	84.99 (67.18)	85.52 (67.61)	78.24 (62.17)	82.92(65.65)
" 4%	96.45 (79.10)	94.96 (76.99)	95.09 (77.17)	95.50(77.76)	83.60 (66.09)	85.96 (67.97)	82.81 (65.48)	84.12(66.512)
Control	82.03 (64.89)	74.46 (59.62)	78.65 (62.45)	78.38(62.80)	75.60 (60.37)	79.07 (62.75)	80.84 (64.01)	78.50(62.38)
Mean	90.65(72.78)	82.96(66.11)	79.26(63.48)		78.48(66.18)	82.15(67.46)	79.21(65.31)	

CD for treatments - (3.62)
Treatments mean – (2.09)
Intervals - (1.04)

CD for treatments - (5.87)
Treatment mean - (3.39)
Intervals - (1.69)

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

The mean percentage of leaf protection given by various concentrations of different plant products showed that nimbecidine four per cent (95.50) was significantly superior among all the treatments. The response of other treatments was same when applied with lower two concentrations of leaf extract of *A. indica* (82.65 and 83.01) and higher two concentrations of leaf extract of *C. infortunatum* (84.85 and 87.86). The effect of nimbecidine two per cent (90.61) and leaf extract of *A. indica* 10 per cent (88.84) was on par. No significant difference was observed between the leaf extract *of* *C.. infortunatum* two per cent (72.65), nimbecidine one per cent (78.54) and control (78.38).

The over all effect of different concentrations of plant products on *C. medinalis* released immediately after application, one day after application and three days after application, recorded significantly higher leaf protection in treatments where the larvae were released at the time of application. This was followed by treatment where release of the larvae was done, one day after application and lowest protection was noticed in treatment where the larvae were released three days after application.

Among various treatments, maximum protection was given by the highest concentration of nimbecidine (96.45), followed by leaf extracts of *A. indica* (95.12) *and* *C. infortunatum* five and 10 per cent (95.06 and 94.96 respectively). The effects of these treatments were statistically on par. When compared with control (82.03) significant protection was obtained in all the other treatments, the values ranged from 87.63 to 93.4 per cent, except in leaf extract of *C. infortunatum* two per cent, where the percentage of leaf protection recorded was only 81.23.

The leaf area protected one day after release of the larvae, was same as that observed at the time of application. Significantly higher protection as compared to control was recorded only in leaves sprayed with the highest concentration of leaf extract of *A. indica* (84.98) and nimbecidine at concentrations of two per cent (86.82) and four per cent (95.09), when the larvae released three after application.

4.2.2 *N. depunctalis*

The mean percentage of leaf protection observed in plants treated with different concentrations of various plant products showed that significant protection was recorded only with highest concentration of leaf extract of *A. indica* (87.06) and nimbecidine (84.12) as compared with control. Significant protection was offered when the larva was released one day after application (82.15). The values obtained at the time of application (78.48) and three days after application (79.21) were on par.

Among the various treatments and different time of release after applications, significant protection of the leaves was obtained only in the highest concentration of the leaf extract of *A. indica* (94.80) and nimbecidine two per cent (84.99).

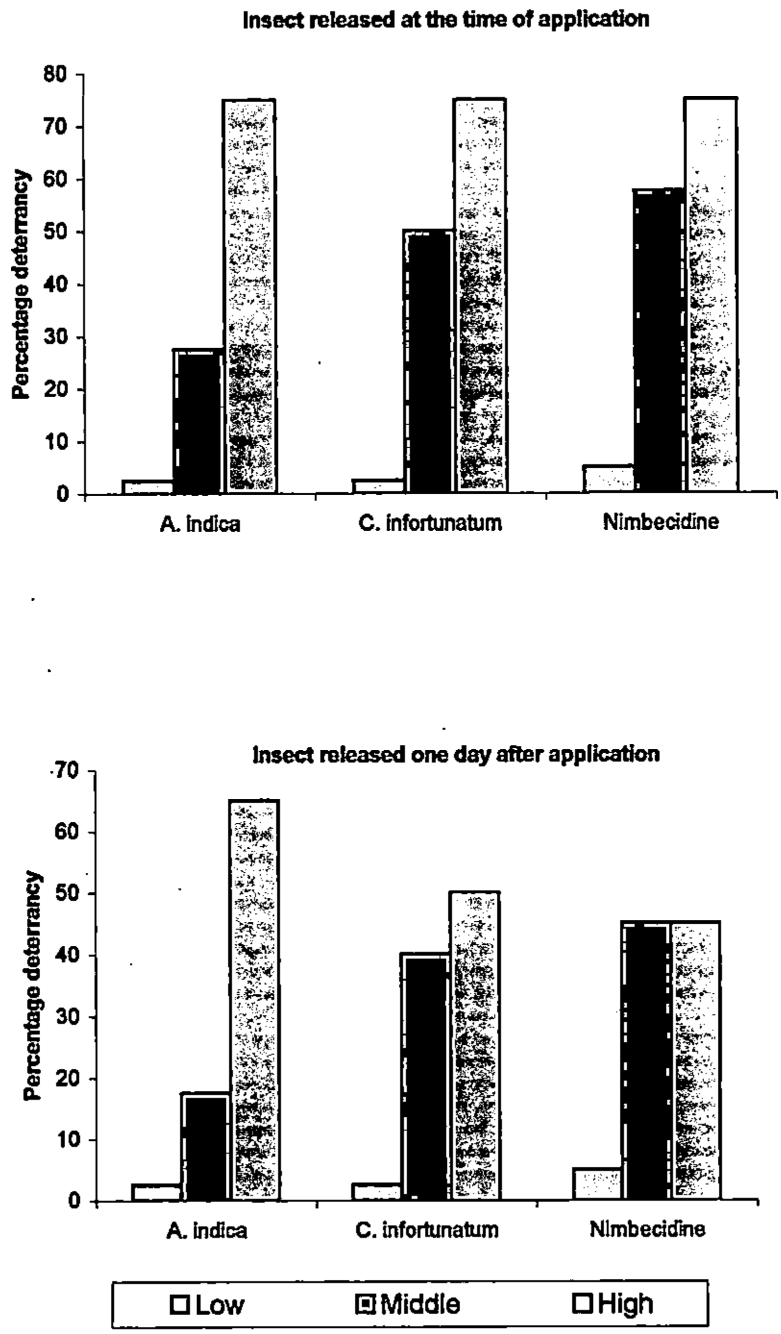
4.3 Estimation of deterrent action of plant products on different test insects

Deterrent effect of different concentrations of the leaf extracts of *A. indica* and *C. infortunatum* and nimbecidine assessed in terms of percentage of insect deterred from treated plant surface is presented in Fig. 2.

4.3.1 *N. lugens*

The study clearly showed that the deterrent effect of *A. indica*, *C .infortunatum* and nimbecidine at their highest doses, observed 24 h after release, recorded high level of deterrent effect. (75 per cent in the three treatments) when the insect was released at the time of application and one day after application (65, 50 and 45). At the middle dose, the

Fig. 2. Deterrent effect of leaf extracts of *A. indica* and *C. infortunatum* and *nimbecidine* on *N. lugens* released at different periods after application.



percentage of deterrent effect was 27.5, 50.0 and 57.5 when released at the time of application and 17.5, 40, 45 one day after application of leaf extracts of *A. indica, C. infortunatum* and nimbecidine respectively. At lowest dose such effect was not noticed in any of the plant products. No deterrant effect was observed when the insect was released three days after application in all the treatments.

4.3.2 *L. acuta*

Different concentration of various plant products tested did not show any deterrant activity against the adults of *L. acuta.*

4.4 Evaluation of the toxicity of plant products on various test insects

When different concentrations of the leaf extracts of *A. indica* and *C. infortunatum* and nimbecidine were sprayed on the second instar larvae of *C. medinalis* and *N. depunctalis* and the adults of *N. lugens* and *L. acuta,* no mortality was observed.

4.5 Evaluation of bioefficacy of plant products on defenders

Mortality studies carried out using different plant products on *L. pseudoannulata* and *O. nigrofasciata* showed that there was no toxic effect of those plant products on the defenders 48 h after release.

Number of *N. lugens* consumed by *L. pseudoannulata* did not show any variation when tested using different plant products. In all the treatments including control, two to three hoppers were consumed 24 h after release.

The rate of consumption of *O. nigrofasciata* using the second instar larvae of *C. medinalis* after 24 h of release, was the same (one to two larvae consumed per beetle) in the treatments as well as in the control.

4.6 Effect of various plant products and insecticides on pests in rice field

The population of *C. medinalis* and *N. depunctalis* was observed only at 20 DAT and that of *L. acuta* was recorded at 60 DAT in the experimental plot. The population recorded just before spraying, one, three and seven days after spraying is presented in Table. 3.

4.6.1 *C. medinalis*

The population of *C. medinalis* recorded one day after spraying did not show any significant variation among the treatments when compared with control, the number of insects ranging from 0.64 to 2.20. Significant reduction in the population was recorded three days after spraying with *C. infortunatum* five per cent (0.96), carbaryl 0.2 per cent (1.62) and in monocrotophos 0.05 per cent (0.93). Spraying of the leaf extract of *A. indica* and nimbecidine did not cause suppression of pests, the population being 2.96 and 2.76 respectively. The suppressing trend of population was also noticed seven days after treatment only in insecticide treatments, the population being 1.37 with carbaryl and 0.71 with monocrotophos.

4.6.2 *N. depunctalis*

Significant reduction in the number of insect was noticed one day after spraying only in treatments with leaf extracts of *A. indica* and *C. infortunatum*, the population being 0.08 and 0.17 respectively. There was no significant difference between nimbecidine, carbaryl and monocrotophos and the control, the number of insects observed

Table 3. **Effect of leaf extracts of *A. indica* and *C. infortunatum* and Nimbecidine on various pests infesting rice during different growth stages**

Treatments	Number of insects observed at different intervals after spraying (days)											
	C.. medinalis				*N. depunctalis*				*L. acuta*			
	20 DAT				20 DAT				60 DAT			
	Precount	1	3	7	Precount	1	3	7	Precount	1	3	7
Leaf extract of *A.indica* 5%	1.46 (1.57)	0.74 (1.32)	2.96 (1.99)	3.84 (2.20)	0.93 (1.39)	0.08 (1.04)	1.31 (1.52)	0.64 (1.28)	41.90 (6.55)	42.56 (6.60)	45.24 (6.80)	38.19 (6.26)
Leaf extract of C. *infortunatum* 5%	1.69 (1.64)	0.77 (1.33)	0.96 (1.40)	2.42 (1.85)	1.46 (1.57)	0.17 (1.08)	0.54 (1.24)	0.44 (1.20)	22.43 (4.84)	23.30 (4.93)	23.60 (4.96)	33.57 (5.88)
Nimbecidine 2%	1.69 (1.64)	0.77 (1.33)	2.76 (1.94)	3.08 (2.02)	2.17 (1.78)	1.31 (1.52)	0.39 (1.18)	0.72 (1.31)	28.81 (5.46)	26.88 (5.28)	42.16 (6.57)	48.14 (7.01)
Carbaryl 0.2%	0.93 (1.39)	0.64 (1.28)	1.62 (1.62)	1.37 (1.54)	1.96 (1.72)	1.04 (1.42)	0.69 (1.30)	0.66 (1.29)	46.33 (6.88)	5.35 (2.52)	21.85 (4.78)	31.83 (5.73)
Monocrotophos 0.05%	3.71 (2.17)	1.19 (1.48)	0.93 (1.39)	0.71 (1.31)	1.96 (1.72)	1.25 (1.50)	1.66 (1.63)	1.16 (1.47)	36.45 (6.12)	6.08 (2.66)	14.84 (3.98)	34.76 (5.98)
Control	3.20 (2.05)	2.20 (1.79)	5.55 (2.56)	5.05 (2.46)	2.46 (1.86)	1.62 (1.62)	1.99 (1.73)	2.76 (1.94)	24.30 (5.03)	28.38 (5.42)	32.29 (5.77)	39.96 (6.40)
CD		NS	(0.730)	(0.625)		(0.249)	(0.332)	NS		NS	NS	NS

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

being 1.31, 1.04, 1.25 and 1.62 respectively. Observations recorded three days after spraying showed that there was significant reduction in number of insect in treatments with leaf extracts of *C. infortunatum* (0.54), nimbecidine (0.39) and carbaryl (0.69). However, no significant difference in the population of this pest was noticed on treatments with leaf extracts of *A. indica* (1.31) and monocrotophos (1.66). The number of insects recorded seven days after spraying showed no significant variation among treatments, the range being 0.44 to 2.76.

