IMPACT OF NEW GENERATION GRANULAR INSECTICIDES ON BENEFICIAL FAUNA OF PADDY ECOSYSTEM

by

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(2016-11-050)

THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Impact of new generation granular insecticides on beneficial fauna of paddy ecosystem"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associate ship, fellowship or other similar title, of any other university or society.

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4

Dedicated to

My Beloved Parents

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CONTENTS

LIST OF TABLES

LIST OF TABLES Continued

LIST OF FIGURES

LIST OF FIGURES Continued

LIST OF PLATES

LIST OF ABBREVIATIONS AND SYMBOLS USED

% - Per cent	< - lesser than
± - Plus or Minus	> - more than
°C - degree Celsius	® - Registered
µg L^{-1} - micro gram per Litre	µg g^{-1} - micro gram per gram
cc – Cubic Centimeter	C: B - Cost: Benefit ratio
d - Days	cm - Centimeter
DAT – Days after transplant	DAT – Days after treatment
et al - And others	EC – Emulsifiable Concentrate
Fig. - Figure	etc., - Et cetera
GR / G - Granule	FS – Flowable concentrate for seed treatment
g. a.i. ha^{-1} - Gram active ingredient per hectare	g - Gram
hill^{-1} - per hill	h - Hour
IPM – Integrated Pest Management	i.e. - that is
kg ha^{-1} - Kilogram per hectare	kg a.i. ha^{-1} - Kilogram active ingredient per hectare
L^{-1}- Litre	L ha^{-1}- Litre per hectare
m^{2} – Square meter	m - Meter
mg kg^{-1}- Milligram per Kilogram	mg a.i. mL^{-1} - Milligram active ingredient per Litre
mg L^{-1}- Milligram per Litre	mg kgdw^{-1}- Milligram per Kilogram dry weight
mL ha^{-1}- Millilitre per hectare	mL – Millilitre
mm - Millimeter	mL L^{-1}- Millilitre per Litre
q ha^{-1} – Quintal per hectare	n - Number
SC – Suspension Concentrate	rpm – Rotation per minute
SL – Soluble Concentrate	SG – Water soluble granule
spp - Species	SP – Water soluble Powder
t ha^{-1} – tones per hectare	Std - Standard
WG / WDG – water dispersible granule	*viz.,* - namely
WP – Wettable powder	µg·g^{-1} -- micro gram per gram
µg·mL^{-1}-- micro gram per mili Litre	

INTRODUCTION

1. INTRODUCTION

Oryza sativa L. is commonly cultivated in Asia and the most prominent crop of India. More than 3.5 billion of world's population i.e. almost half of the world's population rely on rice as staple food (Ghule *et al.,* 2008). India is the second largest producer and consumer of rice in world; it accounts for 22.3 per cent of global production (Khatkar and Dangi, 2016). Rice is the backbone of subsistence for millions of country households and play a prominent role in food security in India (Mondal and Chakraborty, 2016; Mahajan *et al.,* 2017). In India rice is cultivated in area of 433.88 lakh ha with production of 104.32 m t and in Kerala it corresponds to 1.71 lakh ha area with 4.36 lakh t of production (GOI, 2017). Considerable reduction in area of wet land paddy has been noticed during the previous years, leading to reduction in rice production of the Kerala.

In India 20 out of 300 species of insects which have been reported to infest the rice crop (Arora and Dhaliwal, 1996). The overall loss due to insect pest is about 25 per cent (Dhaliwal *et al.*, 2004). Among the various biotic and abiotic constraints of production, insect pests significantly contribute to the loss in yield of rice. Large scale cultivation of high yielding, fertilizer responsive rice varieties with secure irrigation have amplified the severity of attack by rice insect pests (Prasad, 2010).

Yellow stem borer (*Scirpophaga incertulas* Walker), leaf folder (*Cnaphalocrocis medinalis* Guenee) and ear head bug (*Leptocorisa acuta* Thunb.) are the major insect pests in paddy fields of Kerala. They infest all stages of growth and lead to a variety of damage such as tissue boring, leaf scrapping and sap sucking (Sharma, 2004). Farmers generally rely on chemicals for the management of the insect pests. Although the insecticidal use on managing these pests increased day by day over several years in an indiscriminate manner, the problem of rice stem borer and leaf folder silently endured.

The paddy ecosystem is a gifted reserve of beneficial organisms like parasitoids, predators and pathogens of insect pests. On an average five to seven million parasitoids, predators and neutrals may be present under one hectare paddy fields; in the early growth stages predator populations develops by feeding on neutrals thus signifying that due to the development of predators in early season before pest population, rice fields are more stable and flexible to invasion of pests (Settle, 1994). Soil flora and fauna play an important role in soil dynamics by participating in the decomposition of organic matter, dead animals and plant bodies in soil environment, thus keeping up the physical and chemical properties of the soil. Despite of the high population of natural enemies, outbreaks of pests are reported following pesticide application (Ooi, 1998), which interrupt the natural equilibrium between insect pests and their natural enemies (Gangurde, 2007). The continuous use of chemicals snuffs out the living organisms which caused ecological imbalance (Tuan, 2014); the negative impacts of chemical insecticides are represented by 4 R's - residue, resurgence, resistance and risk. This aspect has been extensively studied in the case of insect pests. On the other hand, the safety of insecticides is either insufficiently known or scanty in case of natural enemies and soil fauna.

Pesticides introduced into soil affect the population of the flora and fauna (Thompson and Edwards, 1974), it is evident that the indiscriminate use of insecticides of organochlorines, organophosphates and synthetic pyrethroids groups were found to affect the non-target beneficial organisms in paddy ecosystem including soils; particularly the spray formulations negatively affected the natural enemies of major pests of rice (Patel *et al.*, 1997). The introduction of granular insecticide formulations which are applied straight into the soil resulted in massive increase in the quantum of insecticides reaching the soil environment.

The effect of application of granular insecticides like phorate, carbofuran and quinalphos were studied extensively. However these are banned in Kerala and many safe new generation pesticides of di-amide groups, neonicotinoids etc., were tested and recommended in the rice ecosystem. Of these granular formulation *viz.,* Chlorantraniliprole 0.4 G, Fipronil 0.3 G and Cartap hydrochloride 4 G were found to be promising and recommended for pest management in paddy. Granular pesticides are being used extensively in India especially because of the easiness in application and lesser labour cost.

With this background the present study "Impact of new generation granular insecticides on beneficial fauna of paddy ecosystem" was attempted with an objective - **To study the effect of newly recommended granular insecticides on the non-target organisms *viz.*, parasitoids, predators and soil fauna**

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Literatures on the effect of new generation insecticides on major pests, non target organisms and soil fauna of paddy are reviewed. This section consists of the previous works done by various research workers and their findings, based on which the present study has been conducted.

2.1 EFFECT OF NEW GRNERATION INSECTICIDES ON PESTS OF PADDY

2.1.1 Effect of Chlorantraniliprole on Pests of Paddy

Suri (2011) compared the efficacy of chlorantraniliprole (Coragen 20 SC at 10, 20, 30 and 40 g a.i. ha^{-1}) with thiocyclam hydrogen oxalate (Evisect 50 SP at 400 g a.i. ha^{-1}) and the check insecticide chlorpyriphos (500 g a.i. ha^{-1}) and found that chlorantraniliprole at 40 g a.i. ha^{-1} was most effective in managing the stem borer and leaf folder incidence with least per cent of 1.62, 2.00 and 3.40 dead hearts, white ear head and leaf damage incidence respectively.

Liu *et al.* (2012) recorded the deleterious effect of indoxcarb and chlorantraniliprole on the reproduction of brown plant hopper (BPH) *Nilaparvatha lugens* Stal with reduced fecundity of the females by suppressing the expression of Nlvg mRNA. Insecticides reduced the vitellin synthesis which is the content of ovaries and fat bodies of adult females, may be due to decreased expression of Nlvg mRNA expression. The ovi-positional period of both brachypterous and macropterous females was decreased at sub-lethal doses i.e. reduction of 6.8 and 8.0 per cent for brachypterous and 7.4 and 13.7 per cent for macropterous females respectively by chlorantraniliprole at 7.5 and 15 mg L^{-1} and reduction of 7.4 and 14.8 per cent for brachypterous and 7.4 and 14.6 per cent for macropterous females by indoxcarb at 5 and 10 mg L^{-1} respectively.

Suri and Brar (2013) reported that chlorantraniliprole 0.4 G at 40 g a.i. ha^{-1} was significantly superior over its lower doses at 30 and 20 g a.i. ha^{-1} and untreated control in controlling stem borer and leaf folder infestation with 1.43 per cent dead hearts, 2.05 per cent white ear heads and 4.12 per cent of leaf folder damage and was found to be on par with the check insecticide cartap hydrochloride 4 G at 1000 g a.i. ha^{-1}.

Chanu (2013) evaluated the bio efficacy of chlorantraniliprole (rynaxypyr - 0.4 G at 40 and 50 g a.i. ha^{-1}; 18.5 SC at 30 and 40 g a.i. ha^{-1}) and emamectin benzoate 5 SG (at 10 and 11.5 g a.i. ha^{-1}) in management of stem borer, leaf folder and their safety to natural enemies. The results revealed that rynaxypyr 0.4 G at 50 g a.i. ha^{-1} was found to be most effective insecticide in reducing stem borer and leaf folder infestation with 80.21 per cent reduction in dead heart symptoms. 80.65 and 83.26 per cent reduction in leaf folder incidence was recorded at 14 days after both the application of treatments at 30 and 50 days after transplanting respectively and recorded the highest yield of 51 q ha^{-1} followed by its lower dose at 40 g a.i. ha^{-1}.

Two different studies on efficacy of chlorantraniliprole 0.4 G (Ferterra 0.4 G at 20, 30, 40 and 50 g a.i. ha^{-1}) showed that at 40 and 50 g a.i. ha^{-1} was found to be effective in controlling the damage by leaf folder with leaf damage of 4.12 and 3.82 per cent respectively (Suri and Brar, 2013). The treatment significantly reduced dead hearts and leaf folder incidence at 70 days and white ear heads at 80 days after transplanting (Sarao and Kaur, 2014).

Chen *et al.* (2015) through hydroponic experiment studied the comparative uptake of insecticides chlorantraniliprole and flubendiamide in rice plant and claimed that only chlorantraniliprole had an uptake character and transport only upwards, while this character was not found in flubendiamide in rice plants. The rice roots incubated in the insecticidal solution of 50 $\mu g \cdot mL^{-1}$ and 200 $\mu g \cdot mL^{-1}$ showed that at above the liquid level part the concentration of chlorantraniliprole in rice plant was found to be 5.13, 9.17 and 12.86 $\mu g \cdot g^{-1}$ (at 50 $\mu g \cdot mL^{-1}$) and 13.87, 19.62 and 22.51 $\mu g \cdot g^{-1}$ (at 200 $\mu g \cdot mL^{-1}$) in 24, 48 and 72 hours after treatment respectively and flubendiamide was not detected.

Chanu and Sontakke (2015) conducted field trails to appraise the relative efficacy of new generation insecticide chlorantraniliprole (rynaxypyr 0.4 G and 18.5 SC) and emamectin benzoate 5 SG at different doses along with the recommended insecticides fipronil, carbofuran and profenophos against the rice leaf folder. Among the treatments chlorantraniliprole 0.4 G at 50 g a.i. ha^{-1} gave the most effective results with 80.27 and 86.12 per cent of leaf damage reduction over control and recorded highest grain yield of 51.00 and 55.00 q ha^{-1}.

The incidence of leaf folder and dead heart was found to be the lowest when chlorantraniliprole granule (0.4 WW/SR at 10 kg ha^{-1}) applied in seed bed along with spraying of chlorantraniliprole (18.5 SC at 3 mL 10 L^{-1}) at 45 or 50 days after transplanting which recorded the highest yield of 4657 kg ha^{-1} and 4790 kg ha^{-1} respectively (Chatterjee *et al.*, 2015).

Chen *et al.* (2016) evaluated the impact of insecticides chlorantraniliprole, thiamethoxam and their mixture Virtako against rice plant hoppers and leaf folders; significant reduction of pests was observed in all the treatments. The insecticide mixture Virtako at 36-60 g a.i. ha^{-1} was found to be best with highest reduction in total number of pests up to 46-60 (*N. lugens*) and 59-66 (*Sogatella furcifera* Horvath) per cent of plant hoppers and 11-46 and 37-76 per cent reduction of leaf folder, *Cnaphalocrosis medinalis* (Guenee) incidence at 7 and 28 days after application respectively.

Rana and singh (2017) endorsed that the infestation of yellow stem borer *Scirpophaga incertulas* (Walker) was effectively managed by chlorantraniliprole 18.5 SC. The minimum infestation of 2.73 and 2.06 per cent of dead hearts and white ear heads respectively was recorded in chlorantraniliprole 18.5 SC at 150 mL ha^{-1} and recorded the highest grain yield of 44.58 q ha^{-1} over the treated check 37.60 q ha^{-1}.

Seni and Naik (2017) registered the efficacy of some of the newer insecticides along with conventional insecticides against major insect pests of rice and reported that the highest grain yield was obtained from the treatment chlorantraniliprole (rynaxypyr 20 SC) at 30 g a.i ha^{-1} with the lowest per cent infestation of stem borer (0.42 and 1.24 per cent of dead heart and white ear head). This also recorded the highest number of spiders in treated plot.

2.1.2 Effect of Fipronil on Pests of Paddy

The rice pre germinated seed treated with fipronil at 12.5 g a.i. ha^{-1} was more effective than malathion at 300 g a.i. ha^{-1} (Stevens *et al.,* 1998). When compared to conventional organo-phosphorus insecticides, fipronil seed treatment provided protection for 9-14 days after sowing against chironomid insects with high toxicity value of LC_{50} (0.43 μg L^{-1}) and LC_{90} (1.05 μg L^{-1}) to final instar larvae of *Chironomus tepperi* Skuse and fipronil also evidenced for the development of stronger root system in treated plants.

Dash and Mukherjee (2003) evaluated the efficacy of some granular and sprayable insecticides against the major insect pests of rice and found that among the granules fipronil 0.075 kg a.i. ha^{-1} showed maximum protection from stem borer with the highest yield of 40.40 q ha^{-1}. Hedge (2003) reported that among varied rates of application, fipronil 0.3 G (Regent) at 75 and 100 g a.i. ha^{-1} and carbofuran 3 G at 570 g a.i. ha^{-1} were found to be proficient in managing the infestation of yellow stem borer.

Jena and Mayabini (2004) reported that fipronil at 0.01 % as seedling root dip emerged as the most promising insecticide in managing the *S. incertulas* (yellow stem borer) and increased the grain yield followed by imidacloprid (0.01 %) and carbofuran (0.02 %). Panda *et al.* (2004a) observed the longer roots, high number of tillers and highest grain yield when the rice seeds treated with the insecticides fipronil at 100 g a.i. ha^{-1} and imidacloprid at 75 g a.i. ha^{-1} as seed treatment.

Panda *et al.* (2004b) compared the efficacy of fipronil (Regent 5 FS) at 3 doses (50, 75 and 100 g a.i. ha^{-1}) with chlorpyriphos 20 EC and imidacloprid 200 SL each at 25 g a.i. ha^{-1} in rice and the results revealed that fipronil at 100 g a.i.

ha^{-1} was found to be effective over other treatments with the lowest of 4.02 and 6.03 per cent of dead hearts recorded at 14 and 21 days after transplanting.

Khan *et al.* (2005) reported that fipronil 300 EC at 29.6 mL ha^{-1} was the most efficient in controlling the infestation of rice stem borer, *S. incertulas*. Singh *et al.* (2005) and Lal (2006) also found the similar results with fipronil 0.3 G granules when applied at 30, 50 and 70 days after transplanting.

Two different studies showed the superiority of fipronil 0.3 G; when applied at 20 days after transplanting (DAT) it protected the crop up to 60 DAT with minimum incidence of stem borer, *S. incertulas* infestation and maximum grain yield. Fipronil 0.3 G at 0.045 kg a.i.ha^{-1} found to be effective when applied at 30, 50 and 70 DAT (Singh *et al.*, 2005) and at 75 g a.i. ha^{-1} was most effective when applied at 20, 50 and 70 DAT (Lal, 2006).

Prasad *et al.* (2007) evaluated the efficacy of insecticides *viz.,* fipronil, thiacloprid, cartap and carbofuran against yellow stem borer as seed treatment and nursery application. The results revealed that the combination treatment of immersing or soaking sprouted seeds and drenching the nursery with fipronil insecticide five days before pulling the seedlings proven to be effective in decreasing the infestation to 3.33 per cent and increased the average grain yield to 24.15 q ha^{-1}.

Sekh *et al.* (2007) evaluated the efficacy of fipronil 80 WG against stem borer (*S. incertulas*) and leaf folder (*C. medinalis*) of rice in West Bengal and reported that fipronil 80 WG at 40 and 50 g a.i. ha^{-1} most effective control of both pests; Mahal *et al.* (2008) also reported that fipronil 80 WG at higher dose of 62.5 g a.i. ha^{-1} was most effective with the lower incidence of 2.61 and 0.52 to 0.61 per cent of white ear head and leaf damage respectively.

Among the granular formulations, Hugar *et al.* (2009) found the superiority of fipronil 0.3 G at 7.5 g a.i. ha^{-1} against yellow stem borer of rice with the least per cent infestation of 3.40 and 2.43 per cent of dead hearts at 50 and 75 days after transplanting respectively.

Firake *et al.* (2010) reported that fipronil 5 SC at 75 g a.i. ha^{-1} efficiently managed the stem borer *S. incertulas* with 49.61 per cent reduction in damage over control followed by cartap hydrochloride 4 G at 750 g a.i. ha^{-1} and imidacloprid 17.8 SL at 25 g a.i. ha^{-1}.

Mishra *et al.* (2012) evaluated the effect of seven insecticides against stem borer out of which the highest grain yield was obtained in fipronil 5 SC (50 g a.i. ha^{-1}) treated plots with the lowest incidence of yellow stem borer followed by cartap hydrochloride 50 SP (300 g a.i. ha^{-1}) and cartap hydrochloride 4 G (750 g a.i. ha^{-1}).

Chormule *et al.* (2014) reported that Lasenta 80 WG (imidacloprid 40 per cent + fipronil 40 per cent w/w) at 250 g a.i. ha^{-1} efficiently reduced the rice stem borer *S. incertulas* infestation with 3.17 and 5.12 per cent of dead hearts after first and second application of treatments at active tillering stage applied in 15 days of interval and recorded the highest yield of 43.30 q ha^{-1} followed by chlorantraniliprole 0.4 G at 30 g a.i. ha^{-1} (3.98 and 6.07 per cent of dead hearts; 41.53 q ha^{-1}) and fipronil 0.3 G at 7.5 g a.i. ha^{-1} (5.44 and 6.44 percent of dead hearts; 39.07 q ha^{-1}).

Fipronil 0.6 GR at 60 g a.i. ha^{-1} was found to be more efficient in reduction of stem borer and brown plant hopper infestation with reduction of 3.40 per cent dead hearts Satyanarayana *et al.* (2014a) and recorded the lowest mean population of 2 hoppers $hill^{-1}$ and recorded 60 per cent (6,115.0 kg ha^{-1}) increase in grain yield (Satyanarayana *et al.*, 2014b).

Vennila *et al.* (2014) tested the efficiency of foliar insecticides against yellow stem borer (*S. incertulas*). Among eight insecticides fipronil 5 FS at 50 g a.i. ha^{-1} was reported to be the most effective one in managing stem borer infestation by reducing the survival of moth, oviposition and larval hatching.

Bhanu *et al.* (2015) in a two season study compared the efficacy of fipronil 200 SC (at 30, 40 and 50 g a.i. ha^{-1}) with treated and untreated check *viz.*, fipronil 80 WG and fipronil 5 SC at 50 g a.i. ha^{-1}. In both the seasons fipronil 200 SC recorded the lowest incidence of white ear heads and dead hearts and phytotoxicity was not observed at all the tested doses. During kharif 2013, the lowest per cent dead hearts of 0.84 was observed in fipronil 5 SC at 50 g a.i. ha^{-1} and on par with all the doses of fipronil 200 SC, fipronil 80 WG at 50 g a.i. ha^{-1} and check insecticide L-cyhalothrin 4.9 SC at 12.5 g a.i. ha^{-1}. The lowest incidence of white ear heads was observed in fipronil 200 SC at 40 g a.i. ha^{-1} (3.42 per cent). The highest grain yield was recorded in fipronil 5 SC at 50 g a.i. ha^{-1} (4051 kg ha^{-1}) followed by fipronil 200 SC at 50 g a.i. ha^{-1} (3512 kg ha^{-1}) and fipronil 80 WG at 50 g a.i. ha^{-1} (3397 kg ha^{-1}).

Singh *et al.* (2015) evaluated the bio-efficacy of insecticides and bio pesticides on yellow stem borer, *S. incertulus* and found that among the treatments fipronil 5 SC at 0.5 L ha^{-1} and cartap hydrochloride 50 SP at 1 kg a.i. ha^{-1} were found to be effective in controlling stem borer with dead heart or white ear head infestation of 3.43 and 3.90 percent respectively at 21 days after first application. The treatments fipronil 5 SC at 0.5 L ha^{-1} and cartap hydrochloride 50 SP at 1 kg a.i. ha^{-1} recorded the maximum yield of 45.83 and 44.96 q ha^{-1} respectively. The highest cost: benefit ratio was worked out for the treatment fipronil 5 SC (1: 14.4).

Aulakh *et al.* (2016) reported that lower incidence of dead hearts and leaf folder was observed in plots treated with Regent (fipronil 0.3 G) followed by cartap hydrochloride 4 G.

In a field trial during kharif 2013-14, fipronil 5 SC at 75 g a.i ha^{-1} was found to be effective against gall midge with the least incidence of 2.6 per cent silver shoots (Seni and Naik, 2017).

2.1.3 Effect of Cartap Hydrochloride on Pests of Paddy

Cartap hydrochloride 4 G was found to be the most effective insecticide against yellow stem borer with significantly less per cent infection of dead heart and white ear heads symptoms and highest grain yield. Being superior it was on par with the other treatments *viz.*, fipronil, thiodicarb, flubendiamide, and significantly superior to remaining treatments in the experiment (Kumar, 2001; Karthikeyan *et al.*, 2007).

Kumar (2001) tested the efficacy of cartap hydrochloride 4 G at 500, 750 and 1000 g a.i. ha^{-1}, and revealed that all the treatments were superior to control, where cartap hydrochloride 4 G at 750 and 1000 g a.i. ha^{-1} and carbofuron 3 G at 750 g a.i. ha^{-1} effectively managed the major pests of rice and recorded higher grain yield. Both the insecticides were found to be non phytotoxic to rice plant at any dosage of their application.

Cartap hydrochloride 4 G at 25 kg a.i. ha^{-1} and ethofenoprox 10 EC at 1.5 mL L^{-1} were found to be more effective in controlling rice leaf folder when applied at 30 and 45 days after transplanting (Madhumathi and Srinivas, 2001).

Saljoqi *et al.* (2002) evaluated the efficacy of fipronil and other insecticides and reported that cartap hydrochloride 4 G (Padan) at 22.23 kg ha^{-1} was found to be the most effective one against rice stem borer followed by fipronil 300 EC (Regent) at 197.6 mL ha^{-1}.

Cartap hydrochloride 4 G at 0.75 kg a.i. ha^{-1} was found to be the most proficient insecticide against leaf folder in rice among seven treatments *viz.*, cartap hydrochloride 4 G, monocrotophos 36 SL, *Bacillus thuringenesis* var. krustaki, endosulfan 35 EC, 300 ppm neem (azadirachtin), ethofenprox 10 EC and release of *T. chilonis* an egg parasitoid of leaf folder (Sehrawat *et al.*, 2002).

Prasad *et al.* (2005) tested the efficacy of insecticides chlorpyriphos 10G (at 0.75, 1.0 and 1.25 kg a.i. ha^{-1}), cartap 4G (at 0.6, 0.8 and 1.0 kg a.i. ha^{-1}), carbofuran 3G (at 1 kg a.i. ha^{-1}) and fipronil 0.4 G (at 0.05, 0.075 and 0.1 kg a.i.

ha^{-1}). Among the tested insecticides cartap 4 G at 0.6 kg a.i. ha^{-1} was reported to be the most effective insecticide against yellow stem borer with minimum of 2.9 per cent infestation followed by 3.4 per cent infestation in treatments *viz.*, chlorpyriphos 10 G (1.25 kg a.i. ha^{-1}), fipronil 0.4 G (0.075 kg a.i. ha^{-1}) and chlorpyriphos 10 G (0.75 kg a.i. ha^{-1}) over the untreated control treatment (8.10 per cent).

In an efficacy study of certain granular insecticides cartap hydrochloride 4 G at 1.0 kg a.i. ha^{-1} was reported to be more effective against rice leaf folder *C. medinalis* with minimum leaf damage and maximum grain yield among the granular insecticides *viz.,* carbofuran 3 G, cartap 4 G, fenthion 5 G, fenitrothion 5 G and phorate 10 G. Cartap hydrochloride 4 G at 1.0 kg a.i. ha^{-1} was found to be statistically on par with phorate 10 G and carbofuran 3 G at 1.0 kg a.i. ha^{-1} (Mishra *et al*., 2007).

Karthikeyan *et al*. (2007) compared the efficiency of cartap hydrochloride at 1 kg a.i. ha^{-1} with check insecticide carbofuran (1 kg a.i. ha^{-1}) against stem borer and leaf folder of rice. The results revealed that the highest reduction in incidence of dead heart and white ear heads by 35.60 and 28.40 per cent respectively and the leaf folder incidence by 47.70 per cent were recorded in cartap hydrochloride at 1 kg a.i. ha^{-1}. This treatment recorded the highest grain yield of 3113 kg ha^{-1} compared to control (2576 kg ha^{-1}) and found to be on par with check insecticide carbofuran (2861 kg ha^{-1}).

Hugar *et al.* (2009) reported that cartap hydrochloride 4 G @ 1000 g a.i. ha^{-1} was found to be least effective among the granular formulations against rice yellow stem borer.

Tanveer *et al.* (2012) evaluated the effect of insecticides on yellow stem borer (*S. incertulas*) in rice and claimed that cartap hydrochloride 4 G at 750 g a.i. ha^{-1} was more effective in management of stem borer with least per cent infestation of 6.0 compared to carbofuran 3 G (14.00 per cent) followed by fipronil 0.3 G.

Abro *et al.* (2013) evaluated the efficacy of insecticides against rice stem borer, (*S. incertulas*) claimed that application of insecticides caused significant decrease in the incidence of rice stem borer and considerable increase in the filling of rice grain and yield. Cartap hydrochloride was found to be the most effective with the least infestation of 4.37 per cent and with cost: benefit ratio of 1: 50.3 followed by carbofuran.

Singh *et al.* (2013) evaluated the efficacy of seven newer insecticides against yellow stem borer and reported that cartap hydrochloride 4 G at 750 g a.i. ha^{-1} was found to be the most effective one with least infestation of yellow stem borers and recorded the highest grain yield of 28.20 q ha^{-1} followed by cartap hydrochloride 75 SG and fipronil 5 SC with 25.43 and 24.61 q ha^{-1} respectively.

2.2 EFFECT OF NEW GRNERATION INSECTICIDES ON BENIFICIAL FAUNA OF PADDY ECOSYSTEM

Cloyd and Bethke (2011) claimed that parasitoids may be indirectly affected because of foliar, drench or granular applications of insecticides. Insecticides may decrease host population to levels such that they are not enough to sustain them furthermore, host quality may be unacceptable for egg laying by parasitoid females.

Among seven classes of insecticides, Zhao *et al.* (2012b) studied the impact of 30 insecticides on *Trichogramma japonicum* Ahmead (an egg parasitoid of rice lepidopterans) based on risk quotient analysis reported that phenyl pyrazoles, pyrethroids, insect growth regulators, neonicotinoids (except thiamethoxam), and antibiotics (except abamectin) are found to be safe to parasitoid while organophosphates and carbamates are found to be toxic and classified as slightly, moderately or highly toxic to *T. japonicum*.

2.2.1 Effect of Chlorantraniliprole on Beneficial Fauna

Formulations of chlorantraniliprole affords a venerable tool for IPM programs to safeguard pollinating bumble bees and honey bees at application rates of Coragen (chlorantraniliprole) up to 60 g a.i. ha^{-1} (Dinter *et al.*, 2009).

Preetha *et al.* (2009) found that chlorantraniliprole at 25 g a.i. ha^{-1} was found to be the safest insecticide with LC_{50} 1.9530 mg a.i. L^{-1} and lower Risk quotient of 12.08 to major egg parasitoid *Trichogramma chilonis* Ishii in rice ecosystem. And chlorantraniliprole found to be non-toxic to the parasitoid wasp species tested with less than 30 per cent effects (Brugger *et al.*, 2010).

Chlorantraniliprole with various LD_{50} values which ranged from 2.00 to 18.70 mg per larva shown by *Chilo suppressalis* (Walker), had negligible acute contact toxicity (LC_{50} >500 mg L^{-1}) to *Cotesia chilonis* (Munakata), egg parasitoid of rice leaf folders and its oral toxicity was found to be much lesser than that of fipronil (>2800 fold difference in LC_{50}) and proven to be less toxic to the wasp *C. chilonis* with LC_{50} of 55.51 and 39.78 mg L^{-1} respectively in two distinct methods. They also suggested chlorantraniliprole as a good choice in rice integrated pest management programs (Jia *et al.*, 2011).

Zhao *et al.* (2012a) tested the predatory efficiency of *Cyrtorhinus lividipennis* Reuter, pre treated with a label dose of chlorantraniliprole and reported that the insecticide had adversely affected the predation capacity of *C. lividipennis* with the decreased rate of instant attacking and searching capacity of adult predator.

Larson *et al.* (2012) claimed that chlorantraniliprole at 0.23 kg a.i. ha^{-1} was found to be safe to soil invertebrates with no or little effects on predatory or soil invertebrates in predation or decomposition. It was found to be compatible with preservation of biocontrol agents and a better tool for industry initiatives to use comparatively less poisonous pesticides.

Chlorantraniliprole 0.4 G (40 and 50 g a.i. ha^{-1}) and emamectin benzoate 5 SG (10 and 11.5 g a.i. ha^{-1}) at both doses were reported to be safe to natural enemies of rice insect pests which recorded higher number of predators after application and found the higher toxicity of chlorantraniliprole (18.5 SC) with relative toxicity of 5.81 and LC_{50} of 0.069 compared to emamectin benzoate. (Chanu, 2013).

In rice ecosystem Jaafar *et al.* (2013) evaluated the effect of insecticides *viz.,* chlorantraniliprole at 0.4 L ha^{-1}, fipronil at 0.3 L ha^{-1} and cartap hydrochloride at 2 kg ha^{-1} on biodiversity of arthropods and reported that chlorantraniliprole efficiently controlled the insect pests and also found to be safe with least effects on non-target arthropods when compared to fipronil and cartap hydrochloride, which reduced the natural enemy populations and also failed to check the pest populations compared to control

Martinou *et al.* (2014) evaluated the impact of pesticides on hemipteran predator *Macrolophus pygmaeus* Rambur (miridae), and the results confirmed the safety of insecticides chlorantraniliprole and emamectin-benzoate to the predator with less than 25 per cent mortality. Whereas the pesticides thiacloprid and metaflumizone were reported to be highly toxic with 100 and 80 per cent mortality respectively and thiacloprid significantly condensed the predation rate.

Maximum spider population of 1.55 $hill^{-1}$ was recorded in the plots treated with chlorantraniliprole granule at 10 kg ha^{-1} compared to plots sprayed with other new molecules *viz.,* indoxacarb, flubendiamide and spinosad. Control recorded the highest mean population of 1.82 $hill^{-1}$ (Chatterjee *et al.*, 2015).

Zhang *et al.* (2015) evaluated the sub lethal effects of four insecticides with technical grade chlorantraniliprole (95.3%), deltamethrin (98.0%), pymetrozine (96.1%) and triazophos (84.8%) on *C. lividipennis* and found that chlorantraniliprole, pymetrozine and trizophos at sub lethal concentrations had no impact on the behavior of the predator, while deltamethrin (LC_{20} and LC_{10})

interrupt the orientation of behavior and also negatively affected the olfactory response of *C. lividipennis* at sub lethal concentrations. Chlorantraniliprole and pymetrozine had none of the unfavorable effects such as lethal effect, disturbed behavioral responses to host-infested plant odors or decreased predator capability, and pepsin activity and thus they were reported to be safe and superior in compatibility with *C. lividipennis* compared to triazophos and deltamethrin.

Karthick *et al.* (2015) evaluated the effect of newer insecticides sprayed at fifteen days interval after transplanting on natural enemies in Karaikal district of Puducherry and reported that chlorantraniliprole 18.5 SC at 27.75 g a.i. ha^{-1} was found to be safe to predatory spiders and coccinellids after indoxcarb14.5 SC at 72.5 g a.i. ha^{-1} with overall mean populations of 0.95 and 0.79 at first spray and 0.97 and 0.98 at second spray respectively.

Plankton species were adversely affected by chlorantraniliprole and clothianidin right after the applications but they recovered after the concentrations decreased (Kasai *et al.*, 2016).

Vesna *et al.* (2016) claimed that even at higher concentrations of 1000 mg kg^{-1} of soil chlorantraniliprole was found to be non toxic to enchytraeids, oribatid, mites and isopods, and a toxic effect was noticed in the springtails *Folsomia candida* which negatively affected the locomotory abilities. The survival and reproduction was affected with an EC_{50} on reproduction of 0.14 mg kg dw^{-1}.

Virtako (36 g a.i. ha^{-1}) caused the short term reduction in the population of insect predators which was reported to be quickly recovered after 21 days of application representing the total number of predators appears to be similar to those in untreated plots (Chen *et al.*, 2016).

Mandal and Riso (2017) evaluated the effect of some granular and sprayable insecticides on soil fauna and found that rynaxypyr 0.4 G at 40 g a.i. ha^{-1} was safe to soil fauna like earthworms, collembola and soil oribatid mites with mean population of 22.67, 1.00 and 0.67 respectively and found to be on par with control in the case of earthworms.

Liu *et al.* (2018) studied the eco toxicity of chlorantraniliprole (at 0.1, 1.0, 5.0 and 10.0 mg kg^{-1}) on earthworms, *Eisenia fetida* in soil and found that the accumulation rate of chlorantraniliprole in earthworms was 0.03, 0.58, 4.28, and 7.21 mg kg^{-1} of earthworm's fresh weight respectively after 42 days of exposure. Chlorantraniliprole had no effect on earthworms at 0.1 and 1.0 mg kg^{-1} where as reproductive toxicity was reported at 5.0 and 10.0 mg kg^{-1}. It induced damage to bio-macromolecules and caused significant reduction in weight after 28 and 42 days of application.

2.2.2 Effect of Fipronil on Beneficial Fauna

In the management of stem borer of rice Panda *et al.* (2004a) observed that fipronil (0.075 and 0.05 kg a.i. ha^{-1}) showed efficient control of stem borer and superior than carbofuran and phorate and also found to be safer molecule to the natural enemies of stem borer.

Seetharamu *et al.* (2006) evaluated the safety of new insecticides *viz.,* fipronil, imidacloprid, cartap hydrochloride, ethofenprox, thiodicarb, spinosad and chlorpyriphos to spiders and mirid bugs in rice fields. Among the insecticides fipronil at 25 kg ha^{-1} was found to be safer to spiders and mirid bugs with overall cumulative mean efficiency values of 63.50 and 44.83 respectively, followed by ethofenprox 1.5 mL L^{-1} (50.58 spiders; 46.50 mirid bugs). Chlorpyriphos 25 mL L^{-1} (17.77 spiders; 17.17 mirid bugs) was found to be highly toxic to both spiders and mirid bug populations when compared to untreated control (73.08 spiders; 61.33 mirid bugs).

Fipronil was found to be toxic to earthworms with the recorded value of 96.7 per cent mortality at 48 h after treatment in filter paper test and the maximum of up to 10 per cent mortality observed even after four weeks of exposure in soil (Karanjkar, 2009).

In the micro-paddy lysimeter system, Jinguji *et al.* (2013) found that the use of imidacloprid and fipronil as nursery box application caused the decline of *Sympetrum infuscatum* Selys. The results revealed that fipronil (0.4–1.3 µg L^{-1}) completely wiped out the young *S. infuscatum* larvae in the first 9 days after treatment where imidacloprid did not eliminate them but indirectly affected their survival by diminishing prey availability. Both insecticides were directly and indirectly reported to be responsible for the reduction in the abundance of *S. infuscatum* larvae and adults.

Salokhe *et al.* (2014) studied the impact of fipronil on earthworm *Eudrilus eugeniae* and found that the population was significantly reduced with fipronil (LC_{20} 20.7 mg kg^{-1} soil) treated soil and it negatively affected the growth and reproductive potential of earthworms with decline in the number of cocoons and juveniles compared to control. It also had adverse effect on earthworms gut micro flora and their enzyme production and due to this the quality of nutrient content was affected. Thus the natural process of verminculture which maintains the balance in environment was affected and resulted in plummeting the fertility of soil.

Adarsha *et al.* (2015) studied the impact of insecticides on soil arthropods and earthworms in arecanut ecosystem and the results revealed that Phorate 10 G at 25 kg ha^{-1} and fipronil 5 SC at 2.5 L ha^{-1} were found to be highly toxic to earth worms. Fipronil also showed negative effects on non target soil arthropods.

In paddy mesocosm experiment Kasai *et al.* (2016) investigated the effect of the systemic insecticides *viz.,* clothianidin, fipronil and chlorantraniliprole on paddy field biological communities and reported that the effects of fipronil treatment were larger than those of any other treatment especially on Odonata

2.2.3 Effect of Cartap Hydrochloride on Beneficial Fauna

Cartap hydrochloride at 1.0 and 0.75 kg a.i. ha^{-1} was found to be safer and selective insecticide to the egg parasitoid *Telenomus dignoides* Nixon, with highest parasitism of 62.3 to 81.6 per cent compared to carbofuran (40 to 59 per cent). Cartap hydrochloride at both the dose of application showed the least incidence of white ear heads (1.9 to 11.9 per cent) and recorded the highest yield of 23.6 to 48.0 q ha^{-1} in efficacy studies against *S. incertulas* on basmati rice (Singh *et al.*, 2003).

Nazir *et al.* (2005) revealed that cartap hydrochloride 4 G was found to be the most proficient among the tested insecticides with reduced population of stem borers and also reported to be non toxic to the natural enemies of stem borer.

Cartap hydrochloride at 1 kg a.i. ha^{-1} was reported to be safe to natural enemies of rice when compared to untreated plots by increase in the population of spiders, damselflies, green mirid bugs and larval parasitoids by 18.27, 42.86, 54.55 and 49.15 per cent respectively (Karthikeyan *et al.*, 2007).

Response of granular insecticides *viz.* phorate, cartap hydrochloride and carbofuran at recommended and double dosage was tested against earthworm, *Eisenia fetida.* The results revealed that all the tested insecticides were toxic to juveniles while phorate at both the doses found toxic to cocoon production. However, these insecticides did not affect the increase in biomass and survival of adult earthworms (Palta and Srivastava, 2007).

Among the different insecticides tested Sarao *et al.* (2012) reported that cartap hydrochloride 4 G followed by endosulfan 35 EC and imidacloprid 200 SL were found to be safe by recording highest natural enemy diversity of 1.803-1.943, 1.437-1.833 and 1.550-1.847 respectively. Monocrotophos 36 SL (1.195-1.335), chlorpyriphos 20 EC (1.002-1.429) and methyl parathion 50 EC (0.861-1.522) were found harmful to natural enemies. By this he concluded that cartap hydrochloride and endosulfan were safe while chlorpyriphos and methyl parathion were reported to be toxic to the natural enemies.

Singh *et al.* (2015) conducted a bio-efficacy study of insecticides and bio-pesticides against yellow stem borer, *S. incertulas* and their effect on spiders in rice crop. Maximum numbers of predatory spiders were recorded in control plot (3.26 per hill). Among the treatments the highest number of spiders was recorded in cartap hydrochloride 4 G at 18.75 kg ha^{-1} (1.66 $hill^{-1}$) followed by fipronil 5 SC 0.5 L ha^{-1} (1.53 $hill^{-1}$) at 21 days after second application at 75 days after transplanting.

2.3 DISSIPATION STUDIES OF INSECTICIDES

The dissipation of the pesticide residues in soil generally depending on the various parameters *viz.,* dosage, environmental conditions, temperature, pH, type of application, and interval between the applications (Khay *et al.,* 2008). The literature pertains to the dissipation studies of chlorantraniliprole and fipronil insecticides in soil and water given in Table 1 and 2.

Table 1. Dissipation of chlorantraniliprole in soil and water

Crop	Sample		Insecticide formulation	Dosage (g a.i.ha^{-1})	Initial concentration (mg kg^{-1})	Days taken to reach BDL	Hal life (days)	Reference
Corn	Soil		20% (w/w)	30	0.28 and 0.09	35	12.6 and 23.1	Dong *et al.*, 2011
Tomato	Soil		20 % SC	60	4.555	21	3.66	Malhat *et al.*, 2012
Sugarcane	Soil		18.5 % SC	100 g	0.208	45	6.50	Ramasubramanian *et al.*, 2012
				200 g	0.461	45	6.81	
Paddy	Soil			150 mL			16.00	Zhang *et al.*, 2012
	Water						0.85	
Sugarcane	Soil		0.4 G	100 g	0.88	56	8.36	Sharma *et al.*, 2014
				200 g	1.59	56	8.25	
Paddy	Water		0.75 % G	50 g	2.06 μg L^{-1}	-	16.10	Kasai *et al.*, 2016
Maize	Soil	Beijing	40 % WP	118 g	3.27	-	9.50	He *et al.*, 2016
		Anhui			3.14		21.70	
Laboratory studies	Alluvial soil		Technical grade	50 μg g^{-1}	56.64 μg g^{-1}	60	7.52to 11.55	Badawy *et al.*, 2017
	Calcareous soil				53.03 μg g^{-1}		9.01 to 11.63	

Table 2. Dissipation of fipronil in soil and water

Crop	Sample	Insecticide formulation	Dosage (g a.i.ha^{-1})	Initial concentration (mg kg^{-1})	Days taken to reach BDL	Hal life (days)	Reference
Paddy	Water	80 WDG	560	-	-	67.60 h	Ngim and Crosby, 2001
		1.5 G	28			125 h	
		1.67 SC	42.6			75.8 h	
	Soil	80 WDG	560	-	-	533 h	
		1.5 G	28			438 h	
		1.67 SC	42.6			95.9 h	
Paddy	Water	2 GR (0.2%)	40	0.018	40	-	Hadjmohammadi *et al.*, 2006
	Soil			0.032	14		
Paddy	Water	1.0 % G	50	1.3 at 6 h,	-	5.40 d	Jinguji *et al.*, 2013
	Soil	5 % SC	50	0.034±0.004	90	10.81 d	Saini *et al.*, 2014
			100	0.071±0.002	90	9.97 d	
Paddy	Water	1.0 % G	50	0.394	12 weeks	16.90 d	Kasai *et al.*, 2016

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study entitled "Impact of new generation granular insecticides on beneficial fauna of paddy ecosystem" has been carried out at College of Agriculture, Vellayani and the field experiment was conducted at Integrated Farming System Research Station (IFSRS), Karamana in Thiruvananthapuram during the first crop season of 2017. The residue analysis of soil and water was carried out at Pesticide Residue Research and Analytical Laboratory, College of Agriculture, Vellayani.

3.1 EFFECT OF NEW GENERATION GRANULAR INSECTICIDES ON THE DAMAGE/POPULATION OF MAJOR PESTS, NATURAL ENEMIES AND SOIL FAUNA IN PADDY ECOSYSTEM

A field experiment was conducted to evaluate the impact of new generation granular insecticides *viz.,* chlorantraniliprole 0.4 G, fipronil 0.3 G and cartap hydrochloride 4 G at recommended and double the recommended doses on arthropod community and soil fauna in paddy ecosystem at IFSRS, Karamana.

The experiment was laid out in a randomised block design using the medium duration variety Uma with seven treatments replicated thrice. A spacing of 20 cm between rows and 15 cm between plants was adopted with a plot size of 5m x 4m. All the other agronomic practices were followed according to the Package of Practices recommendations of Kerala Agricultural University (KAU, 2016).

The general view of experimental plot is given in Plate 1.

Treatments

T_1- Chlorantraniliprole 0.4 G 10 kg ha^{-1}

T_2- Fipronil 0.3 G 10 kg ha^{-1}

T_3- Cartap hydrochloride 4 G 25 kg ha^{-1}

Plate 1. Layout of the experiment

T_4- Chlorantraniliprole 0.4 G 20 kg ha^{-1}

T_5- Fipronil 0.3 G 20 kg ha^{-1}

T_6- Cartap hydrochloride 4 G 50 kg ha^{-1}

T_7- Untreated Control

The treatments were given at 15 and 30 days after transplanting (DAT) and the control plot maintained separately.

3.1.1. Insecticides Selected and Preparation of Insecticides for Application

Quantity of insecticide required for 5 m × 4 m (20 m^2) experimental plots were calculated and required amount weighed and used for application.

3.1.1.1 Chlorantraniliprole

A commercial insecticide Ferterra® of E. I. DuPont India Private limited 0.4G at 20 and 40 g was used for application.

3.1.1.2 Fipronil

A commercial insecticide, Progent 0.3 G of K. P. R Agrochem. Limited at 20 and 40 g was used for application.