4.6.3 *L. acuta*

Neither the plant products nor the insecticides showed any effect on population suppression in the observations made one, three and seven days after spraying.

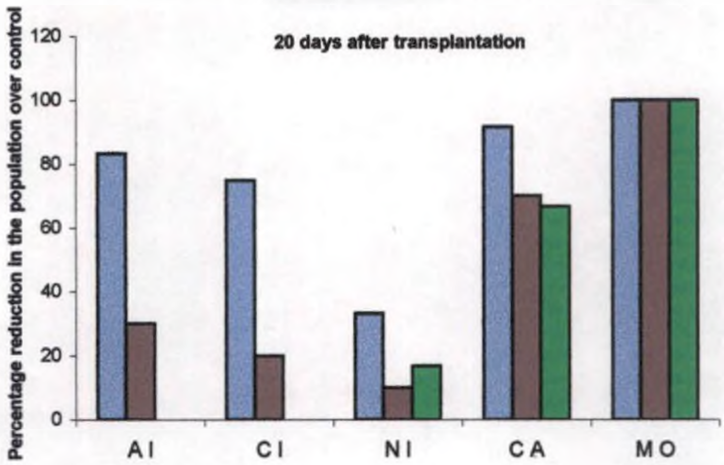
4.6.4 *N. lugens*

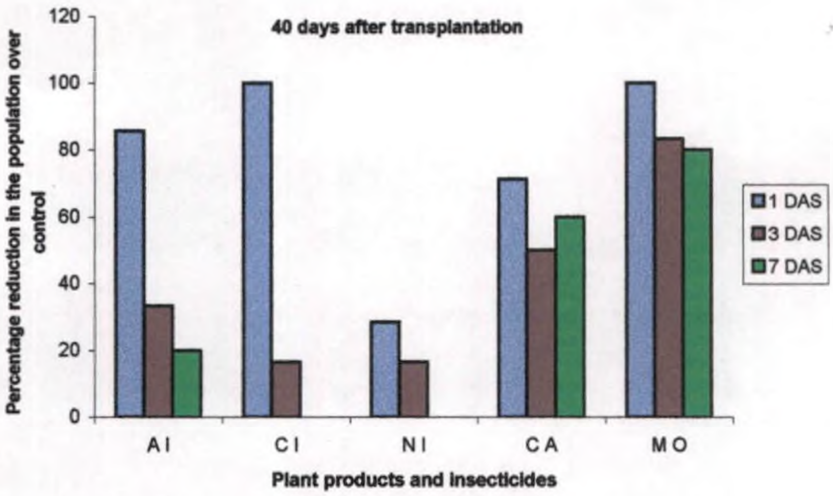
The presence of *N. lugens* was noticed only at 20 DAT and 40 DAT. The percentage reduction noticed during 20 DAT and 40 DAT is expressed as the percentage reduction in population over control and presented in Fig. 3.

The percentage reduction in the population of the insect was highest one day after spraying during both the periods. At 20 DAT, hundred percent reduction was noticed only in monocrotophos in the first, third and seventh days after spraying, followed by carbaryl (91.67, 70.70 and 66.67), leaf extracts of *A. indica* (83.33, 30.0 and 0.00), *C. infortunatum* (75, 20, 0.00). The lowest protection was recorded in nimbecidine, the percentage reduction being 33.33, 10.0 and 16.67.

At 40 DAT, cent per cent reduction in the pest population was recorded one day after spraying in treatments with monocrotophos and *C. infortunatum*, which was followed by *A. indica*, carbaryl and nimbecidine, the percentage reduction over control being 85.71, 71.43 and 28.57. A gradual reduction in population was observed in various

Fig. 3. Effect of plant products and insecticides on field population of *N. lugens* observed at different days after application and different growth stages.





AI - *A. indica* 5% NI - Nimbecidine 2%

CI - *C. infortunatum* 5% CA - Carbaryl 0.2%

MO - Monocrotophos 0.05%

treatments three days after spraying (range being 16.67 to 83.33). Seven days after spraying the percentage reduction in the population over control was noticed only in treatment with leaf extract of *A. indica* (20.0) and with carbaryl (60.0) and monocrotophos (80.0).

4.6.5 Total population of pests

The total population of various pests present in the rice ecosystem at different intervals after spraying during different growth stages of the plant is depicted in Table. 4.

At 20 DAT significant reduction in total population of pests was recorded only in treatment with leaf extract of *C. infortunatum* (8.92) and in carbaryl (6.67) and other treatments were on par with control at one day after spraying. None of the treatments except carbaryl (10.63), showed significant reduction in the total population of pests at three days after spraying.

At 40 DAT, it was found that treatment with leaf extracts of *A. indica* suppressed the total pest population consecutively in the two observations, namely, one day (6.4) and 3 days (5.10) after spraying. Both treatments with *C. infortunatum* and nimbecidine were on par with control. At 60 DAT, significant lower total population was recorded in *C. infortunatum* (30.70) at three days after spraying. Seven days after spraying, none of the treatments was effective in suppressing the total population of pests through out the growth stages of the crop. The total population of pests ranged from 13.06 to 36.70 (20DAT), 12.69 to 54.50 (40 DAT) and 37.69 to 57.37 (60 DAT). Significantly high population of the total pest was recorded in treatment with nimbecidine at 20 DAT (36.70) and 60 DAT (57.37), leaf extract of *C. infortunatum* at 40 DAT (54.50).

Table 4. Effect of leaf extracts of *A. indica* and *C. infortunatum* and Nimbecidine on total population of Pests infesting rice during different growth stages

Treatments	Number of pests observed at different intervals after spraying (days)											
	20 DAT				40 DAT				60 DAT			
	Precount	1	3	7	Precount	1	3	7	Precount	1	3	7
Leaf extract of *A. indica* 5%	14.84 (3.98)	9.63 (3.26)	14.76 (3.97)	16.31 (4.16)	15.16 (4.02)	6.40 (2.72)	5.10 (2.47)	20.44 (4.63)	53.17 (7.36)	48.00 (7.00)	51.42 (7.24)	40.73 (6.46)
Leaf extract of C. *infortunatum* 5%	15.24 (4.03)	8.92 (3.15)	18.89 (4.46)	21.47 (4.74)	29.69 (5.54)	8.55 (3.09)	16.14 (4.14)	54.50 (7.45)	30.70 (5.63)	28.16 (5.40)	30.70 (5.63)	37.69 (6.22)
Nimbecidine 2%	29.14 (5.49)	21.09 (4.70)	24.81 (5.08)	36.70 (6.14)	14.68 (3.96)	10.56 (3.40)	14.37 (3.92)	14.60 (3.95)	35.36 (6.03)	32.18 (5.76)	53.46 (7.38)	57.37 (7.64)
Carbaryl 0.2%	23.50 (4.90)	6.67 (2.77)	10.63 (3.41)	14.60 (3.95)	21.09 (4.70)	4.29 (2.30)	5.20 (2.49)	12.69 (3.70)	63.96 (8.06)	12.54 (3.68)	28.70 (5.45)	38.94 (6.32)
Monocrotophos 0.05%	23.40 (4.94)	12.62 (3.69)	13.06 (3.75)	13.44 (3.80)	23.11 (4.91)	5.30 (2.51)	10.36 (3.37)	19.07 (4.48)	51.27 (7.22)	13.21 (3.77)	17.15 (4.26)	41.64 (6.53)
Control	17.58 (4.31)	17.75 (4.33)	19.98 (4.58)	13.06 (3.75)	12.25 (3.64)	12.91 (3.73)	15.08 (4.01)	15.81 (4.10)	32.76 (5.81)	36.58 (6.13)	42.16 (6.57)	42.69 (6.61)
CD		(1.175)	(0.930)	(1.076)		(0.906)	(0.854)	(0.922)		(1.120)	(0.786)	(0.857)

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

4.7 Effect of various plant products and insecticides on defenders in rice field

4.7.1 Spiders

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

The total population of the three spiders recorded before and after spraying at 20, 40 and 60 DAT is presented in Table. 5.

At 20 DAT, the population of spiders recorded one day after spraying showed that insecticide treatment significantly reduced the population, the population being 5.60 in carbaryl and 4.24 in monocrotophos. Other treatments were on par with control, population ranging from 10.56 to 15.65. Population of spiders at 3 days after spraying clearly indicated that insecticides significantly reduced spider population (carbaryl 0.2 per cent 4.43 and monocrotophos 0.05 per cent 7.82) and that the population observed in nimbecidine treated plots (14.29) was on par with control (13.98). Significantly higher population of spiders was recorded in treatments with *A. indica* (21.85) and *C. infortunatum* (23.40). Seven days after spraying, the same trend was observed in the case of insecticides, where the population recorded was 5.66 in treatment with carbaryl and 9.63 in monocrotophos. Treatments with *C. infortunatum* (19.79) and nimbecidine (16.14) were on par with control (18.36). Highest population of 30.25 was recorded from plots sprayed with leaf extracts of *A. indica,* which was significantly higher than other two plant products.