3.1.1.3 Cartap Hydrochloride

A commercial insecticide TOP 4 G of K. P. R. Fertilizers Limited at 50 and 100 g was used for application.

3.1.2 Assessment of Population of Arthropods

The observations on incidence of pests and population of pests and natural enemies were recorded at fortnightly intervals after the application of treatments by the method followed by Reissig *et al*. (1986). As such five observations were recorded. The Pest: Defender ratio for every treatment was also worked out.

The infestation by pests was recorded from randomly selected ten hills.

The population of pests and natural enemies were recorded by counting the number in ten sweeps. The population of beneficial soil fauna of paddy ecosystem were taken at 50th and 70th DAT. The count of earthworms and soil arthropods were taken in one cubic feet area and the count of nematodes taken by collecting the soil samples randomly

3.1.2.1 Assessment of Incidence of Pests

Fortnightly observations of major insect pests, symptoms of yellow stem borer attack and leaf roller attack were recorded from 10 randomly selected hills.

3.1.2.1.1 Yellow Stem Borer (S. incertulas)

The incidence of *S. incertulas* was documented from each plot at fortnightly intervals by recording the total numbers of dead hearts caused by yellow stem borer from 10 randomly selected hills after application of treatments and per cent dead hearts were worked out. At flowering stage and before harvest of the crop, the number of productive tillers/panicles as well as white ear heads were recorded in 10 hills and per cent white ear heads were worked out.

$$\text{Dead heart (\%)} = \frac{\text{Number of dead hearts / hill}}{\text{Total number of tillers / hill}} \times 100$$

$$\text{White ear head (\%)} = \frac{\text{Number of white ear head / hill}}{\text{Total number of panicles/ hill}} \times 100$$

3.1.2.1.2 Leaf Roller (C. medinalis)

The incidence of leaf folder was documented by counting damaged leaves and total leaves from 10 randomly selected hills and per cent leaf damage due to leaf folder was worked out.

$$\text{Leaf roller (\%)} = \frac{\text{Number of leaves rolled / hill}}{\text{Total number of leaves /hill}} \times 100$$

3.1.2.2 Assessment of Incidence of Natural Enemies

For assessing the safety of new generation granular insecticides on natural enemies (Parasitiods and Predators) of rice ecosystem, observations of natural enemy population in each treatment were recorded at fortnight intervals by counting the number of natural enemies collected in 10 sweeps.

3.1.3 Pest: Defender ratio

Total number of pests and natural enemies *viz.*, predators and parasitoids were recorded at fortnightly intervals between 30 and 90 DAT and the Pest: Defender ratio worked out using formula:

$$\text{Pest: Defender ratio} = \frac{\text{Number of pests in each plot}}{\text{Number of natural enemies in each plot}}$$

3.1.4 Assessment of Population of Earthworms, Nematodes and Soil arthropods

Number of earthworms, free living and saprophytic nematodes and soil arthropods were recorded at 50 and 70 DAT.

3.1.4.1 Count of Earthworm

One cubic feet area was randomly selected from each plot and after clearing the surface plant and weeds the earthworms present in that area was counted individually.

3.1.4.2 Extraction of Nematodes

Soil samples were collected from three randomly selected spots in each treatment from which representative samples of 250 cc was taken for nematode extraction. Nematodes were extracted by following the method of Cobb's sieving and decanting technique modified by Christie and Perry (1951) followed by modified Bearmanns funnel method. Nematodes were extracted from the nematode suspension in the dish was made up to 100 mL and an aliquot of 5 mL was pipetted out into a counting dish and the nematodes present in the aliquot were counted under a zoom stereo binocular microscope. This process was repeated for 3 times and the average of three counts were taken and multiplied with 20 gave the nematode population in 100 mL of aliquot representing soil sample of 250 cc.

3.1.4.3 Count of Soil Arthropods

One square feet area was randomly selected from each plot and after clearing the surface plant and weeds the soil arthropods present in that area was counted individually.

The method of count of earthworms, soil arthropods and extraction of nematodes is given in Plate 2.

3.1.5 Yield

Grain yield as well as straw yield was recorded plot-wise from each treatment after harvesting of the crop.

3.1.6 Statistical Analysis:

The data were analyzed statistically using appropriate arc-sine and square root transformation wherever necessary. Standard statistical procedure was followed as per Gomez and Gomez (1984).

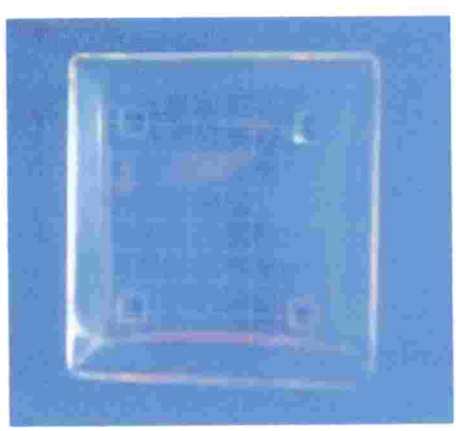
3.2 ESTIMATION OF PESTICIDE RESIDUE IN SOIL AND WATER

3.2.1 Dissipation Studies of New Generation Granular Insecticides in Soil and Water

Soil and water samples from the selected treatments along with control were taken at 0, 1, 3, 5, 7, 10, 15 and 30 days after second application of insecticides. Soil and water samples from the experiment field were collected and carried to Pesticide Residue Research and Analytical Laboratory, College of Agriculture, Vellayani for further processing and estimation of residues.

a. Earthworms and Soil arthropods

b. Extraction of nematodes



c. Counting dish

Plate 2. Counting of soil fauna

Sampling

Soil samples were collected by using a soil auger at depth of 0-15 cm. The soil auger was washed before each sample collection to avoid any cross contamination. Each soil sample was a composite of four sub samples collected at each treatment replication by random sampling from which representative sample of 500 g was drawn by following quartering method. Soil sample was processed by adopting the method suggested by Asensio- Ramos *et al.*, 2010.

Water sample from each replication collected in 2 litre water bottles separately and labelled.

3.2.1. Extraction of Pesticide Residue from Soil

Samples were dried and sieved through 2 mm sieve. Ten gram soil sample was transferred to a 50 mL polypropylene tube to which 20 mL acetonitrile, 4 g magnesium sulphate ($MgSO_4$ - activated) and 1 g sodium chloride (NaCl) were added and shaken vigorously for one minute. The contents were centrifuged at 3300 rpm (rotation per minute) for 4 min. and 10 mL of supernatant was transferred to another 15 mL polypropylene centrifuge containing 1.50 g of $MgSO_4$ and 0.25 g of primary secondary amine (PSA) and the contents were shaken for 30 sec. and then centrifuged for 10 min. at 4400 rpm from which 4 mL aliquot of the supernatant was taken and evaporated to dryness using Turbovap at 40 °C. The dry residue was re-dissolved in 1 mL of methanol for LC analysis.

Calculation

Pesticide residue (mg kg^{-1}) = Concentration obtained from chromatogram by using calibration curve × Dilution factor

$$\text{Dilution factor} = \frac{\text{Volume of the solvent added} \times \text{Final volume of extract}}{\text{Weight of sample} \times \text{Volume of extract taken for concentration}}$$

3.2.2. Extraction of Pesticide Residue from Water

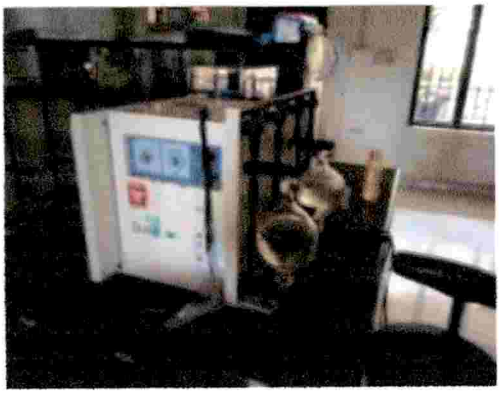
750 mL of representative water sample was taken from 2 litre sample and taken in 1 litre separating funnel to which 150 g of sodium chloride was added and shaken till it dissolved completely. The residues were extracted thrice with dichloromethane (DCM 80 mL) each time shaking vigorously on the mechanical shaker at 250 rpm for 5 min. Organic layer was formed, lower organic layer collected by passing through 5 g anhydrous sodium sulphate (activated) which supported on washed glass wool in a 4 inch filter funnel. The organic layer was combined and concentrated to 0.5 mL using rotary vacuum evaporator. Concentration step was repeated thrice in presence of n-Hexane to remove all traces of DCM. Final volume of the dry residue extract was made up to 1 mL using methanol for LC analysis.

Calculation

Pesticide residue ($\mu g\ L^{-1}$) = Concentration obtained from chromatogram by using calibration curve × Dilution factor

$$\text{Dilution factor} = \frac{\text{Volume of the solvent added} \times \text{Final volume of extract}}{\text{Weight of sample} \times \text{Volume of extract taken for concentration}}$$

The instruments used for extraction of soil and water samples are given in Plate 3.



a. Mechanical shaker

b. Rotary vacuum flash evaporator

c. Centrifuge

d. Turbovap

Plate 3. Instruments used for extraction of soil and water samples

RESULTS

4. RESULTS

The field experiment was carried out in the paddy fields of Integrated Farming System Research Station (IFSRS), Karamana during the first crop season of June 2017 and the results of the research work entitled "Impact of new generation granular insecticides on beneficial fauna of paddy ecosystem" are presented here.

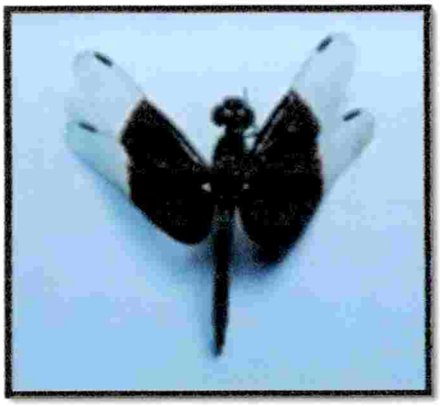
The arthropod community of rice fields of IFSRS, Karamana comprised of rice pests, natural enemies, neutrals and beneficial soil fauna. The arthropods documented during the present study are listed here;

Major pests recorded in the control plot were rice stem borer (*S. incertulas*), leaf folder (*C. medinalis*) and rice bug (*L. acuta*) other minor pests recorded include short horned grasshopper (*Oxya chinensis* Thunberg) and green leaf hoppers (*Nephotettix* spp.) Very low population of the pests *viz.*, red spotted ear bug (*Menida histrio* Fabricius), striped bug (*Tetroda histeroides* Fabricus), rice white leaf hopper (*Cofana spectra* Distant), whorl maggots (*Hydrellia philippina* Ferino), rice black bug (*Scotinophara* sp.), rice hispa (*Dicladispa armigera* Olivier), brown plant hopper (*N. lugens*), white backed plant hopper (*Sogatella furcifera* Horvath), paddy blue beetle (*Leptispa pygmaea* Baly), flea beetle (*Monolepta signata* Oliv) were also present.

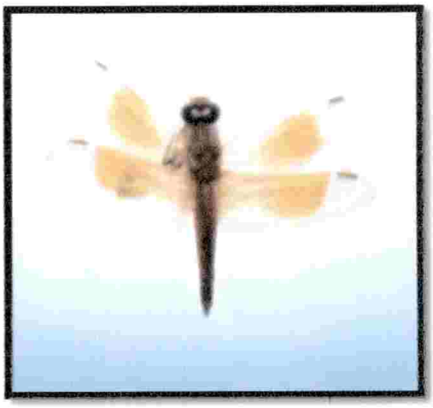
Among natural enemies major predators observed were damselflies, dragonflies, ground beetle (*Ophionea nigrofasciata* Schmidt and Goebel), coccinellids (*Coccinella transversalis* Fabricius and *Micraspis discolour* Fabricius), spiders (*Tetragnatha* sp., *Lycosa* sp. and *Oxyopes* sp.), rove beetle (*Paederus fuscipes* Curtis), long horned grasshopper (*Conocephalus longipennis* de Haan), field crickets (*Metioche vittaticollis* Stal), reduvid bug and syrphids (Plates 4 to 6). Parasitoids *viz.*, *Stenobracon* sp., *Xanthopimpla flavoleneata* Cameron, *Cotesia flavipes* Cameron, *Charops brachypterum* Cameron,

a. Damselfly

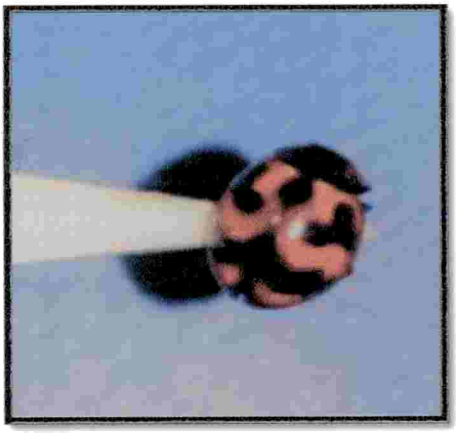
b. Dragonfly



c. Dragonfly



d. Dragonfly



e. Coccinella transversalis

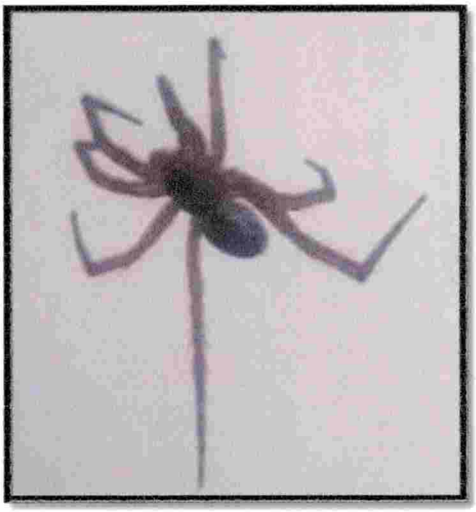
f. *Micraspis discolor*

Plate 4. Predators present in the rice ecosystem

a. *Tetragnatha* sp.

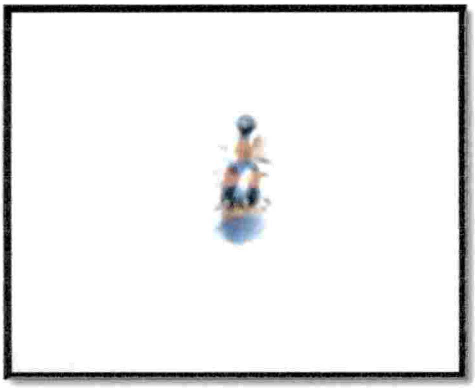
b. *Oxyopes* sp.

c. *Oxyopes* sp.



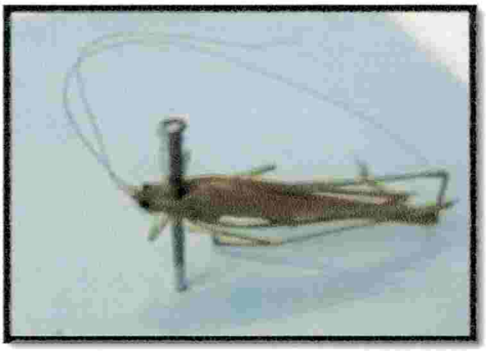
d. *Lycosa* sp.

Plate 5. Spiders present in the rice ecosystem



a. *Ophionea nigrofasciata*

b. *Paederus fuscipes*



c. *Conocephalus longipennis*

d. Reduviid

e. Syrphid

Plate 6. Minor predators present in the rice ecosystem

Tetrastichus sp. and *Telenomus* sp. (Plate 7). Mainly observed neutrals were mosquitoes, house fly and midges.

The soil fauna observed were earthworms, nematodes, snails and soil arthropods *viz.*, spiders, ground beetle, ant and water scavenger (Plates 8 and 9).

4.1 EFFECT OF NEW GENERATION GRANULAR INSECTICIDES ON DAMAGE/POPULATION OF MAJOR PESTS OF PADDY ECOSYSTEM AT DIFFERENT GROWTH STAGES OF THE CROP

Results presented include the data recorded at fortnightly intervals after the two applications of new generation granular insecticides at 15 and 30 days after transplanting (DAT).

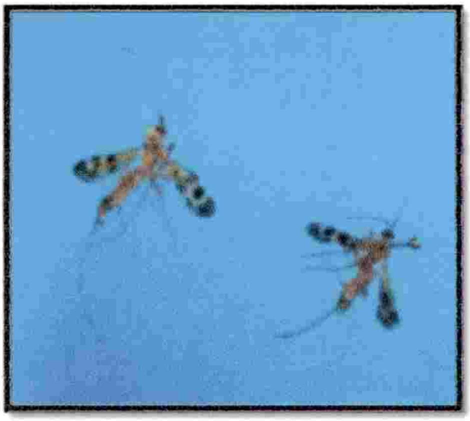
4.1.1 Effect of New Generation Granular Insecticides on Incidence of Stem Borer at Different Growth Stages of the Crop

4.1.1.1 Dead Heart Incidence at 30, 45, 60 and 75 DAT

The mean per cent of dead heart incidence observed at different intervals is given in Table 3.

At 30 DAT, significant reduction in dead heart symptom was observed in all the treatments compared to control. However the lowest incidence was observed in the treatment with fipronil 0.3 G 10 kg ha^{-1} (1.06 per cent) which was on par with fipronil 0.3 G 20 kg ha^{-1} (1.20 per cent) and both these were significantly superior over other treatments. The highest incidence was observed in untreated control with 11.18 per cent damage. The other treatments *viz.,* cartap hydrochloride 4 G 25 kg ha^{-1} (3.96 per cent), cartap hydrochloride 4 G 50 kg ha^{-1} (3.83 per cent), chlorantraniliprole 0.4 G 20 kg ha^{-1} (5.47 per cent) and chlorantraniliprole 0.4 G 10 kg ha^{-1} (6.20 per cent) were on par.

At 45 DAT, the lowest per cent incidence of dead heart was recorded in the treatment with fipronil 0.3 G 10 kg ha^{-1} (1.63 per cent) which was significantly superior over control and on par with fipronil 0.3 G 20 kg ha^{-1} (1.73 per cent). The

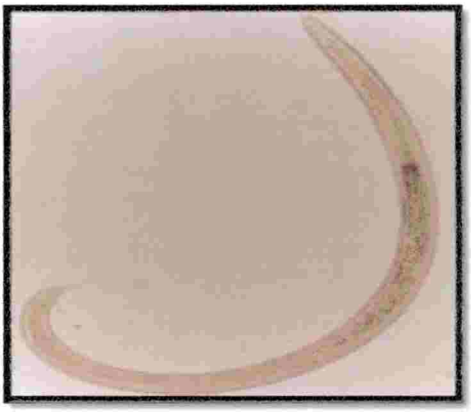


a. *Stenobracon* sp.

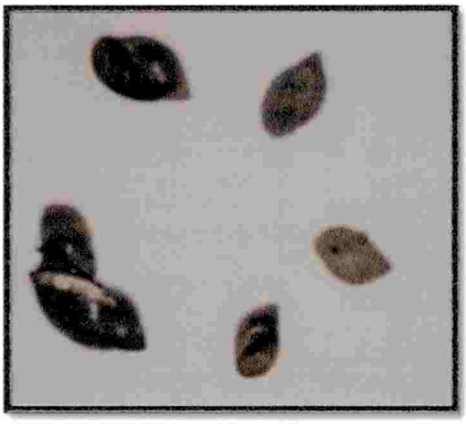
b. *Tetrastichus* sp.

Plate 7. Parasitoids present in the rice ecosystem

a. Earthworms



b. Nematodes



c. Snails

Plate 8. Soil fauna present in the rice ecosystem

a. Ground beetle

b. Ant

c. Water scavenger

d. Spider

Plate 9. Soil arthropods present in the rice ecosystem

highest incidence was observed in untreated control with 11.70 per cent dead heart. The treatments *viz.,* cartap hydrochloride 4 G 50 kg ha^{-1}, chlorantraniliprole 0.4 G 10 kg ha^{-1} and 20 kg ha^{-1} with per cent incidence of 6.40, 7.45 and 6.67 respectively were on par with control.

At 60 DAT, significant reduction in dead heart symptom was recorded by all the treatments when compared to control (10.96 per cent). However the lowest incidence of 2.33 per cent was recorded by the treatment Fipronil 0.3 G 10 kg ha^{-1} which was on par with all the other treatments *viz.,* fipronil 0.3 G 20 kg ha^{-1}, chlorantraniliprole 0.4 G 20 kg ha^{-1}, cartap hydrochloride 4 G 25 kg ha^{-1}, cartap hydrochloride 4 G 50 kg ha^{-1} and chlorantraniliprole 0.4 G 10 kg ha^{-1} with per cent dead heart incidence of 2.80, 3.73, 3.80, 4.17 and 4.44 respectively.

No significant reduction of dead heart incidence was recorded in any of the treatments including untreated control at 75 DAT. However the lowest incidence of 2.33 per cent was recorded in the treatment fipronil 0.3 G 10 kg ha^{-1} and the highest being 4.60 per cent recorded in control.

4.1.1.2 White Ear Head Incidence at 90 DAT

The mean per cent white ear head incidence observed at 90 DAT is given in Table 3.

At 90 DAT, fipronil 0.3 G 20 kg ha^{-1} recorded significantly low incidence of white ear head with a per cent incidence of 4.07 compared to control. This was on par with the treatments fipronil 0.3 G 10 kg ha^{-1}, cartap hydrochloride 4 G 50 kg ha^{-1} and cartap hydrochloride 4 G 25 kg ha^{-1} with per cent incidence of 5.63, 6.40 and 7.00 respectively. The treatments chlorantraniliprole 0.4 G 10 kg ha^{-1} and 20 kg ha^{-1} with mean per cent incidence of 9.23 and 8.93 respectively were on par with control (12.41 per cent).

Table 3. Damage by stem borer at different intervals after treatment with new generation granular insecticides in rice

Treatments	Mean per cent damage by stem borer 10 hills^{-1}				
	Dead heart (%)				White ear head (%)
	30 DAT	45 DAT	60 DAT	75 DAT	90 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	6.20^{b} (14.16)	7.45^{ab} (15.82)	4.44^{b} (11.96)	3.72 (10.84)	9.23^{ab} (17.67)
Fipronil 0.3 G 10 kg ha^{-1}	1.06^{c} (5.13)	1.63^{c} (6.24)	2.33^{b} (8.75)	2.33 (8.75)	5.63^{bc} (13.43)
Cartap hydrochloride 4 G 25 kg ha^{-1}	3.96^{b} (11.38)	6.03^{b} (14.11)	3.80^{b} (11.14)	4.62 (11.99)	7.00^{bc} (15.29)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	5.47^{b} (13.25)	6.67^{ab} (14.92)	3.73^{b} (11.11)	4.01 (11.49)	8.93^{ab} (17.37)
Fipronil 0.3 G 20 kg ha^{-1}	1.20^{c} (6.01)	1.73^{c} (6.31)	2.80^{b} (9.54)	2.79 (9.60)	4.07^{c} (11.37)
Cartap hydrochloride 4 G 50 kg ha^{-1}	3.83^{b} (11.23)	6.40^{ab} (14.62)	4.17^{b} (11.65)	4.13 (11.53)	6.40^{bc} (14.48)
Untreated Control	11.18^{a} (19.52)	11.70^{a} (19.99)	10.96^{a} (19.23)	4.60 (11.68)	12.41^{a} (20.46)
C D (0.05)	(4.851)	(5.464)	(3.463)	NS	(4.833)

Figures in parenthesis are Arc sin transformed values, DAT: Days after transplanting

58

4.1.2 Effect of New Generation Granular Insecticides on Leaf Roller Incidence at Different Growth Stages of the Crop

The attack by leaf roller observed at different intervals after two applications of new generation granular insecticides at 15 and 30 DAT is given in Table 4.

4.1.2.1 Leaf Roller Damage at 30, 45, 60 and 75 DAT

No significant reduction in damage by leaf roller was noticed in any of the treatments at 30 and 60 DAT.

At 30 DAT, the lowest damage was observed in the treatment chlorantraniliprole 0.4 G 10 kg ha^{-1} (0.52 per cent) followed by chlorantraniliprole 0.4 G 20 kg ha^{-1} (0.63 per cent), fipronil 0.3 G 20 kg ha^{-1} (1.23 per cent), fipronil 0.3 G 10 kg ha^{-1} (1.32 per cent), cartap hydrochloride 4 G 50 kg ha^{-1} (1.77 per cent) and cartap hydrochloride 4 G 25 kg ha^{-1} (1.93 per cent).

At 45 DAT, when compared to control, significant reduction in damage by leaf roller was observed in the treatment chlorantraniliprole 0.4 G 20 kg ha^{-1} and 10 kg ha^{-1} with per cent damage of 0.17 and 0.21 per cent respectively. The highest leaf damage was observed in untreated control with 1.99 per cent and was on par with the treatment fipronil 0.3 G 10 kg ha^{-1} (1.22 per cent). The remaining treatments *viz.,* fipronil 0.3 G 20 kg ha^{-1} (0.90 per cent), cartap hydrochloride 4 G 50 kg ha^{-1} (0.94 per cent) and cartap hydrochloride 4 G 25 kg ha^{-1} (1.05 per cent) were on par.

At 60 DAT, No significant reduction in damage by leaf roller was observed among the treatments. The lowest mean per cent damage was recorded in fipronil 0.3 G 20 kg ha^{-1} (0.80 per cent) followed by fipronil 0.3 G 10 kg ha^{-1} (1.19 per cent), chlorantraniliprole 0.4 G 20 kg ha^{-1} (1.39 per cent), cartap hydrochloride 4 G 50 kg ha^{-1} (1.50 per cent), cartap hydrochloride 4 G 25 kg ha^{-1} (1.57 per cent) and chlorantraniliprole 0.4 G 10 kg ha^{-1} (1.62 per cent). The highest damage was recorded by untreated control (2.84 per cent).

Table 4. Damage by leaf roller at different intervals after treatment with new generation granular insecticides in rice

Treatments	Mean per cent damage 10 hills^{-1}			
	30 DAT	45 DAT	60 DAT	75 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	0.52 (3.72)	0.21^{c} (2.64)	1.62 (7.13)	2.00 (8.12)
Fipronil 0.3 G 10 kg ha^{-1}	1.32 (6.12)	1.22^{ab} (6.14)	1.19 (6.15)	0.90 (5.35)
Cartap hydrochloride 4 G 25 kg ha^{-1}	1.93 (7.98)	1.05^{b} (5.88)	1.57 (7.09)	1.90 (7.92)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	0.63 (4.20)	0.17^{c} (2.21)	1.39 (6.71)	1.85 (7.81)
Fipronil 0.3 G 20 kg ha^{-1}	1.23 (6.30)	0.90^{b} (5.30)	0.80 (5.05)	0.93 (5.54)
Cartap hydrochloride 4 G 50 kg ha^{-1}	1.77 (7.63)	0.94^{b} (5.56)	1.50 (6.90)	1.67 (7.37)
Untreated Control	2.27 (8.57)	1.99^{a} (8.03)	2.84 (9.29)	3.06 (9.56)
C D (0.05)	NS	(2.079)	NS	NS

Figures in parenthesis are Arc sin transformed values, DAT: Days after transplanting

Similar trend was observed at 70 DAT also. There was no significant reduction in leaf roller damage among various treatments. However the lowest mean per cent damage was recorded in the treatment fipronil 0.3 G 10 kg ha^{-1} (0.90 per cent) followed by fipronil 0.3 G 20 kg ha^{-1} (0.93 per cent), cartap hydrochloride 4 G 50 kg ha^{-1} (1.67 per cent), chlorantraniliprole 0.4 G 20 kg ha^{-1} (1.85 per cent), cartap hydrochloride 4 G 25 kg ha^{-1} (1.90 per cent) and chlorantraniliprole 0.4 G 10 kg ha^{-1} (2.00 per cent). Control recorded the highest incidence of 3.06 per cent.

4.1.3 Effect of New Generation Granular Insecticides on Population of Major Pests at Different Growth Stages of the Crop

The adult pest population was recorded by counting them in 10 sweeps collected from each plot at fortnightly intervals after the second application of treatment at 30 DAT and the data presented in Tables 5 to 9. The different pests observed were stem borer, leaf roller, grass hopper, green leaf hopper, whorl maggot and rice bug.

4.1.3.1 Stem Borer

The population of adult stem borer was recorded by counting the number in 10 sweeps. The result is presented in Table 5.

At 30 DAT, no significant difference in population of adult stem borer was observed between treatments including control. However, the lowest mean population of 1.33 was recorded by the treatments cartap hydrochloride 4 G 50 kg ha^{-1} and chlorantraniliprole 0.4 G 10 kg ha^{-1} and 20 kg ha^{-1}. This was followed by cartap hydrochloride 4 G 25 kg ha^{-1} and fipronil 0.3 G 20 kg ha^{-1} with mean population of 1.67. Control and the treatment fipronil 0.3 G 10 kg ha^{-1} recorded the highest population of stem borer (2.67).

At 45 DAT also, no significant difference in population of adult stem borer was observed between treatments including control. Stem borer was not observed in treatment chlorantraniliprole 0.4 G 20 kg ha^{-1}. The highest number of stem

Table 5. Population of adult stem borer at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of adult stem borer 10 sweeps^{-1}			
	30 DAT	45 DAT	60 DAT	75 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	1.33 (1.13)	0.33 (0.88)	0.33 (0.88)	0.67 (1.05)
Fipronil 0.3 G 10 kg ha^{-1}	2.67 (1.55)	1.00 (1.09)	0.67 (1.05)	0.67 (1.05)
Cartap hydrochloride 4 G 25 kg ha^{-1}	1.67 (1.27)	0.33 (0.88)	0.33 (0.88)	0.33 (0.88)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	1.33 (1.13)	0.00 (0.70)	0.67 (1.05)	0.33 (0.88)
Fipronil 0.3 G 20 kg ha^{-1}	1.67 (1.13)	1.00 (1.18)	0.67 (0.99)	0.67 (1.05)
Cartap hydrochloride 4 G 50 kg ha^{-1}	1.33 (1.13)	1.00 (1.18)	0.67 (1.05)	0.33 (0.88)
Untreated Control	2.67 (1.60)	1.67 (1.46)	1.67 (1.46)	1.67 (1.46)
C D (0.05)	NS	NS	NS	NS

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

borer was observed in untreated control with a mean population of 1.67 followed by fipronil 0.3 G 10 kg ha^{-1} (1.00), fipronil 0.3 G 20 kg ha^{-1} (1.00), cartap hydrochloride 4 G 50 kg ha^{-1} (1.00), chlorantraniliprole 0.4 G 10 kg ha^{-1} (0.33) and cartap hydrochloride 4 G 25 kg ha^{-1} (0.33).

Similar trend was observed at 60 DAT also. The lowest mean population of 0.33 was recorded by the treatments chlorantraniliprole 0.4 G 10 kg ha^{-1} and cartap hydrochloride 4 G 25 kg ha^{-1}. This was followed by all other treatments *viz.,* chlorantraniliprole 0.4 G 20 kg ha^{-1}, fipronil 0.3 G 10 kg ha^{-1}, fipronil 0.3 G 20 kg ha^{-1} and cartap hydrochloride 4 G 50 kg ha^{-1} with mean population of 0.67. The highest mean population of 1.67 was recorded in untreated control.

At 75 DAT, also there was no significant difference between the treatments including control. The lowest mean population of 0.33 was recorded by the treatments chlorantraniliprole 0.4 G 20 kg ha^{-1} and cartap hydrochloride 4 G 25 kg ha^{-1} and 50 kg ha^{-1}. This was followed by the treatments chlorantraniliprole 0.4 G 10 kg ha^{-1}, fipronil 0.3 G 10 kg ha^{-1} and fipronil 0.3 G 20 kg ha^{-1} with a mean population of 0.67. The highest mean population of 1.67 was observed in untreated control.

4.1.3.2 Leaf Roller

The population of adult leaf roller was recorded by counting the number in 10 sweeps. The result is presented in Table 6.

At 30 DAT, significant reduction in population of adult leaf roller was observed in all the treatments compared to control. The lowest mean population of 0.67 was observed in treatments chlorantraniliprole 0.4 G 20 kg ha^{-1} and cartap hydrochloride 4 G 50 kg ha^{-1} and these treatments were on par with all other treatments *viz.,* fipronil 0.3 G 20 kg ha^{-1} (1.00), chlorantraniliprole 0.4 G 10 kg ha^{-1} (1.33), cartap hydrochloride 4 G 25 kg ha^{-1} (1.33) and fipronil 0.3 G 10 kg ha^{-1} (1.67). The highest mean population of 3.00 was observed in untreated control.

Table 6. Population of adult leaf roller at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of adult leaf roller 10 sweeps^{-1}			
	30 DAT	45 DAT	60 DAT	75 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	1.33^{b} (1.35)	1.00 (1.23)	0.33 (0.88)	0.00^{b} (0.70)
Fipronil 0.3 G 10 kg ha^{-1}	1.67^{b} (1.44)	1.33 (1.27)	1.00 (1.18)	0.33^{b} (0.88)
Cartap hydrochloride 4 G 25 kg ha^{-1}	1.33^{b} (1.29)	0.67 (1.05)	0.33 (0.88)	0.33^{b} (0.88)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	0.67^{b} (1.05)	0.67 (1.05)	0.33 (0.88)	0.00^{b} (0.70)
Fipronil 0.3 G 20 kg ha^{-1}	1.00^{b} (1.23)	1.00 (1.18)	1.00 (1.23)	0.00^{b} (0.70)
Cartap hydrochloride 4 G 50 kg ha^{-1}	0.67^{b} (1.05)	1.00 (1.23)	0.67 (0.99)	0.67^{b} (1.05)
Untreated Control	3.00^{a} (1.89)	2.33 (1.68)	2.00 (1.58)	2.33^{a} (1.68)
C D (0.05)	(0.424)	NS	NS	(0.386)

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

At 45 DAT, no significant difference in population of adult leaf roller was observed among treatments. However the lowest mean population of 0.67 was observed in the treatments cartap hydrochloride 4 G 25 kg ha^{-1} and chlorantraniliprole 0.4 G 20 kg ha^{-1}. The highest mean population of 2.33 was observed in untreated control followed by fipronil 0.3 G 10 kg ha^{-1} (1.33), chlorantraniliprole 0.4 G 10 kg ha^{-1} (1.00), fipronil 0.3 G 20 kg ha^{-1} (1.00) and cartap hydrochloride 4 G 50 kg ha^{-1} (1.00).

Similar trend was observed in 60 DAT also. There was no significant difference in population of adult leaf roller. The lowest mean population of 0.33 was observed in treatments chlorantraniliprole 0.4 G 10 kg ha^{-1}, cartap hydrochloride 4 G 25 kg ha^{-1} and chlorantraniliprole 0.4 G 20 kg ha^{-1}. The highest mean population of adult leaf roller was observed in control (2.00) followed by fipronil 0.3 G 10 kg ha^{-1} and 20 kg ha^{-1} with a mean population of 1.00.

At 75 DAT, significant reduction in population of adult leaf roller was observed in all the treatments over control. Cent per cent reduction in population was observed in the treatments *viz.,* chlorantraniliprole 0.4 G 10 kg ha^{-1} and 20 kg ha^{-1} and fipronil 0.3 G 20 kg ha^{-1}. These treatments were on par with all other treatments *viz.,* fipronil 0.3 G 10 kg ha^{-1} (0.33), cartap hydrochloride 4 G 25 kg ha^{-1} (0.33) and cartap hydrochloride 4 G 50 k g ha^{-1} (0.67).

4.1.3.3 Rice Bug

The population of rice bug was recorded by counting the number of adults and nymphs in 10 sweeps. The result is presented in Table 7.

At 75 DAT, no significant difference in population of rice bug was observed among treatments. However the lowest mean population of 10.33 was recorded in fipronil 0.3 G 20 kg ha^{-1}. This was followed by cartap hydrochloride 4 G 25 kg ha^{-1} (10.67), chlorantraniliprole 0.4 G 20 kg ha^{-1} (10.67), fipronil 0.3 G 10 kg ha^{-1} (11.00), cartap hydrochloride 4 G 50 kg ha^{-1} (11.67) and chlorantraniliprole 0.4 G

Table 7. Population of rice bug at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of rice bugs 10 sweeps^{-1}	
	75 DAT	90 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	12.67 (3.56)	7.33^{bc} (2.71)
Fipronil 0.3 G 10 kg ha^{-1}	11.00 (3.29)	8.33^{b} (2.89)
Cartap hydrochloride 4 G 25 kg ha^{-1}	10.67 (3.27)	6.33^{cde} (2.52)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	10.67 (3.27)	5.33^{e} (2.30)
Fipronil 0.3 G 20 kg ha^{-1}	10.33 (3.18)	7.00^{bcd} (2.64)
Cartap hydrochloride 4 G 50 kg ha^{-1}	11.67 (3.42)	5.67^{de} (2.37)
Untreated Control	15.00 (3.86)	13.33^{a} (3.65)
C D (0.05)	NS	(0.300)

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

10 kg ha^{-1} (12.67). The highest mean population of 15.00 was observed in untreated control.

Significant reduction in population of rice bugs over control was observed in all the treatments at 90 DAT. The lowest mean population of 5.33 was observed in the treatment chlorantraniliprole 0.4 G 20 kg ha^{-1} and this was on par with cartap hydrochloride 4 G 50 kg ha^{-1} and cartap hydrochloride 4 G 25 kg ha^{-1} with mean population of 5.67 and 6.33 respectively. The highest mean population of 13.33 was observed in control followed by fipronil 0.3 G 10 kg ha^{-1} (8.33), chlorantraniliprole 0.4 G 10 kg ha^{-1} (7.33) and fipronil 0.3 G 20 kg ha^{-1} (7.00).

4.1.3.4 Grasshopper

The population of grasshopper was recorded by counting the number in 10 sweeps. The result is presented in Table 8.

At 30 DAT, significant reduction in population of grasshopper over control was observed in all the treatments. The lowest mean population of 2.00 was observed in the treatment fipronil 0.3 G 20 kg ha^{-1} and was on par with fipronil 0.3 G 10 kg ha^{-1} (2.67). A mean population of 4.00 was observed in the treatment cartap hydrochloride 4 G 50 kg ha^{-1} and this was on par with cartap hydrochloride 4 G 25 kg ha^{-1} (4.67), chlorantraniliprole 0.4 G 10 kg ha^{-1} (5.33) and chlorantraniliprole 0.4 G 20 kg ha^{-1} (5.34). The highest population was observed in untreated control (9.67).

At 45 DAT also, all the treatments recorded significant reduction in population of grass hopper compared to control (10.67). The lowest mean population of 3.34 was observed in the treatment fipronil 0.3 G 20 kg ha^{-1} and was on par with fipronil 0.3 G 10 kg ha^{-1} (3.67). All the other treatments *viz.*, chlorantraniliprole 0.4 G 20 kg ha^{-1} (5.00), cartap hydrochloride 4 G 25 kg ha^{-1} (5.34), cartap hydrochloride 4 G 50 kg ha^{-1} (5.67) and chlorantraniliprole 0.4 G 10 kg ha^{-1} (6.00) were on par.

Table 8. Population of grasshoppers at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of grass hoppers 10 sweeps^{-1}			
	30 DAT	45 DAT	60 DAT	75 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	5.33^{b} (2.30)	6.00^{b} (2.45)	6.67^{b} (2.58)	4.00^{b} (1.98)
Fipronil 0.3 G 10 kg ha^{-1}	2.67^{c} (1.62)	3.67^{c} (1.92)	4.67^{d} (2.15)	1.34^{d} (1.13)
Cartap hydrochloride 4 G 25 kg ha^{-1}	4.67^{b} (2.15)	5.34^{b} (2.30)	6.00^{bc} (2.45)	3.67^{b} (1.92)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	5.34^{b} (2.30)	5.00^{b} (2.23)	6.34^{bc} (2.52)	4.34^{b} (2.08)
Fipronil 0.3 G 20 kg ha^{-1}	2.00^{c} (1.38)	3.34^{c} (1.82)	4.00^{d} (2.00)	1.34^{d} (1.13)
Cartap hydrochloride 4 G 50 kg ha^{-1}	4.00^{b} (2.00)	5.67^{b} (2.37)	5.00^{c} (2.37)	2.34^{c} (1.52)
Untreated Control	9.67^{a} (3.10)	10.67^{a} (3.27)	9.34^{a} (3.05)	8.00^{a} (2.83)
C D (0.05)	(0.337)	(0.266)	(0.187)	(0.372)

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

At 60 DAT, all the treatments recorded significant reduction in the grasshopper population over untreated control. The lowest mean population was recorded in fipronil 0.3 G 20 kg ha^{-1} (4.00) which was on par with fipronil 0.3 G 10 kg ha^{-1} (4.67). All the other treatments *viz.,* cartap hydrochloride 4 G 50 kg ha^{-1} (5.00), cartap hydrochloride 4 G 25 kg ha^{-1} (6.00), chlorantraniliprole 0.4 G 20 kg ha^{-1} (6.34), and chlorantraniliprole 0.4 G 10 kg ha^{-1} (6.67) were on par. Control recorded a mean population of 9.34.

All the treatments significantly reduced the grasshopper population at 75 DAT over control. Treatments *viz.,* fipronil 0.3 G 20 kg ha^{-1} and 10 kg ha^{-1} recorded the lowest mean population of 1.34. All the other treatments *viz.,* cartap hydrochloride 4 G 50 kg ha^{-1} (2.34), cartap hydrochloride 4 G 25 kg ha^{-1} (3.67), chlorantraniliprole 0.4 G 10 kg ha^{-1} (4.00) and chlorantraniliprole 0.4 G 20 kg ha^{-1} (4.34) were on par. Control recorded the highest mean population of 8.00.

4.1.3.5 Green Leafhoppers (GLH)

The population of green leafhoppers was recorded by counting the number in 10 sweeps. The result is presented in Table 9.

Significant reduction in population of GLH was recorded in all the treatments compared to control at 30 DAT. The lowest population was observed in the treatment fipronil 0.3 G 20 kg ha^{-1} (1.33) which was on par with fipronil 0.3 G 10 kg ha^{-1} and chlorantraniliprole 0.4 G 20 kg ha^{-1} with a mean population of 1.66. The highest population was recorded in control (6.66) and this was on par with cartap hydrochloride 4 G 25 kg ha^{-1} (5.66).

At 45 DAT also, all the treatments reduced the population of GLH over control significantly. The lowest mean population of 2.00 was recorded in chlorantraniliprole 0.4 G 10 kg ha^{-1} and 20 kg ha^{-1}. These treatments were on par with fipronil 0.3 G 20 kg ha^{-1} (2.33) and fipronil 0.3 G 10 kg ha^{-1} (2.66). The highest population was recorded in untreated control (9.00) followed by cartap

Table 9. Population of GLH at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of GLH 10 sweeps^{-1}			
	30 DAT	45 DAT	60 DAT	75 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	2.66^{c} (1.62)	2.00^{d} (1.41)	2.66^{cd} (1.62)	1.66^{c} (1.46)
Fipronil 0.3 G 10 kg ha^{-1}	1.66^{d} (1.27)	2.66^{d} (1.62)	3.00^{cd} (1.71)	2.00^{c} (1.58)
Cartap hydrochloride 4 G 25 kg ha^{-1}	5.66^{ab} (2.37)	4.33^{c} (2.08)	4.33^{bc} (2.07)	3.00^{b} (2.04)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	1.66^{d} (1.27)	2.00^{d} (1.41)	2.00^{d} (1.38)	2.33^{c} (1.35)
Fipronil 0.3 G 20 kg ha^{-1}	1.33^{d} (1.13)	2.33^{d} (1.52)	2.33^{d} (1.47)	1.00^{c} (1.38)
Cartap hydrochloride 4 G 50 kg ha^{-1}	4.66^{b} (2.15)	6.00^{b} (2.45)	6.66^{b} (2.58)	4.00^{ab} (2.20)
Untreated Control	6.66^{a} (2.58)	9.00^{a} (2.99)	11.66^{a} (3.42)	6.33^{a} (2.62)
C D (0.05)	(0.288)	(0.270)	(0.584)	(0.435)

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

hydrochloride 4 G 50 kg ha^{-1} (6.00) and cartap hydrochloride 4 G 25 kg ha^{-1} (4.33).

Similar trend was observed at 60 DAT also. All the treatments recorded significant reduction in population of GLH over control (11.66). The lowest mean population of 2.00 was observed in chlorantraniliprole 0.4 G 20 kg ha^{-1} and found on par with chlorantraniliprole 0.4 G 10 kg ha^{-1}, fipronil 0.3 G 20 kg ha^{-1} and fipronil 0.3 G 10 kg ha^{-1} with 2.66, 2.33 and 3.00 respectively.

At 75 DAT, significant reduction in population of GLH over control was observed in all treatments. The treatment fipronil 0.3 G 20 kg ha^{-1} recorded the lowest mean population of 1.00 and was on par with chlorantraniliprole 0.4 G 10 kg ha^{-1}, fipronil 0.3 G 10 kg ha^{-1} and chlorantraniliprole 0.4 G 20 kg ha^{-1} with mean population of 1.66, 2.00 and 2.33 respectively. The highest mean population was recorded in control (6.33). The treatment cartap hydrochloride 4 G 25 kg ha^{-1} (3.00) was on par with cartap hydrochloride 4 G 50 kg ha^{-1} (4.00).

4.1.3.6 Total Pests

The mean population of total pests observed at fortnightly intervals after the second application of treatments is depicted in Table 10.