Forty days after transplanting the insecticide treatments significantly reduced spider population one day after spraying, the number of spiders recorded in treatments with carbaryl being 10.36 and monocrotophos 8.36. The number of spiders recorded in treatments receiving plant products did not show any significant reduction, the population

Table 5. **Effect of leaf extracts of *A. indica* and *C. infortunatum* and Nimbecidine on spiders observed during different growth stages**

Treatments	Number of spiders observed at different intervals after spraying (days)											
	20 DAT				40 DAT				60 DAT			
	Precount	1	3	7	Precount	1	3	7	Precount	1	3	7
Leaf extract of *A. indica* 5%	13.36 (3.79)	10.56 (3.40)	21.85 (4.78)	30.25 (5.59)	16.14 (4.14)	18.36 (4.40)	25.63 (5.16)	31.83 (5.73)	1.22 (1.49)	0.66 (1.29)	0.46 (1.21)	0.88 (1.37)
Leaf extract of *C. infortunatum* 5%	11.46 (3.53)	12.69 (3.70)	23.40 (4.94)	19.79 (4.56)	25.32 (5.13)	26.77 (5.27)	25.21 (5.12)	23.21 (4.92)	7.47 (2.91)	6.34 (2.71)	4.62 (2.37)	0.00 (0.77)
Nimbecidine 2%	14.05 (3.88)	15.65 (4.08)	14.29 (3.91)	16.14 (4.14)	15.89 (4.11)	18.45 (4.41)	22.43 (4.84)	27.84 (5.37)	3.20 (2.05)	2.72 (1.93)	0.44 (1.20)	0.74 (1.32)
Carbaryl 0.2%	16.14 (4.14)	5.60 (2.57)	4.43 (2.33)	5.66 (2.58)	18.45 (4.41)	10.36 (3.37)	14.60 (3.95)	29.80 (5.55)	4.34 (2.31)	2.28 (1.81)	3.08 (2.02)	0.54 (1.24)
Monocrotophos 0.05%	12.62 (3.69)	4.24 (2.29)	7.82 (2.97)	9.63 (3.26)	18.80 (4.45)	8.36 (3.06)	14.76 (3.97)	26.35 (5.23)	2.96 (1.99)	3.20 (2.05)	0.69 (1.30)	0.77 (1.33)
Control	10.76 (3.43)	14.21 (3.90)	13.98 (3.87)	18.36 (4.40)	23.70 (4.97)	27.09 (5.30)	22.23 (4.82)	21.47 (4.74)	1.69 (1.64)	2.39 (1.84)	1.46 (1.57)	1.04 (1.43)
CD		(1.133)	(0.853)	(1.008)		(0.928)	(0.609)	(0.546)		(0.631)	(0.436)	NS

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

ranged from 18.36 to 26.77. The same trend was continued in three days after spraying, where significantly lower population of spider was recorded in treatments with insecticides (carbaryl 14.60; monocrotophos 14.76). The number of spiders recorded in treatments with plant products were 25.63, 25.21 and 22.43 in treatments with *A. indica*, *C. infortunatum* and nimbecidine respectively which were on par with control (22.23). On the seventh day after spraying none of the treatments showed adverse effect on spider population. Significantly higher population was recorded in treatments with *A. indica* (31.83), nimbecidine (27.84) and carbaryl (29.80). In other treatments, namely *C. infortunatum*, monocrotophos and control the population ranged from 21.47 to 26.35.

The effect of spraying plant products and insecticides on plants 60 days after transplanting, the observation recorded one day after spraying, did not show any significant reduction in any of the treatments, the population ranging from 0.66 to 6.34. Significantly higher population (6.34) was recorded only in treatment with *C. infortunatum*. Three days after spraying significantly higher population was recorded in treatments with *C. infortunatum* (4.62) and carbaryl (3.08) and the other treatments were on par with control, the range being 0.44 to 1.46. Number of spiders recorded at seven days after spraying did not show any significant difference among treatments, the values ranged from 0.0 to 1.04.

4.7.2 *O. nigrofasciata*

The population of *O. nigrofasciata* recorded 20, 40 and 60 DAT is presented in Table.6. At 20 DAT, the observations recorded did not show any significant reduction in any of the treatments one day after spraying, the population ranged from 0.21 to 2.28.

Table 6. **Effect of leaf extracts of *A. indica* and *C. infortunatum* and Nimbecidine on *O. nigrofasciata* during different growth stages**

Treatments	Number of defenders observed at different intervals after spraying (days)											
	20 DAT				40 DAT				60 DAT			
	Precount	1	3	7	Precount	1	3	7	Precount	1	3	7
Leaf extract of *A. indica* 5%	1.69 (1.64)	2.28 (1.81)	3.24 (2.06)	1.96 (1.72)	2.20 (1.79)	1.43 (1.56)	2.69 (1.92)	1.32 (1.52)	1.96 (1.72)	3.88 (2.21)	1.59 (1.61)	1.31 (1.52)
Leaf extract of *C. infortunatum* 5%	2.84 (1.96)	1.56 (1.60)	7.01 (2.83)	6.08 (2.66)	1.96 (1.72)	2.80 (1.95)	7.29 (2.88)	3.24 (2.06)	5.45 (2.54)	4.81 (2.41)	5.71 (2.59)	6.84 (2.80)
Nimbecidine 2%	1.16 (1.47)	1.02 (1.42)	5.81 (2.61)	2.50 (1.87)	1.56 (1.60)	1.25 (1.50)	3.62 (2.15)	1.31 (1.52)	3.97 (2.23)	5.81 (2.61)	2.46 (1.86)	2.88 (1.97)
Carbaryl 0.2%	0.93 (1.39)	0.21 (1.10)	0.21 (1.10)	1.99 (1.73)	3.88 (2.21)	1.07 (1.44)	1.59 (1.61)	3.28 (2.07)	3.97 (2.23)	1.19 (1.48)	3.67 (2.13)	1.92 (1.71)
Monocrotophos 0.05%	2.28 (1.81)	0.35 (1.16)	0.35 (1.16)	1.13 (1.46)	3.28 (2.07)	1.10 (1.45)	1.50 (1.58)	3.41 (2.10)	6.67 (2.77)	1.16 (1.47)	1.31 (1.52)	0.08 (1.04)
Control	0.46 (1.21)	0.69 (1.30)	5.81 (2.61)	3.04 (2.01)	1.37 (1.54)	0.80 (1.34)	1.16 (1.47)	1.43 (1.56)	5.71 (2.59)	6.62 (2.76)	6.24 (2.69)	0.51 (1.23)
CD		(0.390)	(0.738)	(0.593)		NS	(0.477)	(0.425)		(0.576)	NS	(0.580)

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

Significantly higher population was observed in treatment with leaf extracts of *A. indica* (2.28). On the third day after spraying, adverse effect on population of the predator was noticed only in insecticide treatments (carbaryl- 0.21 and monocrotophos- 0.35). Treatments receiving plant products were on par with control, the population ranged from 3.24 to 7.01. The effect of insecticide on the predator was found to reduce on the seventh day after spraying and all the treatments were on par with control (range being 1.13 to 3.04) whereas, in treatment with *C. infortunatum,* significantly higher population of 6.08 was observed.

Over all view of the effect of plant products and insecticides on *O. nigrofasciata* at 40 DAT did not record any adverse effect on the population first day, third day and seventh day after spraying. There was no significant difference in population among the treatments one day after spraying (population ranged from 0.80 to 2.80). On the third day after spraying significantly higher population was recorded in treatment with *C. infortunatum* (7.29) and nimbecidine (3.62). The other treatments were on par with control the population ranged from 1.16 to 2.69. Significantly higher population was observed on the seventh day after spraying in treatments with *C. infortunatum* (3.24), carbaryl (3.28) and monocrotophos (3.41). The other treatments were on par with control (range being 1.31 to 1.43).

At 60 DAT, significant reduction in the population was noticed in insecticide treatments (carbaryl 1.19 and monocrotophos 1.16). The treatments receiving plant products were on par with control and the population ranged from 3.88 to 6.62, on the first day after spraying. Observation recorded on the third day after spraying did not show any variation among the treatments and the values ranged between 1.31 to 6.24. On the seventh day, a significant increase in the number of defender was recorded in treatments with *C. infortunatum* (6.84) and nimbecidine (2.88), the other treatments gave identical result with that of control.

4.7.3 *Agriocnemis* spp.

Sizable population of *Agriocnemis* spp. was recorded at 20 and 40 DAT. The population recorded just before spraying and one, three and seven days after spraying is given in Table. 7.

It is very clear from the data that none of the treatments had adversely affected the defender one day after spraying in both the observations, the number of insects ranged from 1.56 to 3.67 (20 DAT) and 0.69 to 1.72 (40 DAT). On the third day after spraying at 20 DAT, significant reduction in the population was recorded in treatments with *C. infortunatum* (0.56) and with carbaryl (1.37) and the other treatments were on par with control, the range being 3.0 to 5.3. The same trend was noticed at 40 DAT, where significantly reduced population of 1.02 and 1.43 was noticed in treatments with *C. infortunatum* and carbaryl respectively. The range in population recorded in other treatments was 1.69 to 2.69, which did not show any statistical difference. On the seventh day after spraying, no adverse effect was noticed in the two observations. Significantly higher population was recorded in three treatments namely, treatments with *A. indica* (2.65), carbaryl (3.71) and monocrotophos (3.24) at 20 DAT and the same effect was noticed only in treatments with *A. indica* (3.0) and carbaryl (3.62) at 40 DAT. All the other treatments were on par with control which ranged from 0.66 to 0.96 at 20 DAT, 0.99 to 1.69 at 40 DAT respectively.

4.7.4 *M. crocea*

Number of *Micraspis* spp. observed during various growth stages of the plant at different intervals, before and after spraying is depicted in Table 8. Sizable number of

Table 7. **Effect of leaf extracts of *A. indica* and *C. infortunatum* and Nimbecidine on *Agriocnemis* spp during different growth stages**

Treatments		Number of defenders observed at different intervals after spraying (days)							
		20 DAT				40 DAT			
		Precount	1	3	7	Precount	1	3	7
Leaf extract of *A. indica*	5%	2.72 (1.93)	1.79 (1.67)	4.24 (2.29)	2.65 (1.91)	1.46 (1.57)	1.22 (1.49)	1.72 (1.65)	3.00 (2.00)
Leaf extract of *C. infortunatum*	5%	0.46 (1.21)	1.56 (1.60)	0.56 (1.25)	0.88 (1.37)	1.37 (1.54)	1.72 (1.65)	1.02 (1.42)	0.99 (1.41)
Nimbecidine	2%	1.96 (1.72)	3.08 (2.02)	3.00 (2.00)	0.66 (1.29)	1.62 (1.62)	1.37 (1.54)	2.69 (1.92)	1.46 (1.57)
Carbaryl	0.2%	2.28 (1.81)	3.67 (2.16)	1.37 (1.54)	3.71 (2.17)	2.24 (1.80)	0.69 (1.30)	1.43 (1.56)	3.62 (2.15)
Monocrotophos	0.05%	3.62 (2.15)	3.45 (2.11)	5.30 (2.51)	3.24 (2.06)	1.43 (1.56)	0.99 (1.41)	1.69 (1.64)	1.02 (1.42)
Control		2.65 (1.91)	3.67 (2.16)	4.57 (2.36)	0.96 (1.40)	1.46 (1.57)	1.22 (1.49)	2.65 (1.91)	1.69 (1.64)
CD			NS	(0.652)	(0.378)		NS	(0.325)	(0.337)

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

Table 8. **Effect of leaf extracts of *A. indica* and *C. infortunatum* and Nimbecidine on *M. crocea* during different growth stages**