All the treatments recorded significant reduction in population of total pests in comparison with control (31.67) at 30 DAT. The treatment fipronil 0.3 G 20 kg ha^{-1} recorded the lowest population of 7.33 which was significantly lower compared to other treatments and control followed by fipronil 0.3 G 10 kg ha^{-1} (10.33). The treatments chlorantraniliprole 0.4 G 20 kg ha^{-1} (12.67) and cartap hydrochloride 4 G 50 kg ha^{-1} (13.00) were found to be on par. A mean population of 14.67 and 16.33 were observed in the treatments chlorantraniliprole 0.4 G 10 kg ha^{-1} and cartap hydrochloride 4 G 25 kg ha^{-1} respectively.

At 45 DAT, all the treatments recorded significant reduction in population of total pests compared to control (36.00). The treatment fipronil 0.3 G 20 kg ha^{-1} recorded the lowest population of 9.67 and found to be on par with fipronil 0.3 G

Table 10. Population of total pests at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of total pests 10 sweeps^{-1}			
	30 DAT	45 DAT	60 DAT	75 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	14.67^{bc} (3.83)	14.33^{c} (3.78)	16.00^{b} (3.99)	22.00^{b} (4.69)
Fipronil 0.3 G 10 kg ha^{-1}	10.33^{e} (3.20)	11.00^{de} (3.30)	12.00^{c} (3.46)	15.67^{cd} (3.92)
Cartap hydrochloride 4 G 25 kg ha^{-1}	16.33^{b} (4.04)	14.33^{c} (3.78)	15.00^{b} (3.87)	20.33^{bc} (4.50)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	12.67^{d} (3.55)	12.33^{cd} (3.51)	15.00^{b} (3.87)	19.33^{bcd} (4.38)
Fipronil 0.3 G 20 kg ha^{-1}	7.33^{f} (2.71)	9.67^{e} (3.10)	10.00^{c} (3.16)	14.00^{d} (3.71)
Cartap hydrochloride 4 G 50 kg ha^{-1}	13.00^{cd} (3.61)	16.67^{b} (4.08)	17.33^{b} (4.17)	20.33^{bc} (4.50)
Untreated Control	31.67^{a} (5.62)	36.00^{a} (5.99)	38.67^{a} (6.22)	44.00^{a} (6.63)
C D (0.05)	(0.254)	(0.291)	(0.316)	(0.683)

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

10 kg ha^{-1} (11.00). The treatments chlorantraniliprole 0.4 G 20 kg ha^{-1} (12.33), cartap hydrochloride 4 G 25 kg ha^{-1} (14.33) and chlorantraniliprole 0.4 G 10 kg ha^{-1} (14.33) were on par. Cartap hydrochloride 4 G 50 kg ha^{-1} recorded the highest population of total pests among treatments (16.67).

Similar trend was observed in the population of total pests at 60 DAT also. Significant reduction in total pest population was recorded in all treatments compared to control (38.67). The lowest population of pests was observed in the treatment fipronil 0.3 G 20 kg ha^{-1} (10.00). The highest population of total pests among treatments was recorded by cartap hydrochloride 4 G 50 kg ha^{-1} (17.33).

At 75 DAT also, significant reduction in total pest population was recorded in all the treatments compared to control (44.00). The lowest population of total pests was observed in the treatment fipronil 0.3 G 20 kg ha^{-1} (14.00) which significantly reduced the population compared to other treatments and was on par with fipronil 0.3 G 10 kg ha^{-1} (15.67) and chlorantraniliprole 0.4 G 20 kg ha^{-1} (19.33). The treatments cartap hydrochloride 4 G 50 kg ha^{-1} and 25 kg ha^{-1} recorded a mean population of 20.33 and were on par. The highest population among treatments was recorded by chlorantraniliprole 0.4 G 10 kg ha^{-1} (22.00).

4.2 EFFECT OF NEW GENERATION GRANULAR INSECTICIDES ON POPULATION OF MAJOR PREDATORS AND PARASITOIDS OF PADDY ECOSYSTEM

The population of major predators was recorded by counting the number in 10 sweeps. The results were presented in Table 11 to 14.

4.2.1 Effect of New Generation Granular Insecticides on Damselflies at Different Growth Stages of the Crop

The mean population of damselflies observed at fortnightly intervals after the second application of treatments is presented in Table 11.

At 30 DAT, all the treatments recorded significantly low population of damselflies over control (6.33). Among the treatments chlorantraniliprole 0.4 G 10 kg ha^{-1} recorded the highest mean population of 3.67 which was on par with chlorantraniliprole 0.4 G 20 kg ha^{-1} (1.95) and cartap hydrochloride 4 G 25 kg ha^{-1} (2.33). The treatment Fipronil 0.3 G 20 kg ha^{-1} recorded the lowest population of 1.00 which was on par with fipronil 0.3 G 10 kg ha^{-1} (1.67) and cartap hydrochloride 4 G 50 kg ha^{-1} (2.00).

At 45 DAT also, significant reduction in damselfly population was observed in all the treatments over control (7.67). However among the treatments the highest mean population of damselflies was recorded in the treatment chlorantraniliprole 0.4 G 10 kg ha^{-1} (3.67) which was on par with chlorantraniliprole 0.4 G 20 kg ha^{-1} (3.33). The lowest mean population of 1.33 was recorded in fipronil 0.3 G 20 kg ha^{-1} which was on par with fipronil 0.3 G 10 kg ha^{-1} (2.00). A mean population of 2.33 was observed in cartap hydrochloride 4 G 50 kg ha^{-1} which was on par with cartap hydrochloride 4 G 25 kg ha^{-1} (2.67).

The same trend was observed at 60 DAT also. All the treatments recorded significantly low population of damselflies when compared to control (9.00). Among the treatments the highest population was recorded in chlorantraniliprole 0.4 G 10 kg ha^{-1} (3.33) which was on par with chlorantraniliprole 0.4 G 20 kg ha^{-1} (3.00) and cartap hydrochloride 4 G 50 kg ha^{-1} (2.33). The lowest mean population of 2.00 was observed in treatments fipronil 0.3 G 20 kg ha^{-1}, fipronil 0.3 G 10 kg ha^{-1} and cartap hydrochloride 4 G 25 kg ha^{-1} which were on par with cartap hydrochloride 4 G 50 kg ha^{-1} (2.33) and chlorantraniliprole 0.4 G 20 kg ha^{-1} (3.00).

At 75 DAT, all the treatments except chlorantraniliprole 0.4 G 10 kg ha^{-1} (4.00) showed significant reduction in population of damselflies over control (6.00). Among the treatments chlorantraniliprole 0.4 G 10 kg ha^{-1} was found to be safe to damselflies with mean population of 4.00 and on par with control. This was on par with the treatments chlorantraniliprole 0.4 G 20 kg ha^{-1} (2.67) and

Table 11. Population of damselfly at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of damselflies 10 sweeps^{-1}			
	30 DAT	45 DAT	60 DAT	75 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	3.67^{b} (2.03)	3.67^{b} (1.92)	3.33^{b} (1.82)	4.00^{ab} (2.11)
Fipronil 0.3 G 10 kg ha^{-1}	1.67^{de} (1.46)	2.00^{de} (1.41)	2.00^{c} (1.41)	0.67^{de} (1.05)
Cartap hydrochloride 4 G 25 kg ha^{-1}	2.33^{bcd} (1.68)	2.67^{bcd} (1.62)	2.00^{c} (1.38)	2.33^{bc} (1.68)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	3.33^{bc} (1.95)	3.33^{bc} (1.82)	3.00^{bc} (1.71)	2.67^{bc} (1.76)
Fipronil 0.3 G 20 kg ha^{-1}	1.00^{e} (1.18)	1.33^{e} (1.13)	2.00^{c} (1.41)	0.33^{e} (0.88)
Cartap hydrochloride 4 G 50 kg ha^{-1}	2.00^{cde} (1.56)	2.33^{cd} (1.52)	2.33^{bc} (1.52)	1.67^{cd} (1.46)
Untreated Control	6.33^{a} (2.62)	7.67^{a} (2.77)	9.00^{a} (2.99)	6.00^{a} (2.54)
C D (0.05)	(0.450)	(0.306)	(0.394)	(0.467)

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

cartap hydrochloride 4 G 25 kg ha^{-1} (2.33). The lowest mean population of 0.33 was recorded in the treatment fipronil 0.3 G 20 kg ha^{-1} and found to be on par with fipronil 0.3 G 10 kg ha^{-1} (0.67). The mean population of 1.67 was observed in cartap hydrochloride 4 G 50 kg ha^{-1} which was on par with cartap hydrochloride 4 G 25 kg ha^{-1} (2.33) and chlorantraniliprole 0.4 G 20 kg ha^{-1} (2.67).

Fipronil 0.3 G 10 kg ha^{-1} and 20 kg ha^{-1} negatively affected the damselflies by causing significantly high reduction in mean population of damselflies at all stages of observation under study and chlorantraniliprole 0.4 G 10 and 20 kg ha^{-1} was found to be safe to damselflies.

4.2.2 Effect of New Generation Granular Insecticides on Ground Beetle (*O. nigrofasciata*) at Different Growth Stages of the Crop

The mean population of ground beetle (*O. nigrofasciata*) observed at fortnightly intervals after the second application of treatments is presented in Table 12.

At 30 DAT, all the treatments recorded significant reduction in ground beetle population over control (4.67). Among the treatments, chlorantraniliprole 0.4 G 10 kg ha^{-1} recorded the highest population of 3.33 which was on par with chlorantraniliprole 0.4 G 20 kg ha^{-1} (2.67). The lowest mean population was recorded by fipronil 0.3 G 20 kg ha^{-1} (1.00) and was on par with fipronil 0.3 G 10 kg ha^{-1} (1.33) and cartap hydrochloride 4 G 50 kg ha^{-1} (1.67). The treatments cartap hydrochloride 4 G 25 kg ha^{-1} and chlorantraniliprole 0.4 G 20 kg ha^{-1} were on par with a mean population of 2.00 and 2.67 respectively.

At 45 DAT, there was significant reduction in population of ground beetles in all the treatments compared to control (6.33). The highest population of 3.67 was recorded by the treatment chlorantraniliprole 0.4 G 10 kg ha^{-1} and found to be on par with chlorantraniliprole 0.4 G 20 kg ha^{-1} (3.33). The lowest population of 1.33 was recorded in treatments fipronil 0.3 G 20 kg ha^{-1} and 10 kg ha^{-1} which were on par with cartap hydrochloride 4 G 50 kg ha^{-1} (2.00). Cartap hydrochloride

Table 12. Population of ground beetle (*O. nigrofasciata*) at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of *O. nigrofasciata* 10 sweeps^{-1}			
	30 DAT	45 DAT	60 DAT	75 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	3.33^{b} (1.82)	3.67^{b} (1.92)	4.00^{b} (2.00)	2.33^{b} (1.68)
Fipronil 0.3 G 10 kg ha^{-1}	1.33^{de} (1.13)	1.33^{e} (1.13)	2.00^{de} (1.41)	1.33^{bc} (1.29)
Cartap hydrochloride 4 G 25 kg ha^{-1}	2.00^{cd} (1.41)	2.33^{cd} (1.52)	2.33^{cd} (1.52)	1.33^{bc} (1.35)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	2.67^{bc} (1.62)	3.33^{bc} (1.82)	3.00^{bc} (1.73)	2.00^{bc} (1.56)
Fipronil 0.3 G 20 kg ha^{-1}	1.00^{e} (1.00)	1.33^{e} (1.13)	1.33^{e} (1.13)	0.67^{c} (0.99)
Cartap hydrochloride 4 G 50 kg ha^{-1}	1.67^{de} (1.27)	2.00^{de} (1.41)	2.33^{cd} (1.52)	1.33^{bc} (1.35)
Untreated Control	4.67^{a} (2.15)	6.33^{a} (2.51)	5.67^{a} (2.36)	5.67^{a} (2.48)
C D (0.05)	(0.277)	(0.359)	(0.305)	(0.615)

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

4 G 25 kg ha^{-1} recorded a mean population of 2.33 and was on par with chlorantraniliprole 0.4 G 20 kg ha^{-1} (3.33).

Similar trend was observed at 60 DAT also. All the treatments recorded significant reduction in the population of ground beetles over control (5.67). Next to the control, a mean population of 4.00 was recorded by the treatment chlorantraniliprole 0.4 G 10 kg ha^{-1}. This was on par with chlorantraniliprole 0.4 G 20 kg ha^{-1} (3.00). Fipronil 0.3 G 20 kg ha^{-1} (1.33) recorded the lowest population of ground beetles which was on par with fipronil 0.3 G 10 kg ha^{-1} (2.00). The mean population of 2.33 was recorded in cartap hydrochloride 4 G 50 kg ha^{-1} and 25 kg ha^{-1}.

At 75 DAT also, all the treatments recorded significantly low population of ground beetles compared to control (5.67). However the lowest mean population of 0.67 was recorded by the treatment fipronil 0.3 G 20 kg ha^{-1} which was on par with fipronil 0.3 G 10 kg ha^{-1} (1.33), cartap hydrochloride 4 G 50 kg ha^{-1} (1.33), cartap hydrochloride 4 G 25 kg ha^{-1} (1.33) and chlorantraniliprole 0.4 G 20 kg ha^{-1} (2.00). Chlorantraniliprole 0.4 G 10 kg ha^{-1} (2.33) recorded the highest mean population among all the treatments.

Generally the highest reduction of ground beetles was observed in the treatment fipronil 0.3 G at both doses of application (10 and 20 kg ha^{-1}) which caused significantly high reduction in mean population of ground beetles throughout the period and chlorantraniliprole 0.4 G at both doses (10 and 20 kg ha^{-1}) was found to be safe to ground beetles

4.2.3 Effect of New Generation Granular Insecticides on Coccinellids at Different Growth Stages of the Crop

The mean population coccinellids in 10 sweeps observed at fortnightly intervals after the second application of treatments is presented in Table 13.

No significant difference in population of coccinellids was observed between the treatments and control throughout the period of observation.

Table 13. Population of coccinellids at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of coccinellids 10 sweeps^{-1}			
	30 DAT	45 DAT	60 DAT	75 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	5.00 (2.21)	5.33 (2.28)	4.67 (2.13)	4.67 (2.15)
Fipronil 0.3 G 10 kg ha^{-1}	5.00 (2.23)	4.67 (2.15)	3.67 (1.92)	4.33 (2.03)
Cartap hydrochloride 4 G 25 kg ha^{-1}	4.33 (2.07)	5.00 (2.23)	3.67 (1.86)	3.67 (1.92)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	6.00 (2.45)	5.67 (2.36)	5.00 (2.21)	5.67 (2.36)
Fipronil 0.3 G 20 kg ha^{-1}	4.67 (2.15)	5.33 (2.30)	4.67 (2.15)	3.33 (1.82)
Cartap hydrochloride 4 G 50 kg ha^{-1}	5.00 (2.21)	6.00 (2.45)	4.00 (1.98)	4.00 (1.98)
Untreated Control	5.33 (2.30)	5.00 (2.23)	4.33 (2.08)	4.67 (2.15)
C D (0.05)	NS	NS	NS	NS

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

At 30 DAT, the highest mean population of 6.00 was recorded from chlorantraniliprole 0.4 G 20 kg ha^{-1} and the lowest from cartap hydrochloride 4 G 25 kg ha^{-1} (4.33). The treatments *viz.,* fipronil 0.3 G 20 kg ha^{-1}, cartap hydrochloride 4 G 50 kg ha^{-1}, fipronil 0.3 G 10 kg ha^{-1} and chlorantraniliprole 0.4 G 10 kg ha^{-1} recorded mean population of 4.67, 5.00, 5.00 and 5.00 respectively.

At 45 DAT, the mean population of coccinellids ranged from 4.67 to 6.00. However, the highest mean population of 6.00 was recorded from cartap hydrochloride 4 G 50 kg ha^{-1}. The lowest population was recorded by fipronil 0.3 G 10 kg ha^{-1} (4.67) and the mean population of 5.00, 5.00, 5.33, 5.33 and 5.67 were recorded by control, cartap hydrochloride 4 G 25 kg ha^{-1}, chlorantraniliprole 0.4 G 10 kg ha^{-1}, fipronil 0.3 G 20 kg ha^{-1} and chlorantraniliprole 0.4 G 20 kg ha^{-1} respectively.

The mean population of coccinellids ranged between 3.67 to 5.00 at 60 DAT. The highest mean population of 5.00 was recorded by the treatment chlorantraniliprole 0.4 G 20 kg ha^{-1} and the lowest by cartap hydrochloride 4 G 25 kg ha^{-1} and fipronil 0.3 G 10 kg ha^{-1} (3.67). The mean population of 4.00, 4.33, 4.67and 4.67 were recorded by cartap hydrochloride 4 G 50 kg ha^{-1}, untreated control, fipronil 0.3 G 20 kg ha^{-1} and chlorantraniliprole 0.4 G 10 kg ha^{-1}.

At 75 DAT, chlorantraniliprole 0.4 G 20 kg ha^{-1} (5.67) recorded the highest mean population of coccinellids among the seven treatments. The lowest population was recorded by fipronil 0.3 G 20 kg ha^{-1} (3.33) followed by cartap hydrochloride 4 G 25 kg ha^{-1} (3.67), cartap hydrochloride 4 G 50 kg ha^{-1} (4.00), fipronil 0.3 G 10 kg ha^{-1} (4.33), chlorantraniliprole 0.4 G 10 kg ha^{-1} (4.67) and control (4.67).

4.2.4 Effect of New Generation Granular Insecticides on Spiders at Different Growth Stages of the Crop

The mean population of spiders in 10 sweeps recorded at fortnightly intervals after the second application of treatments is presented in Table 14.

At 30 DAT, significant reduction in spider population was recorded in all the treatments compared to control except chlorantraniliprole 0.4 G 10 kg ha^{-1} and 20 kg ha^{-1}. The highest population was recorded in control (4.33) and found to be on par with chlorantraniliprole 0.4 G at 10 kg ha^{-1} and 20 kg ha^{-1} with mean population of 4.00. The lowest mean population of 1.67 spiders was observed in fipronil 0.3 G 20 kg ha^{-1} and cartap hydrochloride 4 G 50 kg ha^{-1} and was on par with cartap hydrochloride 4 G 25 kg ha^{-1} (2.33) and fipronil 0.3 G 10 kg ha^{-1} (2.00).

At 45 DAT, there was significant difference in population of spiders between the treatments and control. The highest mean population was recorded in treatment chlorantraniliprole 0.4 G 20 kg ha^{-1} (6.67) and was statistically on par with control (6.00), chlorantraniliprole 0.4 G 10 kg ha^{-1} (6.00) and cartap hydrochloride 4 G 25 kg ha^{-1} (5.00). Fipronil 0.3 G 20 kg ha^{-1} recorded the lowest population of 1.33 and found to be on par with fipronil 0.3 G 10 kg ha^{-1} (2.00) and cartap hydrochloride 4 G 50 kg ha^{-1} (2.33).

No significant difference in population of spiders was observed between the treatments and control at both 60 and 75 DAT. The mean population ranged between 2.67 to 6.67 at 60 DAT and 2.67 to 6.00 at 75 DAT. At both 60 DAT and 75 DAT, the mean population of spiders followed similar trend by recording the highest mean population in chlorantraniliprole 0.4 G 10 kg ha^{-1} with 6.67 and 6.00 respectively followed by control (6.00 and 5.67) and chlorantraniliprole 0.4 G 20 kg ha^{-1} (5.67 and 6.00). The highest reduction in population was recorded in the treatment cartap hydrochloride 4 G 50 kg ha^{-1} (2.67 and 2.67) followed by fipronil 0.3 G 20 kg ha^{-1} (3.00 and 3.33), fipronil 0.3 G 10 kg ha^{-1} (4.00 and 3.67) and cartap hydrochloride 4 G 25 kg ha^{-1} (4.33 and 4.00) respectively at 60 and 75 DAT.

Table 14. Population of spiders at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of spiders 10 sweeps^{-1}			
	30 DAT	45 DAT	60 DAT	75 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	4.00^{a} (1.98)	6.00^{a} (2.45)	6.67 (2.66)	6.00 (2.43)
Fipronil 0.3 G 10 kg ha^{-1}	2.00^{b} (1.41)	2.00^{b} (1.38)	4.00 (2.11)	3.67 (1.90)
Cartap hydrochloride 4 G 25 kg ha^{-1}	2.33^{b} (1.52)	5.00^{a} (2.23)	4.33 (2.18)	4.00 (1.98)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	4.00^{a} (2.00)	6.67^{a} (2.58)	5.67 (2.47)	6.00 (2.45)
Fipronil 0.3 G 20 kg ha^{-1}	1.67^{b} (1.27)	1.33^{b} (1.13)	3.00 (1.73)	3.33 (1.74)
Cartap hydrochloride 4 G 50 kg ha^{-1}	1.67^{b} (1.27)	2.33^{b} (1.52)	2.67 (1.74)	2.67 (1.57)
Untreated Control	4.33^{a} (2.08)	6.00^{a} (2.45)	6.00 (2.54)	5.67 (2.37)
C D (0.05)	(0.303)	(0.440)	NS	NS

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

4.2.5 Effect of New Generation Granular Insecticides on Total Predators at Different Growth Stages of the Crop

The mean population of total predators recorded in 10 sweeps at fortnightly intervals after the second application of treatments is presented in Table 15.

At 30 DAT, there was significant reduction in total predator population in all the treatments compared to control. The highest population was recorded in control (28.67). Among the treatments, the highest reduction in population of total predators was observed in the treatment fipronil 0.3 G 20 kg ha^{-1} (12.33) which was on par with cartap hydrochloride 4 G 50 kg ha^{-1} (14.33) and fipronil 0.3 G 10 kg ha^{-1} (14.67). The mean population of 23.00 was recorded by chlorantraniliprole 0.4 G 10 kg ha^{-1} which was on par with chlorantraniliprole 0.4 G 20 kg ha^{-1} (22.00).

At 45 DAT also, significant reduction in total predator population was recorded in all the treatments over control. The highest mean population was recorded in untreated control (33.33). The lowest population was recorded in the treatment fipronil 0.3 G 20 kg ha^{-1} (11.00) and was on par with fipronil 0.3 G 10 kg ha^{-1} with mean population of 12.67. The highest population of total predators was recorded in chlorantraniliprole 0.4 G 10 kg ha^{-1} with mean population of 24.67 and was on par with chlorantraniliprole 0.4 G 20 kg ha^{-1} (23.33). Cartap hydrochloride 4 G 50 kg ha^{-1} and cartap hydrochloride 4 G 25 kg ha^{-1} recorded the mean population of 16.67 and 20.33 respectively.

AT 60 DAT, significant reduction in total predator population was observed in all the treatments when compared to untreated control (32.67). However fipronil 0.3 G 20 kg ha^{-1} recorded the lowest mean population of 14.33 which was on par with cartap hydrochloride 4 G 50 kg ha^{-1}, fipronil 0.3 G 10 kg ha^{-1} and cartap hydrochloride 4 G 25 kg ha^{-1} with mean population of 14.67 15.67 and 16.67 respectively. Among the treatments the highest mean populations of 23.33 was observed in chlorantraniliprole 0.4 G 10 kg ha^{-1} and was found to be on par with chlorantraniliprole 0.4 G 20 kg ha^{-1} (20.67).

Table 15. Population of total predators at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of total predators 10 sweeps^{-1}			
	30 DAT	45 DAT	60 DAT	75 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	23.00^{b} (4.80)	24.67^{b} (4.97)	23.33^{b} (4.81)	21.67^{b} (4.64)
Fipronil 0.3 G 10 kg ha^{-1}	14.67^{cd} (3.82)	12.67^{e} (3.53)	15.67^{cd} (3.95)	13.33^{de} (3.66)
Cartap hydrochloride 4 G 25 kg ha^{-1}	16.00^{c} (3.99)	20.33^{c} (4.50)	16.67^{cd} (4.06)	16.00^{bcd} (3.99)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	22.00^{b} (4.68)	23.33^{bc} (4.81)	20.67^{bc} (4.54)	19.67^{bc} (4.41)
Fipronil 0.3 G 20 kg ha^{-1}	12.33^{d} (3.51)	11.00^{e} (3.31)	14.33^{d} (3.77)	10.33^{e} (3.18)
Cartap hydrochloride 4 G 50 kg ha^{-1}	14.33^{cd} (3.77)	16.67^{d} (4.07)	14.67^{d} (3.82)	13.67^{cde} (3.67)
Untreated Control	28.67^{a} (5.35)	33.33^{a} (5.78)	32.67^{a} (5.72)	30.00a (5.46)
C D (0.05)	(0.392)	(0.372)	(0.659)	(0.752)

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

All the treatments showed significant reduction in total predator population at 75 DAT compared to control (30.00). The lowest population of 10.33 was observed in the treatment fipronil 0.3 G 20 kg ha^{-1} and was on par with fipronil 0.3 G 10 kg ha^{-1} (13.33) and cartap hydrochloride 4 G 50 kg ha^{-1} (13.67). The treatments cartap hydrochloride 4 G 25 kg ha^{-1} (16.00) and chlorantraniliprole 0.4 G 20 kg ha^{-1} (19.67) were found to be on par with chlorantraniliprole 0.4 G 10 kg ha^{-1} with mean population of 21.67.

4.2.6 Effect of New Generation Granular Insecticides on Total Parasitoids at Different Growth Stages of the Crop

The mean population of total parasitoids was recorded by counting the number in 10 sweeps between 30 and 90 DAT and the results presented in Table 16.

There was no significant difference in population of total parasitoids among the treatments and between the treatments and control throughout the period of observation from 30 DAT to 90 DAT.

At 30 DAT, the highest population of total parasitoids was recorded in control (4.00). However, the highest population among the treatments was recorded by chlorantraniliprole 0.4 G 10 kg ha^{-1} with a mean population of 2.00. The lowest population was observed in the treatment fipronil 0.3 G 20 kg ha^{-1} (1.00) and cartap hydrochloride 4 G 50 kg ha^{-1} (1.00) followed by fipronil 0.3 G 10 kg ha^{-1}, cartap hydrochloride 4 G 25 kg ha^{-1}, chlorantraniliprole 0.4 G 20 kg ha^{-i} with mean population of 1.34, 1.34 and 1.67 respectively.

At 45 DAT, though control recorded the highest mean population of total parasitoids, chlorantraniliprole 0.4 G 10 kg ha^{-1} (1.67) ranked first in population among the treatments. The lowest mean population of 0.67 was observed in the treatments fipronil 0.3 G 20 kg ha^{-1} and 10 kg ha^{-i}. The mean population of 1.00, 1.34 and 1.34 were observed in the treatments *viz.,* cartap hydrochloride 4 G 25 kg

Table 16. Population of parasitoids at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of parasitoids 10 sweeps^{-1}			
	30 DAT	45 DAT	60 DAT	75 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	2.00 (1.58)	1.67 (1.46)	3.00 (1.86)	2.00 (1.58)
Fipronil 0.3 G 10 kg ha^{-1}	1.34 (1.35)	0.67 (1.05)	1.67 (1.44)	1.67 (1.46)
Cartap hydrochloride 4 G 25 kg ha^{-1}	1.34 (1.27)	1.00 (1.18)	2.00 (1.58)	2.00 (1.58)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	1.67 (1.46)	1.34 (1.35)	2.34 (1.68)	1.34 (1.35)
Fipronil 0.3 G 20 kg ha^{-1}	1.00 (1.18)	0.67 (1.05)	2.00 (1.58)	1.34 (1.35)
Cartap hydrochloride 4 G 50 kg ha^{-1}	1.00 (1.18)	1.34 (1.35)	1.34 (1.29)	1.34 (1.29)
Untreated Control	4.00 (2.09)	2.34 (1.54)	3.34 (1.95)	3.34 (1.93)
C D (0.05)	NS	NS	NS	NS

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

ha^{-1}, cartap hydrochloride 4 G 50 kg ha^{-1} and chlorantraniliprole 0.4 G 20 kg ha^{-1} respectively.

At 60 DAT, the highest mean population of total parasitoids was recorded in control (3.34). Among the treatments the highest mean population of 3.00 was recorded in the treatment chlorantraniliprole 0.4 G 10 kg ha^{-1} and was followed by the treatments *viz.*, chlorantraniliprole 0.4 G 20 kg ha^{-1}, fipronil 0.3 G 20 kg ha^{-1}, cartap hydrochloride 4 G 25 kg ha^{-1}, fipronil 0.3 G 10 kg ha^{-1}, and cartap hydrochloride 4 G 50 kg ha^{-1} with mean population of 2.34, 2.00, 2.00, 1.67 and 1.34 respectively.

The highest mean population of 3.34 was recorded by control at 75 DAT. The lowest mean population of 1.34 in treatments *viz.,* fipronil 0.3 G 20 kg ha^{-1}, cartap hydrochloride 4 G 50 kg ha^{-1} and chlorantraniliprole 0.4 G 20 kg ha^{-1}. The treatment fipronil 0.3 G 10 kg ha^{-1} recorded a mean population of 1.67 and both cartap hydrochloride 4 G 25 kg ha^{-1} and chlorantraniliprole 0.4 G 10 kg ha^{-1} with a mean population of 2.00.

4.3 PEST: DEFENDER RATIO

The mean Pest: Defender ratio worked out from various treatments in the field experiment is shown in Table 17.

At 30 DAT, the P: D ratio ranged from 0.54 to 0.97. The lowest P: D ratio was recorded in chlorantraniliprole 0.4 G 20 kg ha^{-1} (0.54) followed by fipronil 0.3 G 20 kg ha^{-1} (0.55), chlorantraniliprole 0.4 G 10 kg ha^{-1} (0.59), fipronil 0.3 G 10 kg ha^{-1} (0.65). The highest ratio of 0.97 was recorded in control followed by cartap hydrochloride 4 G 25 kg ha^{-1} (0.94) and cartap hydrochloride 4 G 50 kg ha^{-1} (0.85).

The P: D ratio ranged from 0.50 to 1.01 at 45 DAT. Chlorantraniliprole 0.4 G 20 kg ha^{-1} recorded the lowest P: D ratio of 0.50 followed by chlorantraniliprole 0.4 G 10 kg ha^{-1} (0.54). The highest P: D ratio was recorded in control (1.01) followed by cartap hydrochloride 4 G 50 kg ha^{-1} (0.93), fipronil 0.3 G 20 kg ha^{-1}

Table 17. Pest: Defender ratio at intervals after treatment with new generation granular insecticides

Treatments	Pest: Defender ratio			
	30 DAT	45 DAT	60 DAT	75 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	0.59	0.54	0.61	0.93
Fipronil 0.3 G 10 kg ha^{-1}	0.65	0.82	0.69	1.04
Cartap hydrochloride 4 G 25 kg ha^{-1}	0.94	0.67	0.80	1.13
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	0.54	0.50	0.65	0.92
Fipronil 0.3 G 20 kg ha^{-1}	0.55	0.83	0.61	1.20
Cartap hydrochloride 4 G 50 kg ha^{-1}	0.85	0.93	1.08	1.36
Untreated Control	0.97	1.01	1.06	1.32

(0.83), fipronil 0.3 G 10 kg ha^{-1} (0.82) and cartap hydrochloride 4 G 25 kg ha^{-1} (0.67).

At 60 DAT, the P: D ratio ranged from 0.61 to 1.08. The lowest ratio of 0.61 was recorded in chlorantraniliprole 0.4 G 10 kg ha^{-1} followed by chlorantraniliprole 0.4 G 20 kg ha^{-1} (0.65). Cartap hydrochloride 4 G 50 kg ha^{-1} recorded the highest P: D ratio of 1.08 followed by control, cartap hydrochloride 4 G 25 kg ha^{-1}, fipronil 0.3 G 10 kg ha^{-1} and fipronil 0.3 G 20 kg ha^{-1} with P: D ratios of 1.06, 0.80, 0.69 and 0.61 respectively.

All the treatments except chlorantraniliprole 0.4 G 10 kg ha^{-1} and 20 kg ha^{-1} recorded a P: D ratio of more than 1 at 75 DAT ranging from 0.92 to 1.36. The highest P: D ratio of 1.36 was observed in cartap hydrochloride 4 G 50 kg ha^{-1} followed by control, fipronil 0.3 G 20 kg ha^{-1}, cartap hydrochloride 4 G 25 kg ha^{-1} and fipronil 0.3 G 10 kg ha^{-1} with P: D ratio of 1.32, 1.20, 1.13 and 1.04 respectively. The lowest ratio was observed in chlorantraniliprole 0.4 G 20 kg ha^{-1} (0.92) followed by chlorantraniliprole 0.4 G 10 kg ha^{-1} (0.93).

4.4 EFFECT OF NEW GENERATION GRANULAR INSECTICIDES ON EARTHWORMS, NEMATODES AND SOIL ARTHROPODS AT DIFFERENT GROWTH STAGES OF CROP

The population of earthworms and soil arthropods were recorded by counting them from the selected area of size 1 cubic feet and 1 square feet in each treatment and of nematodes from the soil samples collected from each plot after the second application of treatments (at 30 days after transplanting) at different growth stages of rice *viz.,* 50 and 70 days after transplanting and the data presented in Tables 18 to 22.

The soil fauna observed were earthworms, nematodes, snails and soil arthropods *viz.*, spiders, ground beetle, ant and water scavenger.

4.4.1 Effect of New Generation Granular Insecticides on the Population of Earthworms

The population of earthworms was recorded by counting the number of earthworms present in a selected area of size 1 cubic feet at 50 and 70 DAT. The result is presented in Table 18.

At 50 DAT, when compared to control significantly low population of earthworms were recorded in the treatments fipronil 0.3 G 20 kg ha^{-1} (1.00), cartap hydrochloride 4 G 50 kg ha^{-1} (1.33), cartap hydrochloride 4 G 25 kg ha^{-1} (1.67) and fipronil 0.3 G 10 kg ha^{-1} (2.33). The highest population of earthworms was recorded in control (9.00) which was on par with chlorantraniliprole 0.4 G 10 kg ha^{-1} and 20 kg ha^{-1} with mean population of 6.33 and 5.33 respectively.

At 70 DAT, the treatments *viz.,* fipronil 0.3 G 10 kg ha^{-1}, fipronil 0.3 G 20 kg ha^{-1} and cartap hydrochloride 4 G 50 kg ha^{-1} significantly reduced the earth worm population with a mean value of 1.00. The treatment cartap hydrochloride 4 G at 25 kg ha^{-1} (1.33) was on par with the above treatments. The highest population of earthworms was recorded in control (8.00) which was on par with chlorantraniliprole 0.4 G at 10 kg ha^{-1} and 20 kg ha^{-1} with mean population of 5.67 and 5.00 respectively.

4.4.2. Effect of New Generation Granular Insecticides on the Population of Nematodes

The mean population of free living and predatory nematodes in 250 cc soil samples at 50 and 70 DAT are given in Table 19.

4.4.2.1 Free Living Nematodes

At 50 DAT, there was significant reduction in the population of free living nematodes over control (256.67) in all the treatments except chlorantraniliprole 0.4 G at 10 kg ha^{-1} (206.67). However the lowest population was recorded in the treatment fipronil 0.3 G 20 kg ha^{-1} (26.67) which was on par with fipronil 0.3 G

Table 18. Population of earthworms at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of earthworms 1 cubic feet^{-1}	
	50 DAT	70 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	6.33a (2.60)	5.67a (2.47)
Fipronil 0.3 G 10 kg ha^{-1}	2.33bc (1.65)	1.00b (1.18)
Cartap hydrochloride 4 G 25 kg ha^{-1}	1.67c (1.38)	1.33b (1.29)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	5.33ab (2.38)	5.00a (2.34)
Fipronil 0.3 G 20 kg ha^{-1}	1.00c (1.09)	1.00b (1.18)
Cartap hydrochloride 4 G 50 kg ha^{-1}	1.33c (1.29)	1.00b (1.18)
Untreated Control	9.00a (3.08)	8.00a (2.91)
C D (0.05)	(0.916)	(0.751)

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

Table 19. Population of nematodes at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of nematodes 250 cc soil sample^{-1}			
	Free living nematodes		Predatory nematodes	
	50 DAT	70 DAT	50 DAT	70 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	206.67^{a} (14.20)	316.67^{ab} (17.69)	0.00^{b} (0.70)	30.00^{a} (5.53)
Fipronil 0.3 G 10 kg ha^{-1}	43.33^{de} (6.57)	176.67^{cd} (13.11)	0.00^{b} (0.70)	0.00^{c} (0.70)
Cartap hydrochloride 4 G 25 kg ha^{-1}	10.3.33^{bc} (9.99)	280.00^{abc} (16.43)	0.00^{b} (0.70)	0.00^{c} (0.70)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	146.67^{b} (12.00)	240.00^{bc} (15.48)	0.00^{b} (0.70)	20.00^{b} (4.43)
Fipronil 0.3 G 20 kg ha^{-1}	26.67^{e} (5.14)	86.67^{d} (9.26)	0.00^{b} (0.70)	0.00^{c} (0.70)
Cartap hydrochloride 4 G 50 kg ha^{-1}	76.67^{cd} (8.40)	150.00^{cd} (12.11)	10.00^{b} (2.31)	0.00^{c} (0.70)
Untreated Control	256.67^{a} (15.90)	410^{a} (20.07)	33.33^{a} (5.72)	36.67^{a} (6.06)
C D (0.05)	(2.048)	(4.440)	(2.162)	(1.055)

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

10 kg ha^{-1} with a mean population of 43.33. The treatments *viz.,* cartap hydrochloride 4 G at 50 kg ha^{-1} (76.67) and 25 kg ha^{-1} (103.33) were on par.

There was significant reduction in population of free living nematodes over control (410.0) in all the treatments except chlorantraniliprole 0.4 G 10 kg ha^{-1} (316.67) and cartap hydrochloride 4 G 25 kg ha^{-1} (280.00) at 70 DAT. The lowest population was recorded by fipronil 0.3 G 20 kg ha^{-1} with a mean population of 86.67. This was on par with cartap hydrochloride 4 G 50 kg ha^{-1} (150.00).

4.4.2.2 Predatory Nematodes

At 50 DAT, zero population of predatory nematodes was recorded in the treatments chlorantraniliprole 0.4 G 10 kg ha^{-1} and 20 kg ha^{-1}, fipronil 0.3 G 10 kg ha^{-1} and 20 kg ha^{-1} and cartap hydrochloride 4 G 25 kg ha^{-1}. The highest mean population of 33.33 was recorded in control. Cartap hydrochloride 4 G 50 kg ha^{-1} recorded a mean population of 10.00 and was on par with all the other treatments.

At 70 DAT also, zero population of predatory nematodes was recorded in the treatments fipronil 0.3 G 10 kg ha^{-1} and 20 kg ha^{-1}, cartap hydrochloride 4 G at 25 kg ha^{-1} and 50 kg ha^{-1}. The highest mean population of 36.67 was recorded in control and was on par with chlorantraniliprole 0.4 G at 10 kg ha^{-1} and 20 kg ha^{-1} with mean population of 30.00 and 20.00 respectively.

4.4.3 Effect of New Generation Granular Insecticides on the Population of Soil Arthropods

4.4.3.1 Spiders

The population of spiders was recorded by counting the number present in a selected area of size 1 square feet at 50 and 70 DAT. The results are presented in Table 20.

At 50 DAT, there was no significant difference in spider population between treatments and control. However, zero population was recorded in the treatment fipronil 0.3 G 10 kg ha^{-1} followed by fipronil 0.3 G 20 kg ha^{-1} (0.33),

Table 20. Population of spiders at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of spiders 1 square feet^{-1}	
	50 DAT	70 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	1.33 (1.27)	1.33 (1.29)
Fipronil 0.3 G 10 kg ha^{-1}	0.00 (0.70)	0.00 (0.70)
Cartap hydrochloride 4 G 25 kg ha^{-1}	1.00 (1.09)	1.00 (1.18)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	1.00 (1.09)	0.67 (1.05)
Fipronil 0.3 G 20 kg ha^{-1}	0.33 (0.88)	0.00 (0.70)
Cartap hydrochloride 4 G 50 kg ha^{-1}	1.67 (1.38)	1.33 (1.27)
Untreated Control	2.33 (1.56)	1.67 (1.46)
C D (0.05)	NS	NS

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

cartap hydrochloride 4 G at 25 kg ha^{-1} (1.00), chlorantraniliprole 0.4 G 10 kg ha^{-1} (1.00), chlorantraniliprole 0.4 G 10 kg ha^{-1} (1.33) and cartap hydrochloride 4 G at 25 kg ha^{-1} (1.67). The highest population of 2.33 was recorded in control.

Similar trend was observed at 70 DAT also. There was no significant difference in spider population between treatments and control. No population of spiders was recorded from the treatment fipronil 0.3 G at both the doses. The highest mean population of 1.67 was recorded in untreated control followed by 1.33 in both the treatments *viz.,* chlorantraniliprole 0.4 G 10 kg ha^{-1} and cartap hydrochloride 4 G at 50 kg ha^{-1}. Cartap hydrochloride 4 G at 25 kg ha^{-1} and chlorantraniliprole 0.4 G 20 kg ha^{-1} recorded a mean population of 1.00 and 0.67 spiders respectively.

4.4.3.2 Soil Insects

The population of soil insects was recorded by counting the number of insects present in a selected area of size 1 square feet at 50 and 70 DAT. The results are presented in Table 21.

4.4.3.2.1 Ground Beetle

At 50 DAT, there was no significant difference in ground beetle population between treatments and control. However zero population was recorded in chlorantraniliprole 0.4 G 20 kg ha^{-1}. The highest mean population of 3.33 was recorded in untreated control. A mean population of 1.33 was recorded in the treatments *viz.,* chlorantraniliprole 0.4 G 10 kg ha^{-1}, cartap hydrochloride 4 G 50 kg ha^{-1} and fipronil 0.3 G 20 kg ha^{-1}. The treatments *viz.,* cartap hydrochloride 4 G 50 kg ha^{-1} and fipronil 0.3 G 20 kg ha^{-1} recorded a mean population of 1.00.

At 70 DAT, there was significant difference between treatments and control. Zero population was recorded in the treatment cartap hydrochloride 4 G at 50 kg ha^{-1}. This was on par with all the other treatments except chlorantraniliprole 0.4 G 10 kg ha^{-1} (1.33).

Table 21. Population of soil arthropods at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of soil arthropods 1 square feet^{-1}					
	Ground beetle		Ant		Water scavenger	
	50 DAT	70 DAT	50 DAT	70 DAT	50 DAT	70 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	1.33 (1.35)	1.33^{b} (1.35)	0.67 (0.99)	1.00 (1.09)	0.00 (0.70)	1.67^{a} (1.38)
Fipronil 0.3 G 10 kg ha^{-1}	1.00 (1.18)	0.67^{bc} (1.05)	0.33 (0.88)	0.33 (0.88)	0.00 (0.70)	0.00^{b} (0.70)
Cartap hydrochloride 4 G 25 kg ha^{-1}	1.00 (1.09)	0.33^{bc} (1.05)	3.00 (1.70)	0.67 (0.99)	0.00 (0.70)	0.00^{b} (0.70)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	0.00 (0.70)	0.67^{bc} (1.05)	3.00 (1.70)	1.33 (1.18)	0.67 (0.99)	0.33^{b} (0.88)
Fipronil 0.3 G 20 kg ha^{-1}	1.33 (1.27)	0.33^{bc} (0.88)	1.67 (1.25)	0.33 (0.88)	0.00 (0.70)	0.00^{b} (0.70)
Cartap hydrochloride 4 G 50 kg ha^{-1}	1.33 (1.27)	0.00^{c} (0.70)	1.33 (1.18)	0.00 (0.70)	1.00 (1.09)	0.00^{b} (0.70)
Untreated Control	3.33 (1.95)	3.00^{a} (1.86)	3.33 (1.95)	1.33 (1.27)	0.00 (0.70)	0.00^{b} (0.70)
C D (0.05)	NS	(0.490)	NS	NS	NS	(0.448)

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

4.4.3.2.2 Ant

At 50 DAT, there was no significant difference in ant population between treatments and control. However the lowest mean population of ants (0.33) was recorded in the treatment fipronil 0.3 G 20 kg ha^{-1}. This was followed by chlorantraniliprole 0.4 G 10 kg ha^{-1}, cartap hydrochloride 4 G 50 kg ha^{-1} and fipronil 0.3 G 20 kg ha^{-1} with mean population of 0.67, 1.33 and 1.67 respectively. The highest mean population of 3.33 was recorded in untreated control.

Similar result was obtained at 70 DAT also. There was no significant difference in ant population between treatments and control. However zero population of ants was recorded in the treatment cartap hydrochloride 4 G 50 kg ha^{-1}. The highest mean population of 1.33 was recorded in untreated control and chlorantraniliprole 0.4 G at 20 kg ha^{-1} followed by chlorantraniliprole 0.4 G 10 kg ha^{-1} (1.00), cartap hydrochloride 4 G 25 kg ha^{-1} (0.67) and 0.33 was recorded in the treatments *viz.,* fipronil 0.3 G 10 kg ha^{-1} and fipronil 0.3 G 20 kg ha^{-1}.

4.4.3.2.3 Water Scavenger

At 50 DAT, there was no significant difference in water scavenger population between treatments and control. However zero population of water scavenger was recorded in the treatments chlorantraniliprole 0.4 G 10 kg ha^{-1}, fipronil 0.3 G 10 kg ha^{-1}, cartap hydrochloride 4 G 25 kg ha^{-1}, fipronil 0.3 G 20 kg ha^{-1} and untreated control.