Treatments	Number of defenders observed at different intervals after spraying (days)											
	20 DAT				40 DAT				60 DAT			
	Precount	1	3	7	Precount	1	3	7	Precount	1	3	7
Leaf extract of *A. indica* 5%	4.29 (2.30)	5.25 (2.50)	6.34 (2.71)	5.05 (2.46)	7.82 (2.97)	7.82 (2.97)	15.89 (4.11)	8.18 (3.03)	10.22 (3.35)	8.73 (3.12)	8.18 (3.03)	9.18 (3.19)
Leaf extract of *C. infortunatum* 5%	2.92 (1.98)	2.50 (1.87)	3.62 (2.15)	5.35 (2.52)	2.17 (1.78)	1.07 (1.44)	8.92 (3.15)	2.84 (1.96)	6.24 (2.69)	8.30 (3.05)	12.10 (3.62)	8.73 (3.12)
Nimbecidine 2%	3.88 (2.21)	5.66 (2.58)	1.69 (1.64)	5.81 (2.61)	1.37 (1.54)	0.39 (1.18)	1.02 (1.42)	2.96 (1.99)	13.36 (3.79)	14.44 (3.93)	8.92 (3.15)	13.82 (3.85)
Carbaryl 0.2%	1.96 (1.72)	0.30 (1.14)	0.00 (0.95)	2.31 (1.82)	6.24 (2.69)	1.99 (1.73)	11.46 (3.53)	1.22 (1.49)	10.83 (3.44)	2.03 (1.74)	4.76 (2.40)	2.88 (1.97)
Monocrotophos 0.05%	0.93 (1.39)	0.64 (1.28)	4.38 (2.32)	9.11 (3.18)	8.18 (3.03)	3.33 (2.08)	23.50 (4.95)	12.18 (3.63)	11.39 (3.52)	19.25 (4.50)	11.32 (3.51)	16.89 (4.23)
Control	5.81 (2.61)	5.35 (2.52)	10.29 (3.36)	6.51 (2.74)	14.60 (3.95)	18.98 (4.47)	21.00 (4.69)	5.97 (2.64)	13.06 (3.75)	13.59 (3.82)	9.96 (3.31)	6.34 (2.71)
CD		(0.652)	(0.558)	(0.773)		(1.163)	(0.882)	(0.950)		(0.794)	(0.379)	(0.599)

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

insects was recorded in different growth stages of the crop. At 20 DAT, significant reduction in *Micraspis* population was recorded in treatments receiving insecticides (carbaryl 0.30 and monocrotophos 0.64), the treatments with plant products did not affect the population, one day after spraying (range being 2.5 to 5.66). Three days after spraying a significant reduction in the population was recorded in all the treatments when compared with control, population ranging from 0.00 to 6.34. This trend continued only in treatment with carbaryl on the seventh day after spraying (2.31) and that the other treatments were on par with control, range being 5.05 to 9.11.

At 40 DAT, significant reduction in the predator population was noticed in all the treatments against control (18.98), one day after spraying the number ranged from 0.39 to 7.82. On the third day after spraying, the same trend was noticed in treatments with *C. infortunatum* (8.92), nimbecidine (1.02) and carbaryl (11.46) and the other treatments were on par with control, the population ranged from 15.89 to 23.50. Seven days after treatment significant reduction was recorded only from treatment with carbaryl (1.22), whereas significant increase in population of the defender was observed in treatment with monocrotophos. The treatments receiving plant products did not affect the predator population, which were on par with control.

Sixty days after transplanting, the effect of plant products and monocrotophos was not adverse against *Micraspis* spp. in the three observations. Only carbaryl treatment showed significant reduction in the population, one day after spraying (2.03), three days after spraying (4.76) and seven days after spraying (2.88). On the seventh day significant increase in the population was recorded in nimbecidine (13.82) and monocrotophos (16.89).

4.7.5 Total population of defenders

The total number of predators observed in each observation is presented in Table 9. At 20 DAT, insecticides significantly reduced the total predator population, one day after spraying (carbaryl 13.59 and monocrotophos 15.97 as against control 53.76), three days after spraying the corresponding values were 7.47, 28.27, and 46.75. The population reduction recorded seven days after spraying was only in treatment with carbaryl (18.18) and the treatments receiving plant products showed significant increase over control (38.44), which ranges from 56.15 to 65.26.

Forty days after transplanting, significant reduction in total population was recorded in treatments with nimbecidine (29.69), carbaryl (15.56) and monocrotophos (17.58) as against control (47.44), which was on par with treatment with *A. indica* (39.45) and *C. infortunatum* (36.82). The population mentioned above was recorded one day after spraying. Three days after spraying, significant reduction in the total population of defenders was recorded only in carbaryl (27.30) and the other treatments were on par with control (37.07) with a population range of 32.64 to 42.82. On the seventh day after spraying there was not much variation in the total population and all the treatments were on par in the control (population range of 40.73 to 58.60), except monocrotophos where significantly higher population was observed (62.04) as against control.

At 60 DAT, carbaryl alone showed significant reduction (9.96), one day after spraying whereas, the same effect was noticed in nimbecidine (15.65) at three days after spraying. Seven days after spraying none of the treatments showed significant reduction but an increase in total population was observed in the two treatments with insecticide and in treatment with *C. infortunatum* (with a population range of 20.16 to 26.14).

Table 9. **Effect of leaf extracts of *A. indica* and *C. infortunatum* and Nimbecidine on total population of defenders during different growth stages**

Treatments	Number of defenders observed at different intervals after spraying (days)											
	20 DAT				40 DAT				60 DAT			
	Precount	1	3	7	Precount	1	3	7	Precount	1	3	7
Leaf extract of *A. indica* 5%	39.20 (6.34)	41.25 (6.50)	47.58 (6.97)	56.15 (7.56)	37.94 (6.24)	39.45 (6.36)	41.38 (6.51)	47.86 (6.99)	29.47 (5.52)	29.46 (5.52)	23.80 (4.98)	14.13 (3.89)
Leaf extract of *C. infortunatum* 5%	37.19 (6.18)	43.76 (6.69)	56.76 (7.60)	65.26 (8.14)	34.05 (5.92)	36.82 (6.15)	38.44 (6.28)	47.30 (6.95)	25.11 (5.11)	29.69 (5.54)	29.36 (5.51)	20.16 (4.60)
Nimbecidine 2%	40.47 (6.44)	51.85 (7.27)	35.72 (6.06)	65.10 (8.13)	26.25 (5.22)	29.69 (5.54)	42.82 (6.62)	40.73 (6.46)	29.69 (5.54)	29.47 (5.52)	15.65 (4.08)	11.74 (3.57)
Carbaryl 0.2%	39.96 (6.40)	13.59 (3.82)	7.47 (2.91)	18.18 (4.38)	40.09 (6.41)	15.56 (4.07)	27.30 (5.32)	58.60 (7.72)	36.21 (6.10)	9.96 (3.31)	28.59 (5.44)	25.73 (5.17)
Monocrotophos 0.05%	29.58 (5.53)	15.97 (4.12)	28.27 (5.41)	40.09 (6.41)	46.61 (6.90)	17.58 (4.31)	32.64 (5.80)	62.04 (7.94)	40.73 (6.46)	32.99 (5.83)	24.40 (5.04)	26.14 (5.21)
Control	42.82 (6.62)	53.76 (7.40)	46.75 (6.91)	38.44 (6.28)	48.98 (7.02)	47.44 (6.96)	37.07 (6.17)	48.70 (7.05)	40.34 (6.43)	38.56 (6.29)	28.81 (5.46)	11.74 (3.57)
CD		(1.353)	(0.997)	(0.954)		(1.136)	(0.655)	(0.706)		(0.851)	(0.999)	(0.670)

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

4.8. Effect of plant products on total population of pests and defenders expressed as ratio

The ratio obtained from total population of pests and defenders (P:D ratio) are presented in Table 10.

At 20 DAT, the P:D ratio obtained in various treatments (one day after spraying) did not show any significant reduction (except treatment with monocrotophos), when compared with control, the range being 0.17 to 0.56. Significantly high P:D ratio was obtained in treatments with monocrotophos (1.04) as against control (0. 28). The ratio obtained in treatments with *A. indica* and *C. infortunatum* were on par which were significantly lower than the ratio obtained in treatments with nimbecidine (0.51) and carbaryl (0.56). Three days after spraying, carbaryl alone showed significantly higher ratio of 1.59 when compared with all the other treatments, the other ratios ranged from 0.23 to 0.82. The ratio obtained in treatments with *A. indica* and *C. infortunatum* was on par which were significantly lower than treatment with nimbecidine (0.82). The ratio observed in treatments with nimbecidine and monocrotophos were also on par. The trend recorded on the seventh day after spraying was the same as that on the third day. The highest ratio was noticed in treatment with carbaryl (0.77) when compared with other treatments, which were on par and the value ranged from 0.32 to 0.51.

At 40 DAT, the ratio obtained from all the treatments were on par with control. Third day after spraying significant reduction in the P:D ratio was observed in treatment with *A. indica.* All the other treatments were on par with control except in treatment receiving *C. infortunatum,* where significantly high P:D ratio was observed (0.54). On the seventh day after spraying significantly high P:D ratio was obtained in treatment with *C. infortunatum* (1.04) and the other treatments were on par with control and the ratio ranged from 0.21 to 0.44

Sixty days after transplanting, none of the treatments showed significant difference with control, the ratio ranging from 0.42 to 1.69. Significantly lower P:D ratio was observed in treatment with monocrotophos (0.42), when compared with plant products and carbaryl, at one day after spraying. On the third day after spraying, all the treatments were on par with control except in treatment with nimbecidine, where

Table 10. **Effect of leaf extracts of *A. indica* and *C. infortunatum* and Nimbecidine on pests defender ratio obtained from total population of pests and defenders**

Treatments	Pest defender ratio obtained from total population recorded at different intervals after spraying (days)											
	20 DAT				40 DAT				60 DAT			
	Precount	1	3	7	Precount	1	3	7	Precount	1	3	7
Leaf extract of *A. indica* 5%	0.37 (1.17)	0.17 (1.08)	0.23 (1.11)	0.35 (1.16)	0.39 (1.18)	0.19 (1.09)	0.08 (1.04)	0.44 (1.20)	1.92 (1.71)	1.69 (1.64)	2.10 (1.76)	2.57 (1.89)
Leaf extract of *C. infortunatum* 5%	0.44 (1.20)	0.17 (1.08)	0.25 (1.12)	0.37 (1.17)	0.88 (1.37)	0.19 (1.09)	0.54 (1.24)	1.04 (1.43)	1.25 (1.50)	1.31 (1.52)	1.04 (1.43)	2.06 (1.75)
Nimbecidine 2%	0.77 (1.33)	0.51 (1.23)	0.82 (1.35)	0.51 (1.23)	0.56 (1.25)	0.35 (1.16)	0.35 (1.16)	0.39 (1.18)	1.31 (1.52)	1.16 (1.47)	3.58 (2.14)	5.30 (2.51)
Carbaryl 0.2%	0.61 (1.27)	0.56 (1.25)	1.59 (1.61)	0.77 (1.33)	0.54 (1.24)	0.28 (1.13)	0.21 (1.10)	0.21 (1.10)	1.79 (1.67)	1.31 (1.52)	1.04 (1.43)	1.28 (1.51)
Monocrotophos 0.05%	0.82 (1.35)	1.04 (1.43)	0.64 (1.28)	0.32 (1.15)	0.51 (1.23)	0.35 (1.16)	0.32 (1.15)	0.28 (1.13)	1.37 (1.54)	0.42 (1.19)	0.74 (1.32)	1.59 (1.61)
Control	0.44 (1.20)	0.28 (1.13)	0.37 (1.17)	0.37 (1.17)	0.25 (1.12)	0.35 (1.16)	0.32 (1.15)	0.37 (1.17)	0.82 (1.35)	1.07 (1.44)	1.56 (1.60)	4.20 (2.28)
CD		(0.149)	(0.229)	(0.084)		NS	(0.069)	(0.073)		(0.244)	(0.298)	(0.324)

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

significantly higher ratio of 3.58 was observed. Treatment with *A. indica* showed significantly higher ratio (2.10) than treatments with *C. infortunatum* and both the insecticides and these treatments were on par, the ratio obtained ranged from 0.74 to 1.04. Based on the observations recorded on the seventh day, significantly lower ratio was obtained in all the treatments except nimbecidine (5.30) when compared with control (4.20). Nimbecidine and control were on par. The ratios obtained in treatments with *A. indica, C. infortunatum* and carbaryl were 2.57, 2.06 and 1.28 respectively.

4.9 Effect of spraying plant products on grain and straw yield

The mean grain and straw yield obtained under various treatments in the field experiment are presented in Table 11.

Table. 11. The mean dry weight of grain and straw (kg/ha)

Treatments	Grain	Straw
Leaf extract of *A. indica* 5%	2175.00	3378.00
Leaf extract of *C. infortunatum* 5%	1793.75	3106.25
Nimbecidine 2%	2025.00	3090.50
Carbaryl 0.2%	2212.50	3603.00
Monocrotophos 0.05%	2006.25	2978.00
Control	2112.00	2997.00
CD	NS	NS

The mean yield of grain obtained from plots receiving various treatments did not show any significant difference. The mean grain yield ranged from 1793.75 to 2212.50 kg/ha. The same trend was recorded in the case of mean straw yield. The mean straw yield obtained in the treatments varied from 2978 to 3603 kg/ha.

DISCUSSION

DISCUSSION

Use of tolerant varieties and augmentation of the available defenders in rice ecosystem together with cultural and mechanical means is the ' best mix' for rice pest management, under normal climatic conditions (Pimbert, 1991). In Kerala, rice varieties like *Jyothi*, *Bharathi* and *Triveni* which are reported to be brown plant hopper resistant and giving good yields, are extensively used by the farmers (AICRIP, 1982). According to Bottrell (1993), Kenmore *et al.* (1985), Kenmore *et al.* (1987) and Kenmore (1991); rice areas in Asia using heavy insecticide applications have experienced serious out breaks of pests resulting in the destruction of pest's natural enemies. The present study is, therefore, aimed to search for the presence of pests and defenders in the rice fields cultivated with a most commonly used high yielding variety *Jyothi*, through out the cropping season. As part of the investigation, a detailed survey was undertaken in the wet lands in three taluks of Thiruvananthapuram district. The study was carried out to assess the occurrence, distribution and magnitude of pests and defenders in the variety *Jyothi,* at different growth stages. The study also aimed to assess whether sufficient population of the defenders, capable of suppressing the pests, are present in the wet land ecosystem, in order to avoid economic losses to farmers. As a matter of fact, under certain conditions, pest population flares up and devastates large areas resulting in colossal losses. In order to solve the acute food shortage under such situations, synthetic organic insecticides play a key role, as the last resort, even in integrated pest management,. Further, the intensive and extensive use of poisonous chemicals have created several side problems and it has thus become imperative to replace these miraculous agricultural inputs with effective and more ecofriendly compounds. In this context, the botanical pesticides received a revival and a universal interest has been generated in exploiting the secondary metabolites produced by different species of plants, for containing the pest and disease problems faced by the farmers. Insecticidal properties have been reported for more than 1005 species of plants. Similarly, 384 plants are known to have antifeedant, 297 with repellent, 27 with insect attractant and 31 with growth inhibitory activities (Jayaraj 1991). Among these plants, neem has received universal attention, among agricultural scientists. The limited availability of these plant species, at present, renders the search for other fast growing and easily maintainable plant species imperative, for meeting the huge pesticide demand and for replacing the undesirable synthetic pesticides with botanicals. Among the plants screened out from the rich flora of Kerala, *Azadirachta indica* and *Clerodendron infortunatum* had been identified as potential sources of phytochemicals suited for pest control (Saradamma, 1989). Not much work has been carried out in Kerala using botanicals for rice pest management. The present investigation aims at collecting detailed information on the bioefficacy and mode of action of different concentrations of water extracts of the leaves of *A. indica*, and *C. infortunatum* and nimbecidine. Since leaves are the plant parts easily available through out the year and in sufficient quantities for practical field application, they were ultilised for the studies. Chemical solvents are costly and not easily available at farmer's level, water, which was found effective when tested with many insect pests (Maxwell *et al.* 1965 and Rao and Mehrotra 1977), was used as a solvent for the study. Many reports showed that these products reduced the pest population in the field but have not indicated the exact mode of action. Hence, the objective of the study is also to find out the antifeedant, deterrant and toxic effect of different concentrations of the plant products on rice pests and defenders under the laboratory conditions. A field performance study was also carried out to find out immediate and long lasting efficacy of the leaf extracts of *A. indica* and *C. infortunatum* and nimbecidine in the field, and to compare the results obtained in the laboratory studies. The results of the study are discussed hereunder.

5.1 Occurrence and distribution of pests and defenders in rice ecosystem of Thiruvananthapuram district.

Periodical survey of pests and defenders at different growth stages of the crop was carried out at three locations (9 plots) in the district, cultivated with rice variety *Jyothi*. The pests and defenders recorded were same in all the locations, except at Neyyattinkara and Chirayinkil, where *N. depunctalis* was not observed. Variation was noticed only in their number. Seven pest species and nine defender species were observed in the survey. Very low population of *C. medinalis* was observed at the three locations throughout the growth stages of the crop. *N. depunctalis* was recorded only from the fields at Nedumangad up to 40 days after transplanting. *N. depunctalis* is an aquatic pest and it survives only in water stagnated conditions. That may be the reason for its restricted appearance. Population of *S. incertulas* was very low in these locations. Comparatively higher populations of *N. lugens* were observed at 40 DAT at Neyyattinkara, Nedumangad and Chirayinkil taluks, the mean number being 50.67, 45.33 and 44.33 respectively.

Among the growth stages, the plants at 40 DAT were found to harbor maximum number of pests. However, sizable number of *L. acuta* was recorded at 60 DAT at all the three locations. Even though *Nephotettix* spp. were not serious in virus disease free areas, these pests were present throughout the growth period and the highest population was observed at 20 DAT (range being 37 to 47) in these locations. At 20 and 40 DAT, low populations of *O. chinensis* were recorded from all the plots. According to

Nadarajan (1996), the major pests persistently occur in the two seasons are *O. oryzae*, *S. incertulas*, *C. medinalis*, whereas the pests reported from Kuttanad were *C. medinalis*. *N. lugens*, *S. incertulas*, *O. oryzae*, and *Nephotettix* spp. (Nalinakumari *et al.* 1996).

Many workers (Reghunath *et al.* 1990; Ambikadevi 1998a and Nandakumar and Pramod 1998) have already reported the occurrence of defenders in various rice ecosystems of Kerala. The present study also recorded the magnitude and distribution of various defenders throughout the cropping period. The defenders observed were *Agriocnemis* spp., *Crocothemis* sp., *L. pseudoannulata*, *T. maxillosa*, *M. crocea*, *O. nigrofasciata*, *C. lividipennis*, *C. flavipes*, *T. schoenobii*. These defenders and a few others like *Polytoxus fuscovittatus* (Stal), *Conocephalus longipennis* (de Haan), and *Microvelia douglasi atrolineata* (Bergroth) were earlier reported by Nalinakumari *et al.* (1996) and Ambikadevi (1998 b).

Highest mean population of *Agriocnemis* spp. was recorded from Neyyattinkara, followed by Nedumangad and Chirayinkil (4 to 6). A reverse trend was observed in the case of *Crocothemis* sp. with a population range of three to five. *L. pseudoannulata* was present throughout the cropping period, the highest population recorded was at 40 DAT at Neyyattinkara and at 60 DAT at Nedumangad and the highest population 3.0 was recorded in Chirayinkil at 40 and 60 DAT.

The presence of *T. maxillosa* varied in the three locations at different growth stages of the crop. Maximum population of this spider was noticed 20 DAT at Nedumangad and Chirayinkil and 40 DAT at Neyyattinkara .

Sizable population of *M. crocea* and *O. nigrofasciata* was not present in any of the locations. *C. lividipennis* is the specific predator of *N. lugens*. Highest population of this predator was recorded at 40 DAT in the three locations corresponding to a higher population of *N. lugens*.

Only two parasites viz., *C. flavipes* and *T. schoenobii* were observed during the crop growth period. Highest populations of both the parasites were observed during 60 DAT at the three locations. This has clearly indicated that the parasites have started development after establishment of the pests in the field. Various workers (Hidaka *et al.* 1988 and Heong *et al.* 1991) supported this view.

Interestingly, the predators were seen along with the pests from the initial stages of crop growth. They developed before pest established in the field. This may be due to the development of these predators in the wet land ecosystem on filter feeding insects and detritivores. This view is supported by the work carried out in Philippines and Indonesia (Heong, 1991 and Williamsettle, 1994).

The total population of pests and defenders in the three locations during different growth periods of the crop recorded, showed a definite trend (Fig.1). The total population of defenders recorded was low in the first and second observations and high in the third observation when compared with total population of pests. The population of defenders was higher than the pests through out the crop growth period (Heong *et al.* 1991, Botterell, 1993 and Willamsettle, 1994) and during the vegetative phase (Nalinakumari, *et al.* 1996 and 1997) in an untreated plot. The low population of defenders recorded in the present study may be due to the application of insecticides in the vegetative stage in the observational plot. The farmers of Kerala have the practice of undertaking prophylactic measures in rice field with insecticides in the vegetative phase to avoid attack of pests in the advanced growth stages of the crop, which in turn cause so many bad effects in the ecosystem.

5.2 Antifeedant activity of leaf extracts of *A. indica* and *C. infortunatum* and nimbecidine to *C. medinalis* and *N. depunctalis*.

Antifeedant activity of leaves of *A. indica,* and *C. infortunatum* to various pests was already reported by Saradamma (1989) and nimbecidine by Nandakumar (1999). The water extracts of the fresh leaves collected from plants were used for the study as it is available throughout the season and easy for preparation.