At 70 DAT, the highest mean population of 1.67 was recorded in the treatment chlorantraniliprole 0.4 G 10 kg ha^{-1} followed by chlorantraniliprole 0.4 G at 20 kg ha^{-1} (0.33). Zero population was recorded in treatments *viz.,* cartap hydrochloride 4 G 25 kg ha^{-1}, cartap hydrochloride 4 G 50 kg ha^{-1}, fipronil 0.3 G 10 kg ha^{-1}, fipronil 0.3 G 20 kg ha^{-1} and untreated control.

4.4.4 Effect of New Generation Granular Insecticides on the Population of Snails

The population of snails was recorded by counting the number present in a selected area of size 1 cubic feet at 50 and 70 DAT. The result is presented in Table 22.

At 50 DAT, there was no significant difference in snail population between treatments and control. The highest mean population of 6.67 was recorded in chlorantraniliprole 0.4 G 10 kg ha^{-1} followed by untreated control (3.33) and chlorantraniliprole 0.4 G 20 kg ha^{-1} (3.00). The lowest mean population of 0.33 was recorded in fipronil 0.3 G 10 kg ha^{-1} with a mean population of 0.33.

At 70 DAT, all the treatments significantly reduced the snail population compared to control (3.00). However the lowest population of 0.33 was recorded in treatments fipronil 0.3 G at both the doses of 10 kg ha^{-1} and 20 kg ha^{-1}.

4.5 EFFECT OF NEW GENERATION GRANULAR INSECTICIDES ON GRAIN AND STRAW YEILD

The mean grain and straw yield recorded from various treatments expressed in tonnes per hectare is presented in Table 23.

There was no significant difference in grain yield among treatments and between treatments and control (4.33 t ha^{-1}). The grain yield varied from 4.33 t ha^{-1} to 5.43 t ha^{-1}. The highest grain yield of 5.43 t ha^{-1} was recorded in the treatment chlorantraniliprole 0.4 G 10 kg ha^{-1}. This was followed by cartap hydrochloride 4 G 50 kg ha^{-1} (5.42 t ha^{-1}), fipronil 0.3 G 20 kg ha^{-1} (5.33 t ha^{-1}), fipronil 0.3 G 10 kg ha^{-1} (5.20 t ha^{-1}), cartap hydrochloride 4 G 25 kg ha^{-1} (5.12 t ha^{-1}), and chlorantraniliprole 0.4 G 20 kg ha^{-1} (5.10 t ha^{-1}).

The same trend was observed in the case of straw yield also. The average straw yield obtained ranged from 8.58 t ha^{-1} to 12.83 t ha^{-1}. The highest straw

Table 22. Population of snails at intervals after treatment with new generation granular insecticides in rice

Treatments	Mean population of snails 1 square feet^{-1}	
	50 DAT	70 DAT
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	6.67 (2.60)	2.00^{ab} (1.56)
Fipronil 0.3 G 10 kg ha^{-1}	0.33 (0.88)	0.33^{c} (0.88)
Cartap hydrochloride 4 G 25 kg ha^{-1}	1.67 (1.38)	1.00^{bc} (1.18)
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	3.00 (1.70)	1.33^{abc} (1.35)
Fipronil 0.3 G 20 kg ha^{-1}	1.67 (1.25)	0.33^{c} (0.88)
Cartap hydrochloride 4 G 50 kg ha^{-1}	1.33 (1.18)	1.00^{bc} (1.18)
Untreated Control	3.33 (1.95)	3.00^{a} (1.86)
C D (0.05)	NS	(0.576)

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

Table 23. Effect of new generation granular insecticides on yield of grain and straw (t ha^{-1})

Treatments	Grain Yield (t ha^{-1})	Straw Yield (t ha^{-1})
Chlorantraniliprole 0.4 G 10 kg ha^{-1}	5.43	12.83
Fipronil 0.3 G 10 kg ha^{-1}	5.20	10.07
Cartap hydrochloride 4 G 25 kg ha^{-1}	5.12	10.63
Chlorantraniliprole 0.4 G 20 kg ha^{-1}	5.10	9.15
Fipronil 0.3 G 20 kg ha^{-1}	5.33	12.17
Cartap hydrochloride 4 G 50 kg ha^{-1}	5.42	12.58
Untreated Control	4.33	8.58
C D (0.05)	NS	NS

yield of 12.83 t ha^{-1} was obtained in the treatment chlorantraniliprole 0.4 G 10 kg ha^{-1} followed by cartap hydrochloride 4 G 50 kg ha^{-1} (12.53 t ha^{-1}), fipronil 0.3 G 20 kg ha^{-1} (12.17 t ha^{-1}), cartap hydrochloride 4 G 25 kg ha^{-1} (10.63 t ha^{-1}), fipronil 0.3 G 10 kg ha^{-1} (10.07 t ha^{-1}), chlorantraniliprole 0.4 G 20 kg ha^{-1} (9.15 t ha^{-1}) and control (8.58).

4.6 ESTIMATION OF PESTICIDE RESIDUE IN SOIL AND WATER

4.6.1 Dissipation of Insecticide Residues in Soil

4.6.1.1 Fipronil

The dissipation of fipronil 0.3 G in soil is presented in Table 24. The mean residues of insecticide in the samples collected during the experiment were below detectable levels (BDL) of 0.05 mg kg^{-1} after 0 (2 h), 1, 3, 5, 7, 10, 15 and 30 days after treatment when granular formulation of fipronil 0.3 G applied at 10 and 20 kg ha^{-1}.

4.6.1.2 Chlorantraniliprole

The dissipation of chlorantraniliprole 0.4 G in soil is presented in Table 25. The mean residues of chlorantraniliprole 0.4 G in soil when applied at 10 kg ha^{-1} were observed as 0.23 and 0.07 mg kg^{-1} at one and three days after treatment. The residues became BDL on 5 days after treatment.

The dissipation of chlorantraniliprole 0.4 G in soil when applied at 20 kg ha^{-1} was 0.08 mg kg^{-1} at one day after treatment and 0.07 mg kg^{-1} at three days after treatment. On five days after treatment the mean residues of chlorantraniliprole was observed to be BDL.

Table 24. Residues of fipronil in soil at different intervals

Days after Treatment	Mean residue of fipronil (mg kg^{-1})	
	10 kg ha^{-1}	20 kg ha^{-1}
Before application	BDL	BDL
0 (2 HAT)	BDL	BDL
1	BDL	BDL
3	BDL	BDL
5	BDL	BDL
7	BDL	BDL
10	BDL	BDL
15	BDL	BDL
30	BDL	BDL

HAT: Hours after treatment, BDL – Below detectable level (0.05 mg kg^{-1})

Table 25. Residues of chlorantraniliprole in soil at different intervals

Days after Treatment	Mean residue of chlorantraniliprole (mg kg^{-1})	
	10 kg ha^{-1}	20 kg ha^{-1}
Before application	BDL	BDL
0 (2 HAT)	BDL	BDL
1	0.23	0.08
3	0.07	0.07
5	BDL	BDL
7	BDL	BDL
10	BDL	BDL
15	BDL	BDL
30	BDL	BDL

HAT: Hours after treatment, BDL – Below detectable level (0.05 mg kg^{-1})

4.6.2 Dissipation of Insecticide Residues in Water

4.6.2.1 Fipronil

The degradation of fipronil 0.3 G in water when applied at 10 and 20 kg ha^{-1} is presented in the Table 26. The residues of fipronil 0.3 G were BDL after 0, 1, 3 and 5 days after treatment.

4.6.2.2 Chlorantraniliprole

The degradation of chlorantraniliprole 0.4 G in water when applied at 10 and 20 kg ha^{-1} is presented in the Table 27. The residues of chlorantraniliprole 0.4 G were BDL after 0, 1, 3 and 5 days after treatment.

Table 26. Residues of fipronil in water at different intervals

Duration after Treatment (days)	Mean residue (μg L^{-1})	
	Fipronil (10 kg ha^{-1})	Fipronil (20 kg ha^{-1})
Before application	BDL	BDL
0 (2 HAT)	BDL	BDL
1	BDL	BDL
3	BDL	BDL
5	BDL	BDL

HAT: Hours after treatment, BDL – Below detectable level (10 μg L^{-1})

Table 27. Residues of chlorantraniliprole in water at different intervals

Duration after Treatment (days)	Mean residue (μg L^{-1})	
	Chlorantraniliprole (10 kg ha^{-1})	Chlorantraniliprole (20 kg ha^{-1})
Before application	BDL	BDL
0 (2 HAT)	BDL	BDL
1	BDL	BDL
3	BDL	BDL
5	BDL	BDL

HAT: Hours after treatment, BDL – Below detectable level (10 μg L^{-1})

DISCUSSION

5. DISCUSSION

The results of the investigation made during the first crop season of 2017 on "Impact of new generation granular insecticides on beneficial fauna of paddy ecosystem" are discussed here under.

Nature is at risk from the hazardous effects of pesticides, biodiversity of paddy ecosystems declining gradually and steadily, natural control of pests is being failed due to loss of beneficial fauna caused by the adverse effects of pesticides and its residues, and hence study on ill effects of pesticides fetches importance.

One of the major constraints in paddy cultivation is attack by insect pests. As per the modern technology as the part of chemical control, Integrated Pest Management emphasizes the use of safer chemicals in managing the pests. Quick and high resistance to insecticides led to secondary pest outbreaks, necessitating requirement of increased pesticide dosage which form a ferocious loop (Conway and Pretty, 1991). In order to achieve higher yield in intensive rice cultivation farmers practiced to cultivate fertilizer responsive high yielding varieties. This led pests to acquire an upper hand in decreasing the yield by attacking the crop at every stage from sowing to harvest. Paul (2017) reported the attack of rice thrips in Kuttanadu, paddy fields and are spreading to new areas causing a threat to crops in early stage.

Many studies had been taken up in this regard in the state and emphasized the adverse effects of pesticides and its residual effects on environment which negatively affected the biodiversity and natural biological control. High pesticide residues in the water bodies and agricultural produces resulted in adverse effect on ecosystem. Soil fauna play an important role in soil dynamics and predation of soil pests thus keeping up the physical and chemical properties of the soil. Kumar *et al.*, (1995) reported that persistence of pesticide residues in soil and water adversely affect the soil health, aquatic life and water quality. Other than spray formulation, granular application of insecticides has taken more importance because of its easiness of application and requirement of less labour. About 50 per cent of the applied pesticides reaching soil during application lead to pollution of soil and water bodies (Aswathi *et al.*, 2002). In recent times the plant protection approach has suggested to minimize the use of chemicals. Therefore, studying the adverse effect of insecticides on the natural enemies fetches prime importance in order to rule out the negative effects on the natural enemies.

The study mainly emphasized on the impact of new generation granular insecticides chlorantraniliprole 0.4 G (10 and 20 kg ha^{-1}), fipronil 0.3 G (10 and 20 kg ha^{-1}) and cartap hydrochloride 4 G (25 and 50 kg ha^{-1}) at recommended and double the recommended dose on the beneficial fauna to ensure the safety of insecticides and its residues in soil and water.

5.1 EFFECT OF NEW GENERATION GRANULAR INSECTICIDES ON DAMAGE/POPULATION OF MAJOR PESTS OF PADDY ECOSYSTEM AT DIFFERENT GROWTH STAGES OF THE CROP

Wet land paddy is prone to attack by various insects pests, out of which stem borer, leaf folder and rice bug fetches the major attention. Granular insecticides have given promising results in tackling the damage from the decades. Due to ban on certain high toxic granular insecticides *viz.,* phorate 10 G and carbofuran 3 G in the state, a few safer new generation granular insecticides were tested by KAU, (2016) and recommended for pest management.

The study on impact of new generation granular insecticides on beneficial fauna of paddy ecosystem was undertaken and results on the effect of these insecticides on major pests of paddy is presented in 4.1.

The incidence of dead heart and white ear heads caused by stem borer attack was significantly reduced in all the treatments compared to control. Fipronil 0.3 G

10 kg ha^{-1} recorded the lowest incidence of dead hearts and was on par with fipronil 0.3 G 20 kg ha^{-1} (Fig. 1). The lowest WEH symptom was recorded in the treatment fipronil 0.3 G 20 kg ha^{-1} (Fig. 2). Fipronil 0.3 G at both the doses were found to be effective in managing stem borer infestation throughout the period of observation followed by cartap hydrochloride 4 G 50 kg ha^{-1} (Fig. 1 and 2). Various workers supported the superiority of fipronil granules in suppressing the stem borer attack (Hugar *et al.*, 2009; Satyanarayana *et al.*, 2014a; Aulakh *et al.*, 2016).

Chlorantraniliprole 0.4 G was effective in reducing the damage of leaf roller with comparatively stable persistence and most effective up to 45 DAT (Fig 1), the findings were in coherence with the earlier works of Suri and Brar (2013), Sarao and Kaur (2014) and Chanu and Sontakke (2015) who reported the superiority of chlorantraniliprole in suppressing the leaf roller.

Analysis of the data on the adult pests gave somewhat similar effect of fipronil 0.3 G (10 and 20 kg ha^{-1}) in the suppression of tissue feeders, sucking pests and the total pests (Fig. 3 to 6). At 30 and 45 DAT the population of stem borers, grasshoppers, GLH and total pests was effectively suppressed by fipronil 0.3 G at both doses while leaf roller was efficiently controlled with chlorantraniliprole 0.4 G (Fig. 3 and 4). With the lowest record of pests fipronil 0.3 G was reported to be effective in suppression of the adult pests at 60 and 75 DAT (Fig. 5 and 6). This study is in agreement with the findings of Sekh *et al.* (2007) and Mahal *et al.* (2008) who reported the effectiveness of fipronil against stem borer and leaf roller and also supported works of Satyanarayana *et al.* (2014a and b).

Significant reduction in the population of rice bugs over control was observed at 90 DAT only, as presented in 4.1.3.3. Significantly low population was recorded by chlorantraniliprole 0.4 G 20 kg ha^{-1} and this was on par with cartap hydrochloride 4 G 50 kg ha^{-1} and 25 kg ha^{-1}. Tiwari *et al.* (2014) reported

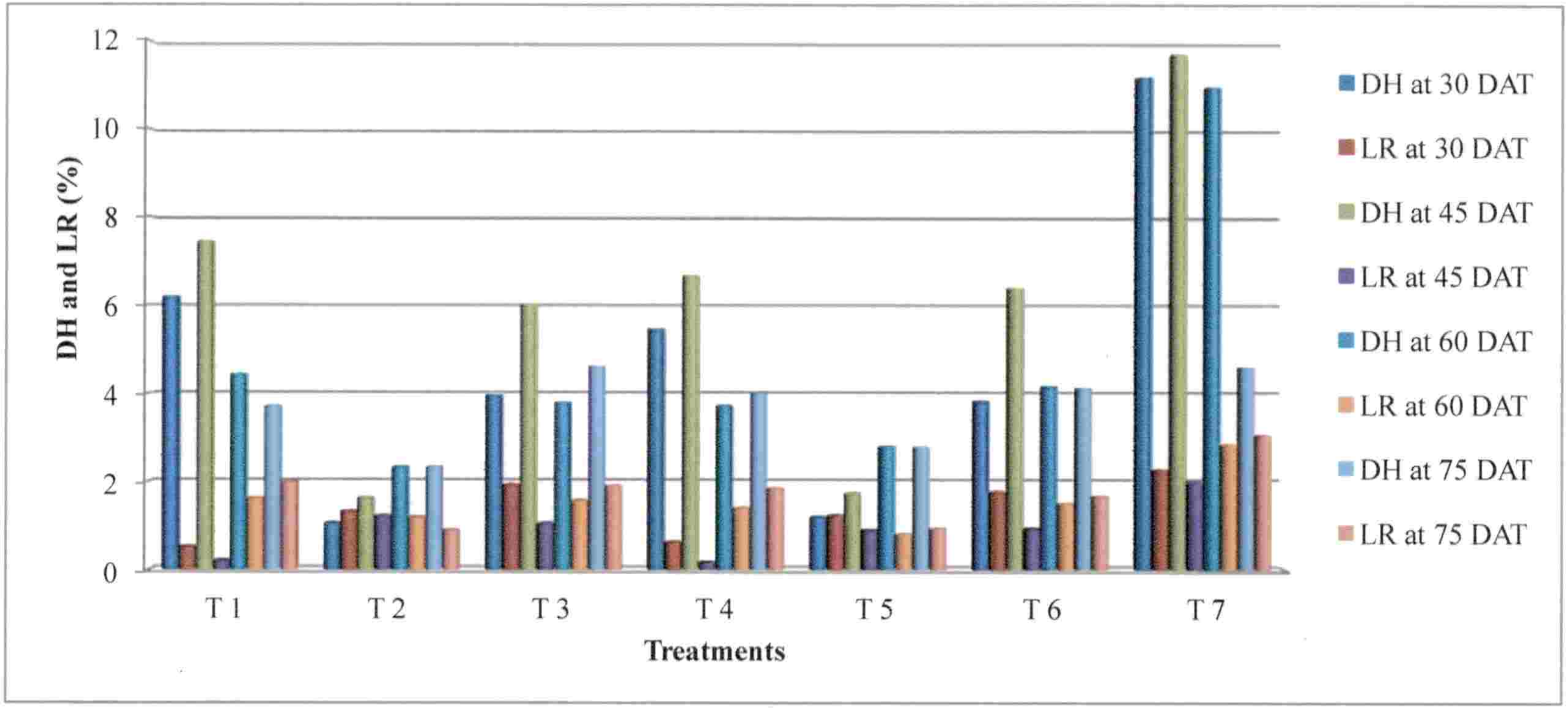


Fig. 1 Impact of new generation granular insecticides on stem borer and leaf roller damage at different growth stages of the crop

Treatments: T1-Chlorantraniliprole 0.4 G 10 kg ha^{-1}, T_2-Fipronil 0.3 G 10 kg ha^{-1}, T_3-Cartap hydrochloride 4 G 25 kg ha^{-1}, T_4-Chlorantraniliprole 0.4 G 20 kg ha^{-1}, T_5-Fipronil 0.3 G 20 kg ha^{-1}, T_6-Cartap hydrochloride 4 G 50 kg ha^{-1}, T_7- Untreated Control.

DH: Dead hearts, LR: Leaf roller, DAT: Days after transplanting

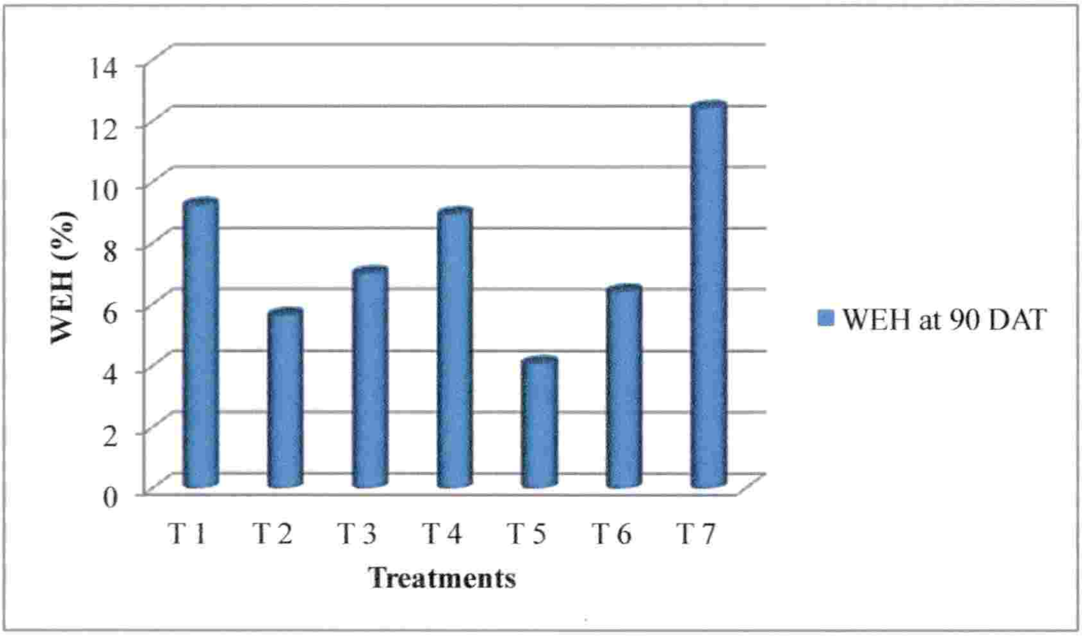


Fig. 2 Impact of new generation granular insecticides on white ear head at different growth stages of the crop

Treatments: T1-Chlorantraniliprole 0.4 G 10 kg ha^{-1}, T_2-Fipronil 0.3 G 10 kg ha^{-1}, T_3-Cartap hydrochloride 4 G 25 kg ha^{-1}, T_4-Chlorantraniliprole 0.4 G 20 kg ha^{-1}, T_5-Fipronil 0.3 G 20 kg ha^{-1}, T_6-Cartap hydrochloride 4 G 50 kg ha^{-1}, T_7- Untreated Control.

WEH: White ear head, DAT: Days after transplanting that rice bug which is considered as a major pest of paddy caused 30 per cent destruction of crop at soft dough stage to harvest.

In the case of grasshopper, fipronil 0.3 G both at recommended and double the recommended dose (10 and 20 kg ha^{-1}) recorded significant reduction in population over control throughout the period of observation (Fig. 3 to 6). Balança and Visscer (1997) reported that outbreak of grasshopper can effectively be managed by fipronil at very low doses. Within 3 to 10 days interval more than 90 per cent of mortality recorded at the rate of 1-2 g a.i. ha^{-1}, and the higher rate can be achieved at shorter period with higher doses.

Plant hopper population was reduced significantly in all the treatments, the highest reduction observed in fipronil 0.3 G at both doses (10 and 20 kg ha^{-1}) and found to be the best among the treatments over control at all intervals after treatment except at 45 DAT (Fig. 3 to 6). This finding is also in coherence with the studies of Satyanarayana *et al.* (2014b) who revealed that fipronil 0.6 GR granules was found to be superior in reducing hopper infestation,

The total pest population recorded in sweep net collection at 30 DAT was the lowest (significantly lower compared to control) in the treatment fipronil 0.3 G at 20 kg ha^{-1} followed by the recommended dose of 10 kg ha^{-1} (Fig. 3). Control recorded the maximum pest population. Fipronil 0.3 G was found to be the most effective granular insecticide in reducing the total pest population at both the doses.

At 45 and 60 DAT though all the treatments recorded significant reduction in population of total pests compared to control, the treatment fipronil 0.3 G 20 kg ha^{-1} recorded significantly low population over other treatments and was found to be on par with fipronil 0.3 G 10 kg ha^{-1} (Fig. 4 and 5). Control recorded the highest population while cartap hydrochloride 4 G 50 kg ha^{-1} recorded the highest population of total pests among the treatments.