The results presented in 4.2.1 showed that among various concentrations of different plant products evaluated, nimbecidine four per cent was found to be superior in producing antifeedant effect against *C. medinalis* when compared with other treatments. The antifeedant effect recorded against C. *medinalis* with nimbecidine two per cent and *A. indica* 10 per cent was on par. The lower two concentrations of *A. indica* (five and two per cent) and higher two concentrations of *C. infortunatum* (10 and five per cent) were also on par and all these treatments were superior to control.

The results of this study showed that the best antifeedant against *C. medinalis* was nimbecidine four and two per cent, leaf extracts of *A. indica* ten, five and two per cent. *C. infortunatum,* ten and five per cent gave statistically the same result and were superior to control. The lowest dose of nimbecidine and leaf extract of *C. infortunatum* had low antifeedant action. Time of release of the test organism on the treated surface had great influence on the antifeedant activity. Highest antifeedant effect was recorded in treatment where the larvae were released immediately after application of the plant product. According to Lim (1991) neem reduced the leaf spinning and feeding of *C. medinalis.* Ambethgar (1996) reported that neem cake and need seed kernel extract five per cent was effective than neem leaf decoction and neem cake in reducing the leaf damage caused by *C. medinalis.* Krishnaiah *et al.* (1999) reported that nimbecidine two per cent was toxic to the pest.

Data presented in 4.2.2 showed that the antifeedant activity of different plant products had less pronounced effect on the larvae of *N. depunctalis* when compared to *C. medinalis.* The leaf extract of *A. indica* 10 per cent and nimbecidine four per cent gave significant antifeedant effect on the larvae released one day after application, when compared with the control. The antifeedant effect of neem oil and aqueous extracts of neem kernel on *C. medinalis* has been reported earlier (Rajasekaran *et al.* 1987 a and Rajasekaran *et al.* 1987 b). Nandakumar (1999) reported antifeedant effect of nimbecidine on third instar larvae of *Henosepilachna septima.*

5.3 Deterrent activity of leaf extracts of *A. indica* and *C. infortunatum* and nimbecidine to *N. lugens and L. acuta.*

N. lugens released at the time of application of the leaf extracts of *A. indica* and *C. infortunatum* and nimbecidine at the highest concentration gave 75 per cent deterrent effect. Insect released one day after application, the deterrent activity was reduced to the tune of 65.0, 50.0 and 45.0 per cent. At the middle dose deterrent effect recorded was 27.5, 50.0 and 57.5 per cent when the adult insect was released at the time of application of plant products. The pest population was reduced to 17.5, 40.0 and 45.0 per cent, when released 24 h after application. No such effect was noticed on insects treated with lower concentrations of plant products and even at higher concentrations three days after application. This may be probably due to the fact that plant products are dose specific and their persistent toxicity is comparatively low. Various workers reported different effects of neem seed oil and aqueous extract of neem kernel on *N. lugens.*

Antifeedant effect was reported by Chiu, (1985); Rajasekharan *et al.* (1986); and Rajasekaran *et al.* (1987 b). Adverse effect on orientation, settling, growth and development was reported by Krishnaiah and Kalode, (1990) and their repellent effect was reported by Telan *et al.* 1994).

Deterrent activity of the plant products evaluated did not show any effect against the adults of *L. acuta* (4.3.2). A perusal of literature did not reveal any report on the effect of these plant products on *L. acuta*. As the insect is sturdy, the concentrations tried may not be sufficient to produce any adverse effect on the pest. *L. acuta* is a sap sucker, the plant products applied on the rice plant may not cause any disturbance to its internal feeding. More over, none of the plant products tested showed any toxic effect on any of the test organisms. Toxicity studies (4.4) also indicated inefficacy of these products against the larvae of *C. medinalis* and *N. depunctalis* and adults of *N. lugens* and *L. acuta.* Rao and Rao (1979) reported high mortality of *N. lugens* with one per cent leaf extract of neem at 48 h after application. According to Krishnaiah and Kalode (1984) neem oil has low acute and persistent toxicity against *N. lugens,* whereas reports of Saxena and Khan (1985), Jayaraj (1991) and Rajendran (1992) showed that neem seed oil was highly effective in reducing the survival of *N. lugens.* Studies on the toxic activity of leaf extracts of these plant products on *C. medinalis*, *N. depunctalis* and *L. acuta* are not yet reported from any of the rice ecosystems. Srinath (1990) reported the toxic effect of the leaf extracts of *C. infortunatum* to *Spodoptera litura* and *A. indica* to *Aphis gossypii.* The variation in the toxicity of these plant products may be due to different detoxification mechanisms present in various insects.

5.4 Evaluation of bioefficacy of leaf extracts of *A. indica* and *C. infortunatum* and nimbecidine on defenders.

The study to evaluate the bioefficacy of various plant products clearly showed that they did not show any toxic or antifeedant effect on predators like *L. pseudoannulata* and *O. nigrofasciata* (4.5). The same trend was observed by various workers (Joshi *et al.*, 1982; Osman and Bradley,1993; Wu, 1996 and Markandeya and Divakar 1999). Because of this, the plant products could successfully be included in the integrated pest management strategies.

5.5 Evaluation of the effect of leaf extracts *A. indica* and *C. infortunatum*, nimbecidine and insecticides on pests in rice field.

The laboratory studies carried out clearly showed that the highest doses of the leaf extracts of *A. indica* and *C. infortunatum* and nimbecidine gave very good result on the antifeedant activity of the second instar larvae of *C. medinalis* and *N. depunctalis* and deterrent activity of the adults of *N. lugens*. A correlation between the bioefficacy of the plant products tested and their concentrations was observed, the higher the concentration more was bioefficacy. The plants sprayed with the highest doses of nimbecidine (four per cent) and leaf extracts of *A. indica* (10 per cent) showed yellowing in the laboratory studies and hence they were not included in the field studies even though they showed the best effect. The middle doses of the plant products namely, leaf extracts of *A. indica* five per cent and *C. infortunatum* five per cent and nimbecidine two per cent were selected for field evaluation.

The result presented in 4.6.1 showed that the population of *C. medinalis* observed in the treatments sprayed with carbaryl 0.2 per cent and monocrotophos 0.05

per cent and in plots treated with leaf extract of *C. infortunatum,* were significantly lower than that of untreated control. Other treatments were ineffective in suppressing the *C. medinalis* population. Antifeedant activity of the leaf extracts of *C. infortunatum* was third in the laboratory studies which was more effective in the field. This may be due to the deterrent activity of the extract of *C. infortunatum* against *C. medinalis,* which accounted for suppression of the pest. At the same time, the antifeedant activity may not play much role in this context.

In the case of *N. depunctalis,* significant reduction in its population was noticed in plots treated with the leaf extracts of *A. indica* and *C. infortunatum.* The significant reduction in the population of the pest was not observed in insecticide check and in nimbecidine one day after spraying. Similar reduction in the population of pests was also noticed in treatment with leaf extract of *C. infortunatum.* Nimbecidine and carbaryl also showed the same effect at three days after spraying. Long term effect was not observed either in plots treated with plant products or with insecticides. The suppression of *N. depunctalis* in the field with insecticide is not very effective because of the aquatic nature of the pest. In such a situation, the leaf extracts of *A. indica, C. infortunatum* or nimbecidine could be used for the effective and immediate suppression of the pests.

The results presented in 4.6.3 showed that the population of *L. acuta* was recorded in the field only at 60 DAT. The plant products or the insecticides applied in the field did not reduce the population of the pest. In the laboratory studies too, this pest was not affected by any of the plant products.

Effect of plant products on *N. lugens* was shown in 4.6.4 and in Fig.3. *N. lugens* was observed up to 40 DAT in the experiment plots. The immediate and long lasting effect of insecticides on *N. lugens* were observed in this study. Among the plant products tried, leaf extracts of *A. indica* gave highest percentage reduction of *N. lugens* over control, followed by *C. infortunatum* at 20 DAT. The trend was reversed at 40 DAT. The percentage reduction in the population of *N. lugens* over control was 100 per cent in *C. infortunatum* followed by *A. indica* where the effect was 86 per cent. Efficacy of nimbecidine in suppressing field population of *N. lugens* was very low, whereas, in the laboratory studies among the treatments, nimbecidine gave the highest deterrent effect on the pest (57.5 per cent over control). Toxic effect of neem azal T/S (having 10,000 ppm azadirachtin) to *N. lugens*, nimbecidine (having 50 ppm azadirachtin) reduced the oviposition of *N. lugens* and nimbecidine having 10 ppm azadirachtin reduced the reproduction of *N. lugens* in the laboratory studies (Krishnaiah *et al.*, 1999 and Maheshkumar *et al.*, 1999). In the present study only deterrent action was observed. As in the case of antifeedant action of nimbecidine against the larvae of *C. medinalis* in laboratory studies, the deterrent activity was also found to be high in *N. lugens* exposed to the nimbecidine treated plants. The same plant products failed to produce effect under field conditions.

The data presented in 4.6.5 showed an overall view of the impact of various plant products on the total population of pests attacking rice in the ecosystem. Studies on the effect of plant products and insecticides on total population of the pests showed that neither the plant products nor the insecticide protects the crop from pest attack up to seven days after spraying. Nimbecidine was found to be ineffective in controlling the pests of rice whereas significant reduction in the total population of pests was achieved in treatment with leaf extracts of *C. infortunatum* sprayed on plant at 20 DAT and 60 DAT. The same effect was exhibited by treatment with *A. indica* at 40

DAT. Carbaryl and monocrotophos gave significant suppression of the total population of the pest up to 3rd day after spraying at 40 DAT and 60 DAT. According to Nalinakumari and Remamony (1999), the effect of carbaryl in suppressing the pests of rice was very short lived and never retained up to seven days after spraying. In this study, it was found that the treatments with *A. indica* and *C. infortunatum* was equally good as carbaryl or monocrotophos in the immediate pest suppression and long lasting effect was not observed. In integrated pest management strategy, immediate suppression of the pests in hot pockets is required and in that sense the leaf extracts of *A. indica and C. infortunatum* are good source of phytochemicals for rice pest management.

5.6 Evaluation of the effect of leaf extracts of *A. indica* and *C. infortunatum*, nimbecidine and insecticides on defenders in rice field.

The results presented in 4.7.1 showed the effect of various plant products and insecticides on the defenders in rice field. The spiders recorded in the study were *L. pseudoannulata*, *T. maxillosa* and *Atypena* sp. These spiders were present in the experiment plot throughout the growth period of the crop.

Various workers reported the safety of different plant products on spiders in rice ecosystem (Saxena *et al.*, 1980; Joshi *et al.*, 1982; Wu 1986 and Osman and Bradley, 1993). The results of the study also supported the above mentioned findings. The adverse effect of both carbaryl and monocrotophos applied at 20 DAT, was observed up to seven days after application of the toxicant. Whereas, treatments with plant products did not affect the spider population even at one day after spraying. Significantly higher population of the spiders was recorded in treatment with *A. indica* and *C. infortunatum* when compared with nimbecidine and control at three days after spraying.

The highest population of the spiders was recorded in treatment with *A. indica* even at seven days after spraying, which was significantly higher than with the other two products.

At 40 DAT, the adverse effect of insecticide lasted for three days. All treatments with plant products were safe to different species of spiders up to seven days after spraying. The effect of spraying leaf extracts of *A. indica* and *C. infortunatum*, nimbecidine and insecticides at 60 DAT gave an entirely different picture. Neither the plant products nor the insecticides reduced the population of spiders in the observations recorded one, three and seven days after spraying. Significantly higher population of spiders were observed in treatments with *C. infortunatum* in one and three days after spraying. According to Saxena *et al.* (1984) even topical application of neem oil 50 µg per *L. pseudoannulata* caused low mortality. This explained the safety of plant products on spiders when applied on the leaf surface.

In all the observations, plant products were found to be safe to the spiders and reduction in spider population recorded in insecticide treatments varied with spiders present in different growth stages of the crop. This may be due to variation in the presence of different spiders and their relative susceptibility to carbaryl and monocrotophos.

The data given in 4.7.2 gave an idea about the impact of plant products on *O. nigrofasciata* in rice field. The plant products tried were found to be safe to the defender and did not reduce its population in the observation made one day, three days and seven days after spraying at 20 DAT. Significantly higher population of the defender was recorded in treatment with *A. indica*, in the observations made one day after spraying and with *C. infortunatum* seven days after spraying. Adverse effect of insecticides was observed only in the observations made three days after spraying.

At 40 DAT also no adverse effect of these plant products on *O. nigrofasciata* was visible in any of the observations. Treatment with *C. infortunatum* was superior where significantly higher population of the defender was recorded in the observations made on the third and seventh day after spraying.

The observations made at 60 DAT clearly showed the effect of plant products and insecticides. None of the observations showed any adverse effect of plant products on *O. nigrofasciata* up to seven days after treatments. Significant reduction in the defender population was recorded in treatments with insecticides only in the first observation. Significant increase in defender population was recorded in treatments with plant products except treated with *A. indica* on the seventh day after application. The trend showed on *O. nigrofasciata* with plant products, was same as that of spiders. The laboratory studies carried out also indicated the same effect. No antifeedant, deterrent or toxic effect of these products on the predator was observed.

As presented in 4.7.3, the population of *Agriocnemis* spp. was recorded only in the observations made at 20 and 40 DAT. No significant difference in the population of the defender was noticed in treatments with *A. indica, C. infortunatum*, nimbecidine, carbaryl or monocrotophos, one day after spraying in both growth stages of the crop, when compared with control. On the third day after spraying, treatments with *C. infortunatum* and carbaryl significantly reduced the population of the defender at 20 DAT and 40 DAT. In the two growth stages of the crop where observations were recorded, treatments with *A. indica* was on par with control up to third day after spraying, whereas, in the seventh day, the treatments with *A. indica* gave an increasing effect on the defender population in both the observations. The leaf extract of *A. indica* was found to be safe to the predator whose population was significantly higher at seven days after application.

Unlike in the case of spiders and *O. nigrofasciata,* adverse effect of the leaf extracts of *C. infortunatum* on *Agriocnemis* spp. was observed in this study, the effect was not immediate but three days after spraying, significant reduction in population was recorded at 20 and 40 DAT. As *Agriocnemis* spp is a generalised predator which could effectively check many small to medium sized pests, it is advisable to resort to spraying of *A. indica* instead, so as not affect the population of this predator.

The results presented in 4.7.4 gave a clear indication that treatments with *A. indica, C. infortunatum* and nimbecidine were harmful to *Micraspis* spp. The effect of various treatments on the defenders present at different growth stages of the plant also varies very much. At 20 DAT, the population of *Micraspis* spp. recorded from various treatments showed that only treatments with insecticide reduced the defender population significantly, one day after spraying. Treatments with plant products were on par with control. Three days after spraying treatments with plant products significantly reduced the defender population when compared with control. This adverse effect was continued in the case of carbaryl up to seven days after spraying.

At 40 DAT all the treatments significantly reduced the population of the defender one-day after spraying. Two days after the first observation, the adverse effect was not manifested in treatments with *A. indica* and monocrotophos. On the seventh day after application, carbaryl continued as the harmful toxicant against *Micraspis* spp., whereas treatment with monocrotophos recorded significantly higher population when compared with control. Treatments with plant products were on par with control.

Adverse effect of plant products on defender was not visible in the three observations when sprayed at 60 DAT. Treatment with carbaryl alone persistently reduced the defender population. Significantly higher population against control was recorded in treatments with nimbecidine and monocrotophos. The effect of different treatments on *Micraspis* spp. showed that plant products were more harmful to the predators at certain stage of crop growth. Carbaryl was found to be harmful throughout the period. The predator is not an active flier, most of the time it remained on the plant surface. Carbaryl, being a contact poison, appears to have more pronounced activity. The exact mode of action of these plant products on the predator has not been studied so far, and hence the reason for their adverse effect on *Micraspis* spp. is difficult to interpret. It is presumed that they may have either toxic or deterrent effect.

As described in 4.7.5, the total number of defenders observed in each treatment during different growth stages of the crop showed an overall view of the impact of leaf extracts of *A. indica* and *C. infortunatum* and nimbecidine on various defenders present in the experiment plots. The study indicates the safety of leaf extracts of *A. indica* and *C. infortunatum* on defenders throughout the growth stages. In the first set of observations, seven days after spraying both these extracts gave an added effect of significant increase in the defender population as against control. The same positive effect was recorded only in treatment with *C. infortunatum* at 60 DAT.

Effect of nimbecidine on the total population of defenders showed that there was no adverse effect on total defender population at 20 DAT. At 40 DAT immediate suppression of the defenders was recorded and the same effect was observed at 60 DAT in the second observation. An added positive effect on the total defender population was recorded only in the observation made seven days after spraying at 20 DAT.

Carbaryl was found to be the most harmful chemical when compared with other treatments. The effect of carbaryl on total population of defenders showed slight variation during different growth stages of the crop. Significant reduction in the total population of defenders was recorded in the three observations at 20 DAT, in the two observations (one and three days after spraying) at 40 DAT and only in first observation at 60 DAT when compared with control.

Treatment with monocrotophos also showed significant reduction in the total population of defenders, though not as persistent as with carbaryl. Significant reduction was recorded in the first two observations at 20 DAT and only in the first observation at 40 DAT. No such effect was recorded at 60 DAT. Seven days after spraying, at 40 DAT and 60 DAT significantly higher population as compared with control was observed. As far as the protection of defender population is concerned monocrotophos is better than carbaryl.

Even though the plant products showed slight variation in the protection of individual defenders, the analysis of total population gave a better idea about its safety. Leaf extracts of *A. indica* and *C. infortunatum* were found to be safe when compared with nimbecidine or monocrotophos. Carbaryl was found to be harmful in suppressing the total population of defenders throughout cropping season.

5.7 Effect of plant products on the ratio obtained from total population of pests and defenders.

As described in 4.8, the P:D ratio obtained from the total population of pests and defenders in most of the cases was less than one at 20 DAT and 40 DAT. This has clearly indicated the presence of either lower population of pests or higher population of defenders during the observations. At 60 DAT, the P:D ratio gone even up to 4.2 which gave an adverse indication.

An overall picture of the results shown by the P:D ratio gave an indication about the usefulness of plant products in integrated pest management. As the population of pests and defenders varied in different growth stages of the crop, comparison of the effect of various treatments on individual pests and defenders did not give a real picture, and hence the ratio of pests and defenders was worked out and interpreted.

At 20 DAT, based on the P:D ratio the best treatments were leaf extracts of *A. indica* and *C. infortunatum* where the ratio obtained were lowest in all the three observations. The treatments with nimbecidine and carbaryl were comparatively better than control and monocrotophos was not only least effective in suppressing the pest but also was found to destroy the defenders in the first observation. In the second and third observations instead of monocrotophos, carbaryl gave higher ratio and nimbecidine was intermediary in position.

At 40 DAT, one day after spraying the suppression of pests and natural enemies in the treatments followed the same trend as that of control. Third day after spraying treatment with *A. indica* was superior in reducing the pests or increasing the defenders and significantly higher ratio was obtained in treatment with *C. infortunatum*. Nimbecidine and insecticides were on par with control. On the seventh day also treatment with *C. infortunatum* alone continued the adverse effect.

Sixty days after transplanting based on the observations recorded one day after spraying, the P:D ratio obtained in all the treatments were statistically same as control. Treatment with monocrotophos showed significantly lower ratio when compared with the other four treatments. On the third day after spraying, treatment with nimbecidine gave higher ratio than control and *A. indica* showed higher ratio than *C. infortunatum.* On comparison with plant products, treatment with *C. infortunatum* was better than other two plant products. On the seventh day significantly lower ratio was obtained in treatments with *A. indica* and *C. infortunatum* than treatment with nimbecidine.

In the present study in most of the cases, treatment with *A. indica* and *C. infortunatum* gave promising results when compared with nimbecidine. During the vegetative phase of the crop treatments with *A. indica* and *C. infortunatum* gave good suppression of the pest, and enhanced the defender population. The same trend was observed during the three observations. During the panicle initiation stage, some differences in the effect of plant products was observed. No immediate effect was observed in any of the treatments, whereas, three days after spraying treatment with *A. indica* alone was found to be beneficial. Treatment with *C. infortunatum* gave an adverse effect up to seven days after spraying. During the reproductive stage, treatment with C. *infortunatum* was more effective in the second observation. During the third observation both leaf extracts gave beneficial effect than nimbecidine.

The variations observed on the effect of different plant products on the P:D ratio may be due the occurrence of different types of pests and defenders during different growth stages of the crop. This fact was supported by the results obtained from the laboratory studies. The P:D ratio obtained in the vegetative and panicle initiation stage was less than one where the predator population out numbered the pest. According to Heong *et al.* (1991), the predator population out numbered the pests in an untreated plot. The same result was obtained in *A. indica* and *C. infortunatum* treated plots at 20 and 40

DAT. At 60 DAT, *L. acuta* appeared to be the major pest. The result of the laboratory study showed the inefficacy of plant products on L. acuta and may be the reason for exhibiting high P:D ratio.

5.8 Effects of plant products on grain and straw yield.

The grain and straw yield obtained in the field experiment (4.9) did not show any significant difference when compared with control even though pests were present in the experiment plot throughout the cropping season. According to Kenmore *et al.* 1991 and Bottrell 1993, the use of tolerant variety and conservation of natural enemies in wet land rice ecosystem was reported to be the 'best mix' for rice pest management and for obtaining better yield. Statistically, the same yield obtained may be due to the capacity of the variety *Jyothi* to tolerate certain level of pest infestation and the availability of large number of defenders in the experiment plot. Various workers from Kerala (Nalinakumari *et al.*, 1996; Nadarajan, 1999 and Nalinakumari and Remamony, 1999 b) also supported the above view.

SUMMARY

SUMMARY

6.1 Survey on the incidence of pests of rice and their defenders

In order to assess the pest and defender complex in rice, a preliminary survey was conducted in the rice fields cultivated with high yielding tolerant variety *Jyothi*, in the three taluks of Thiruvananthapuram district. Observations were taken at different growth stages of the plant (20, 40 and 60 DAT) .The results are summarised hereunder: -

1. Rice was seen infested by seven important pests, *C. medinalis*, *N. depunctalis*, *S. incertulas*, *N. lugens*, *L. acuta*, *Nephotettix* spp. and *O. chinensis*.
2. Major defenders observed were *Agriocnemis* sp., *Crocothemis* sp., *L. pseudoannulata*, *T. maxillosa*, *M. crocea*, *O. nigrofasciata*, *C. lividipennis*, *C. flavipes* and *T. schoenobii*.
3. Higher population of sap sucking pests were present (*N. lugens*, *L. acuta* and *Nephotettix* spp.) in the rice fields when compared with other defoliating and tissue boring pests.
4. *Nephotettix* spp. was the only pest recorded in all the observations.
5. High population of *N. depunctalis* was present in the vegetative phase and only at one location.
6. Low population of *L. acuta* was recorded at 40 DAT and high population was observed at 60 DAT in the three locations.
7. Generalised predators like *Agriocnemis* sp., *Crocothemis* sp., *L. pseudoannulata* and *T. maxillosa* were present in all the locations in fairly good number.

8. Specific predators of important rice pests such as *M. crocea*, *O. nigrofasciata* and *C. lividipennis*, were recorded only in certain observations.

9. Only two types of parasites were observed and their maximum population was recorded at 60 DAT.

10. Total population of pests and defenders showed a definite pattern. High population of the pests was observed at 20 and 40 DAT and low population was recorded at 60 DAT when compared with defenders in the three locations.

6.2 Laboratory studies on the bioefficacy of leaf extracts of *A. indica* and *C. infortunatum* and nimbecidine on pests and defenders

Different concentrations of the water extracts of the leaves of *A. indica* and *C. infortunatum* and nimbecidine were assayed in the laboratory for antifeedant, deterrent or insecticidal activities against rice pests and defenders.

The major findings of the investigation are summarised below: -

1. Based on the percentage of leaf protection in rice against the larvae of *C. medinalis*, nimbecidine four per cent was significantly superior to other treatments. Nimbecidine two per cent, leaf extracts of *A. indica* two, five and 10 per cent and *C. infortunatum* five and 10 per cent also gave significantly higher percentage of leaf protection against control.

2. The different concentrations of plant products based on leaf protection had a less pronounced effect on the larvae of *N. depunctalis* than that of *C. medinalis*. Significant antifeedant effect was observed in treatment with leaf extract of *A. indica* 10 per cent and nimbecidine four per cent.

3. Reaction of various doses of three plant products tested, gave 75 per cent deterrent effect to *N. lugens* at the highest dose and the insect released at the time of application. Gradual reduction in the deterrent action of these products was observed with reduced dose and long exposure period. The effect was nullified three days after release of the test insect.

4. Deterrent activity or contact toxicity of the plant products tested against *L. acuta* showed that no such activities were observed even with highest dose. None of the plant products showed any contact toxicity against *C. medinalis*, *N. depunctalis* and *N. lugens.*

5. Toxic action or antifeedant effect was not observed on *L. pseudoannulata* and *O. nigrofasciata* in any of the plant products tested.

6.3 Effect of leaf extracts of *A. indica* and *C. infortunatum* and nimbecidine on pests and defenders in rice field taking carbaryl and monocrotophos as check

Among the three doses of each plant product evaluated in the laboratory, one dose out of three doses of plant products tested which was effective as well as non phytotoxic was used for field evaluation, the results of which are summarised as follows:-

1. The number of *C. medinalis* was significantly reduced by leaf extracts of *C. infortunatum.* The effect was same as that of insecticides.

2. A fluctuating trend was observed with plant products against *N. depunctalis.* Both leaf extracts significantly reduced the insect population one day after spraying whereas, nimbecidine, leaf extract of *C. infortunatum* and carbaryl gave the same effect three days after spraying.

3. High percentage reduction in the population of *N. lugens* was obtained with insecticide, one day after spraying which was comparable to that of leaf extracts of *A. indica* and *C. infortunatum* at 20 DAT. At 40 DAT, 100 per cent reduction in the population was recorded in plots receiving monocrotophos and leaf extract of *C. infortunatum* which was followed by *A. indica* and carbaryl, one day after application. The effect, however, declined with time of exposure.

4. Suppression of *L. acuta* was not observed with any of the treatments.

5. At 20 DAT and 60 DAT, significant reduction in the total population of pests was recorded from plots receiving leaf extract of *C. infortunatum* at one day after spraying, whereas, the same trend was observed with carbaryl up to three days after spraying. At 40 DAT, leaf extract of *A. indica* alone showed significant reduction in the total population of the pest which lasted up to third day after spraying. Long lasting effect on suppression of the pests was not observed in plots treated with plant products or insecticides.

6. The population of spiders observed in the field showed that both insecticides significantly reduced their population up to three days after application, whereas, plant products were found quite safe. Among the plant products, significantly higher population of spiders was recorded in treatment with *A. indica* at 20 DAT and with *C. infortunatum* at 60 DAT. The adverse effect of insecticides was nullified at seven days after spraying.

7. Adverse effect of the plant products to *O. nigrofasciata* was not observed throughout the growth stages of the crop. Adverse effect on the population was observed with insecticides at 20 DAT and 60 DAT. Significantly higher population of the predator was recorded with leaf extract of *A. indica* at 20 DAT and in the other two periods with leaf extract of *C. infortunatum* (40 and 60 DAT) and nimbecidine gave the same effect as that of *A. indica* (60 DAT). Other treatments were on par with control.

8. *Agriocnemis* spp. was observed only at 20 and 40 DAT. Adverse effect on the population of *Agriocnemis* spp. was not noticed in the first and last observations in both growth stages of the crop. In the second observations, leaf extract of *C. infortunatum* and carbaryl significantly reduced the predator population both at 20 and 40 DAT. Increased population was noticed in treatments with leaf extracts of *A. indica* (in both observations), insecticides (in the first observation) and carbaryl (in the second observation) seven days after spraying.

9. The population of *M. crocea* when treated with plant products and insecticides at different growth stages of the crop exhibited highly fluctuating and adverse effect. At 20 DAT, significant reduction in the population was noticed in treatments with insecticides (one day after spraying), insecticides and plant products (three days after spraying) and carbaryl (seven days after spraying). At 40 DAT, adverse effect was noticed with all the treatments, treatments with leaf extract of *C. infortunatum*, nimbecidine and carbaryl and treatment with carbaryl, one, three and seven days after spraying respectively. At 60 DAT,

carbaryl significantly reduced the population during the three observations. Significant increase in the defender population was recorded in treatments with nimbecidine and monocrotophos.

10. Overall view of the total population of defenders clearly indicated the safety of leaf extracts of *A. indica* and *C. infortunatum* throughout the growth stages of the crop. Insecticides, especially carbaryl caused suppression of population of defenders. Significant increase in the total population was recorded seven days after spraying in treatments with plant products at 20 DAT, with monocrotophos at 40 DAT, with leaf extracts of *C. infortunatum*, carbaryl and monocrotophos at 60 DAT.

11. The leaf extracts *A. indica* and *C. infortunatum* were found to be the best treatment in reducing the P:D ratio, at 20 DAT and 60 DAT. At 40 DAT, treatments with *A. indica* was found to be the superior treatment and the adverse effect on P:D ratio was recorded in treatment with *C. infortunatum* up to seven days after spraying.

12. Statistically same grain and straw yield was obtained in treatments with plant products, insecticides and in control.

The leaf extracts of *A. indica* and *C. infortunatum* were found to be potential sources of botanical pesticides. Effective suppression of certain major pests of rice without much reduction in the defenders are favorable factors which can advantageously fit in integrated pest management strategies.

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IMPACT OF BOTANICALS ON PESTS AND DEFENDERS IN RICE ECOSYSTEM

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ABSTRACT OF THE THESIS

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ABSTRACT

The magnitude and intensity of insect pest and their defenders at different growth stages of rice were assessed in a survey during the *virippu* season of 1998, adopting random sampling technique, in three taluks of Thiruvananthapuram district.

The survey revealed that the occurrence and distribution of the population of pests and defenders were same in the various locations, where the tolerant variety *Jyothi* was cultivated. The total population of pests and defenders observed at different growth stages of the crop followed a definite pattern in the three locations.

Different concentrations of the leaf extracts of *A. indica,* and *C. infortunatum* and nimbecidine were evaluated in the laboratory for their antifeedant and deterrent activity and contact toxicity against important pests of rice and their defenders. Based on the percentage of leaf protection, the plant products tested were superior to control against *C. medinalis.* The same effect was noticed with *N. depunctalis*, only with the highest dose of leaf extracts of *A. indica* and nimbecidine. Seventy five per cent deterrent effect was observed to *N. lugens* at the highest dose of the plant products. None of the plant products showed any deterrent action against *L. acuta* or exhibited contact toxicity to *L. acuta, C. medinalis, N. depunctalis* and *N. lugens.* Both the defenders tested (*L. pseudoannulata* and *O. nigrofasciata*), were safe with the plant products.

Replicated experiment was conducted on rice to evaluate the efficacy of plant products in suppressing the pests as well as in augmenting the defenders under field conditions. The leaf extract of *C. infortunatum* was found to be efficient in suppressing the population of *C. medinalis.* The effect was same as that with insecticides. The population of *N. depunctalis* was reduced by the leaf extracts of *A. indica* and *C. infortunatum* as observed in treatment with carbaryl. The suppressing effect observed on *N. lugens* was same with both the leaf extracts and insecticides, whereas, none of the treatments showed reduction in the population of *L. acuta.*

The total population of the pests in general, showed a varying effect of plant products at different growth stages of the crop. Leaf extracts of *C. infortunatum* resulted in an immediate suppression of the total population of the pest at 20 DAT, whereas, *A. indica* gave significant reduction at 40 DAT. The treatments didnot show any effect on the total pest population at 60 DAT.

The effect of plant products on spider population revealed that they were found to be safe. The leaf extract of *A. indica* increased the spider population at 20 DAT and *C. infortunatum* at 60 DAT, whereas, insecticides showed harmful effect up to three days after application. Adverse effect with plant products on the population of *O. nigrofasciata* was not observed in any of the treatments. An increase in the population of the predator was observed with leaf extracts of *A. indica* at 20 DAT and with *C. infortunatum* at 40 and 60 DAT. Significant reduction in the population of *Agriocnemis* spp. was recorded in treatment with leaf extract of *C. infortunatum,* whereas, significantly higher population was observed in treatment with leaf extract of *A. indica.* The population of *M. crocea* was reduced due to the application of plant products and the effect was retained up to three days after application.

The influence of plant products on the total population of defenders has clearly indicated that the leaf extracts of *A. indica* and *C. infortunatum* were safe to the defenders. Based on the P:D ratio, these products were found to have the best effect in augmenting the population of defenders and suppressing the population of pests. Significant differences in the grain and straw yield was not recorded either in treatments with plant products or with insecticides when compared with control.

Overall assessment of the results obtained revealed that *A. indica* and *C. infortunatum* can be effectively and safely used for the management of important pests of rice with out much adverse effect on non target organisms in the rice ecosystem. Just like *A. indica, C. infortunatum* could also be utilised for developing effective plant protection chemicals for replacing undesirable synthetic insecticides in integrated pest management.