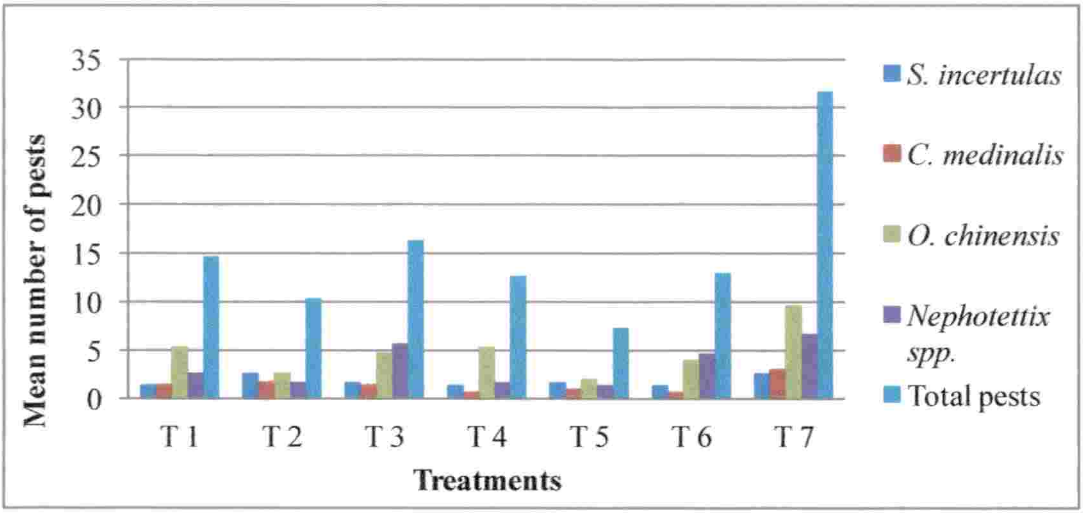


Fig. 3 Impact of new generation granular insecticides on population of adult pests at 30 days after transplanting

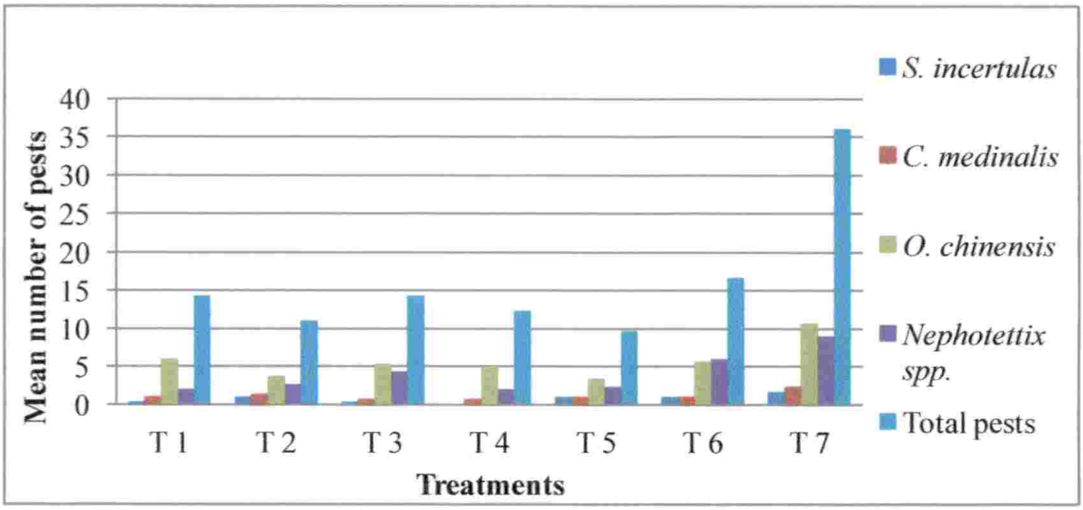


Fig. 4 Impact of new generation granular insecticides on population of adult pests at 45 days after transplanting

Treatments: T1-Chlorantraniliprole 0.4 G 10 kg ha^{-1}, T_2-Fipronil 0.3 G 10 kg ha^{-1}, T_3-Cartap hydrochloride 4 G 25 kg ha^{-1}, T_4-Chlorantraniliprole 0.4 G 20 kg ha^{-1}, T_5-Fipronil 0.3 G 20 kg ha^{-1}, T_6-Cartap hydrochloride 4 G 50 kg ha^{-1}, T_7- Untreated Control.

DAT: Days after transplanting

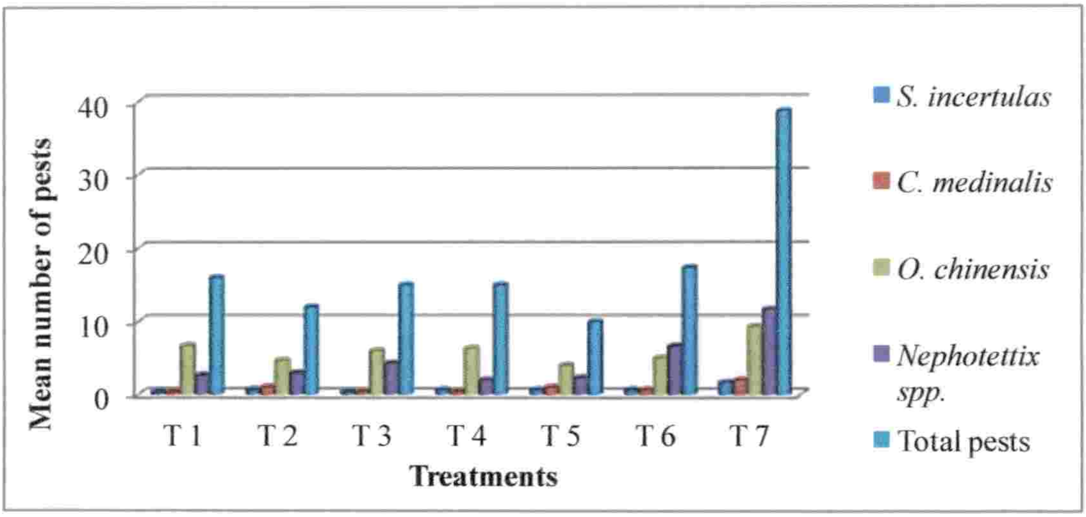


Fig.5 Impact of new generation granular insecticides on population of adult pests at 60 days after transplanting

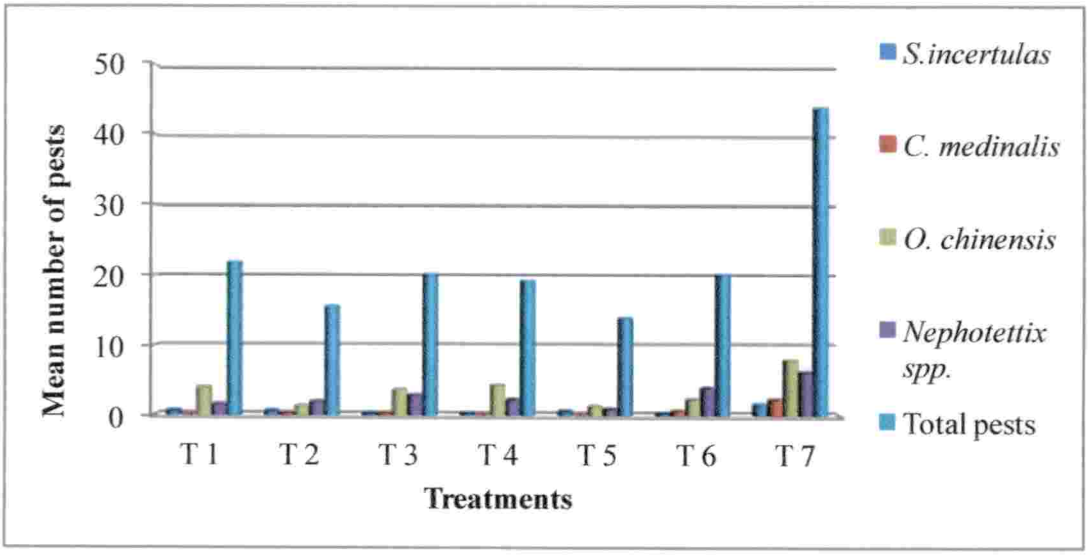


Fig. 6 Impact of new generation granular insecticides on population of adult pests at 75 days after transplanting

Treatments: T1-Chlorantraniliprole 0.4 G 10 kg ha^{-1}, T_2-Fipronil 0.3 G 10 kg ha^{-1}, T_3-Cartap hydrochloride 4 G 25 kg ha^{-1}, T_4-Chlorantraniliprole 0.4 G 20 kg ha^{-1}, T_5-Fipronil 0.3 G 20 kg ha^{-1}, T_6-Cartap hydrochloride 4 G 50 kg ha^{-1}, T_7- Untreated Control.

DAT: Days after transplanting

At 75 DAT also fipronil 0.3 G 20 kg ha^{-1} recorded significantly low population of total pests over other treatments and was on par with fipronil 0.3 G 10 kg ha^{-1} and chlorantraniliprole 0.4 G 20 kg ha^{-1} (Fig. 6).

5.2 EFFECT OF NEW GENERATION GRANULAR INSECTICIDES ON POPULATION OF MAJOR PREDATORS AND PARASITOIDS OF PADDY ECOSYSTEM

Defenders residence at moderate population without the use of chemicals in rice can defend against the pest occurrence up to certain stage and hence the in-situ preservation of carnivorous arthropods is the best measure in restraining the pest population in rice field (Nalinakumari *et al.,* 1996). Natural enemies associated with paddy pests encompasses about 90 predatory and 30 parasitoid species, which plays a decisive role in reducing pests incidence and damage in turn maintaining the balance between the organisms of the ecosystem (Edirisinghe and Bambaradeniya, 2006).

Predators are abundant during vegetative stage as they depend on sap feeders in rice crop (Settle, 1994). On the other hand studies of Premila (2003) showed that various predators are distributed incessantly all the way through cropping interval and amplified steadily from early to later stages of the crop. Impacts of new generation insecticides on natural enemies are presented in Fig. 7 to 14. Among the new generation granular insecticides chlorantraniliprole 0.4 G at both doses was found to be safer to natural enemies followed by cartap hydrochloride 4 G at recommended dose. Fipronil 0.3 G at both recommended and double the recommended doses recorded a high reduction in populations of predators posing a threat to predators population at higher rate compared to chlorantraniliprole 0.4 G and cartap hydrochloride 4 G.

Findings of the study revealed that among the treatments the highest number of damselflies and ground beetles were recorded in chlorantraniliprole

0.4 G at both doses (10 and 20 kg ha^{-1}) throughout the period of observation and found to be safer to major predators followed by cartap hydrochloride 4 G at 25 kg ha^{-1}. Fipronil 0.3 G at both doses (10 and 20 kg ha^{-1}) was found to be harmful by recording the lowest population of damselflies and ground beetles (Fig. 7 to 10).

Though no significant difference in population of coccinellids was observed between the treatments and control throughout the period of observation, the highest population recorded in chlorantraniliprole 0.4 G 20 kg ha^{-1} at 30, 60 and 75 DAT (Fig.7, 9 and 10). Cartap hydrochloride 4 G 50 kg ha^{-1} recorded the highest population at 45 DAT (Fig. 8)

Joseph *et al.* (2010) noticed the presence of *Tetragnatha* sp. and *Argiope* sp. in all stages of rice in Kalliyoor panchayath region of Thiruvananthapuram district. Seventeen species of spiders played an imperative part in pest regulation from rice ecosystem of Kerala documented by Anis and Premila (2016). Significant reduction of spiders due to insecticide application was recorded up to 45 DAT (Fig. 7 and 8) and later the treatments were found to be non significant at 60 DAT (Fig. 9) and 75 DAT (Fig. 10).

The lowest population of damselflies, ground beetles, coccinellids and spiders were recorded in fipronil 0.3 G at both the doses. The results revealed that in all the crop stages chlorantraniliprole 0.4 G at both doses (10 and 20 kg ha^{-1}) was found to be safe to major predators of paddy pests (Fig. 7 to 10). This observation was supported by the results of several works. By supporting the high populations of spiders, damselflies, mirid bugs and larval parasitoids cartap hydrochloride at 1 kg a.i.ha^{-1} was found to be safe to natural enemies and on par with control in rice fields (Karthikeyan *et al.*, 2007). Chanu (2013) compared the efficiency of chlorantraniliprole (Rynaxypyr 18.5 SC) with other insecticides in combating the rice pests and found its safety to natural enemies. Chatterjee *et al.* (2015) also reported that the maximum spider population was recorded in the chlorantraniliprole granule applied plots.

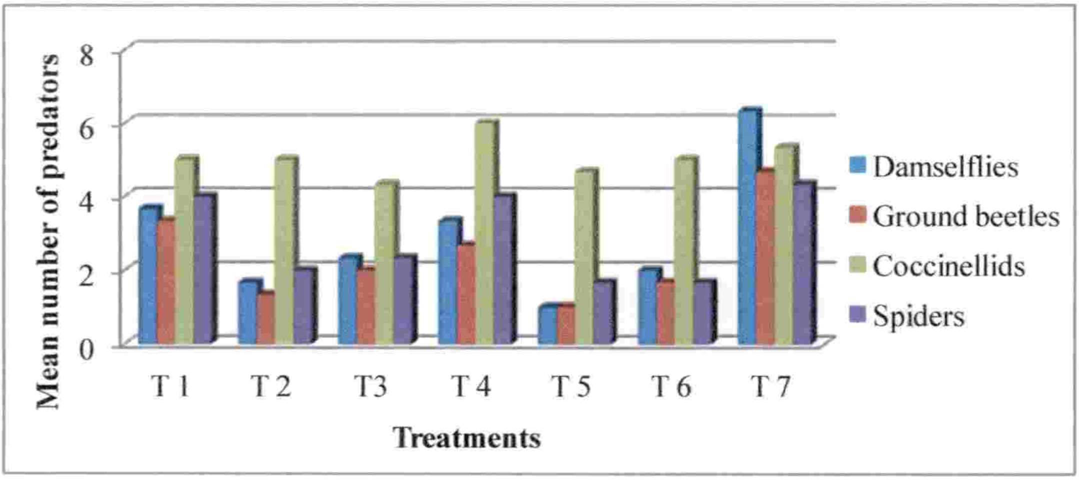


Fig.7 Impact of new generation granular insecticides on population of major predators at 30 days after transplanting

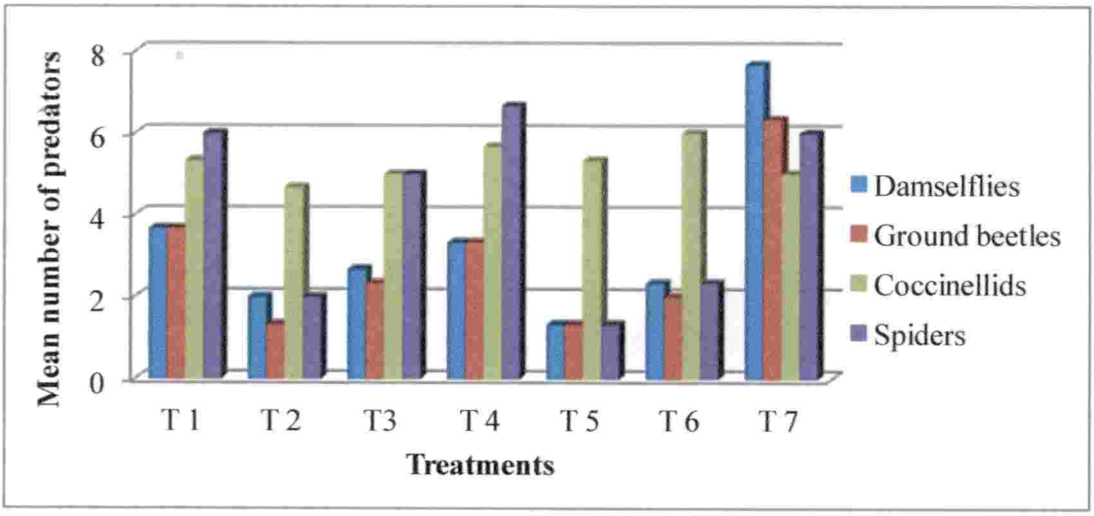


Fig.8 Impact of new generation granular insecticides on population of major predators at 45 days after transplanting

Treatments: T1-Chlorantraniliprole 0.4 G 10 kg ha^{-1}, T_2-Fipronil 0.3 G 10 kg ha^{-1}, T_3-Cartap hydrochloride 4 G 25 kg ha^{-1}, T_4-Chlorantraniliprole 0.4 G 20 kg ha^{-1}, T_5-Fipronil 0.3 G 20 kg ha^{-1}, T_6-Cartap hydrochloride 4 G 50 kg ha^{-1}, T_7- Untreated Control.

DAT: Days after transplanting

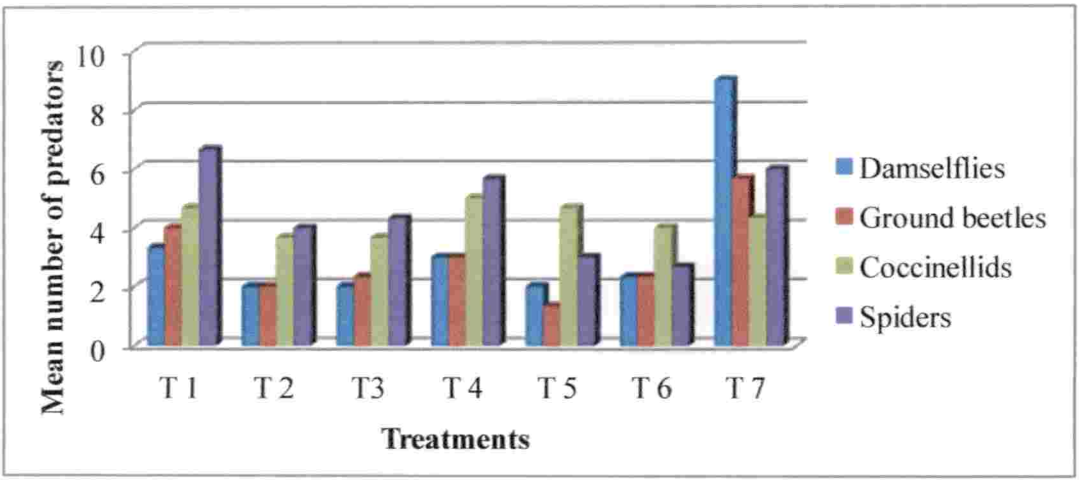


Fig.9 Impact of new generation granular insecticides on population of major predators at 60 days after transplanting

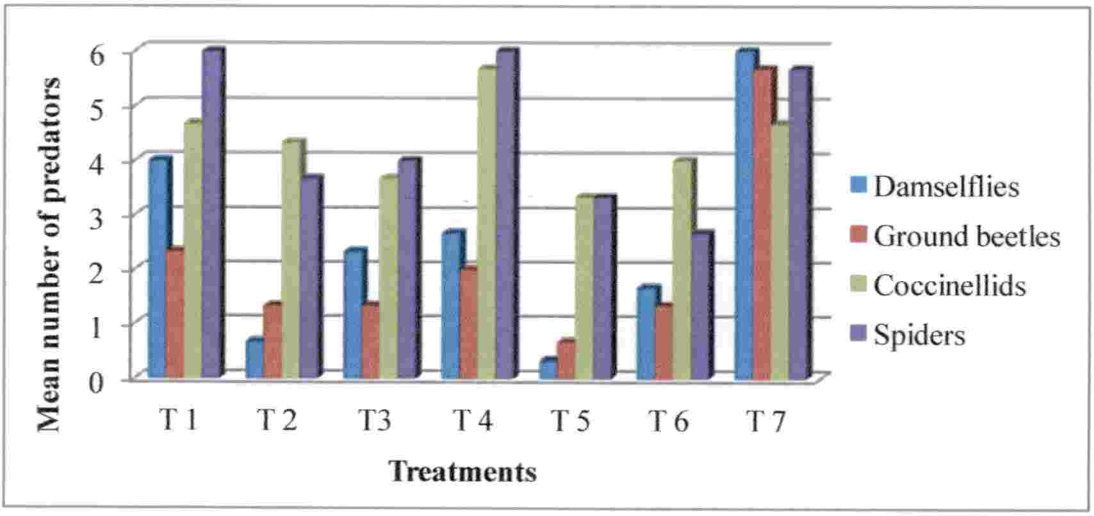


Fig.10 Impact of new generation granular insecticides on population of major predators at 75 days after transplanting

Treatments: T1-Chlorantraniliprole 0.4 G 10 kg ha^{-1}, T_2-Fipronil 0.3 G 10 kg ha^{-1}, T_3-Cartap hydrochloride 4 G 25 kg ha^{-1}, T_4-Chlorantraniliprole 0.4 G 20 kg ha^{-1}, T_5-Fipronil 0.3 G 20 kg ha^{-1}, T_6-Cartap hydrochloride 4 G 50 kg ha^{-1}, T_7- Untreated Control.

DAT: Days after transplanting

On contradiction Zhao *et al.* (2012) observed that chlorantraniliprole at label recommended dose declined searching and predating capacity of *C. lividipennis* with decreased attacking rate and handling the eggs and nymphs of *N. lugens*. In paddy mesocosm experiments, the toxicity of fipronil was studied by Hayasaka *et al.* (2012b) and Kasai *et al.* (2016) that substantiated its harmful effects causing decline in odonata (dragonfly) species. Jinguji *et al.* (2013) also found that the use of fipronil (0.4–1.3 $\mu g\ L^{-1}$) as nursery box application caused decline of *S. infuscatum*.

Higher range of parasitoids in rice ecosystem is favourable for sustainable innate control of rice pests (Buchori *et al.*, 2008). *Cotesia* sp. was the most copious parasitoid population observed in rice fields of Kerala (Ranjith *et al.*, 2015). Parasitoids population was recorded to be low up to 45 DAT (Fig. 11 and 12) and increased from 60 DAT onwards (Fig. 13 and 14). The effect of treatments on parasitoids was found to be non significant throughout the period of observation and followed similar trends as in case of total predators. The highest population of natural enemies i.e. total parasitoids and predators was recorded in the treatment chlorantraniliprole 0.4 G at 10 and 20 kg ha^{-1} followed by cartap hydrochloride 4 G at recommended dose of 25 kg ha^{-1} (Fig. 11 to 14).

When fipronil was applied to manage the grasshoppers at very low doses it affected the non target insects negatively particularly Coleoptera, Diptera and Hymenoptera (Balança and Visscer, 1997). Singh *et al.* (2003) and Nazir *et al.* (2005) reported that cartap hydrochloride at 1.0 and 0.75 kg a.i.ha^{-1} was found to be selective and safer insecticide to *T. dignoides* the egg parasitoid, with highest parasitism rate and found non toxic to the natural enemies of stem borer. These results were also supported by following studies by Brugger *et al.* (2010) who reported that chlorantraniliprole was found to be non toxic and safer molecule to parasitoid wasps, with lower risk quotient. It was also found to be harmless to egg parasitoids *T.chilonis* in rice ecosystem as reported by Preetha *et al.* (2009) and Jia *et al.* (2011). Jaafar *et al.* (2013) also reported that fipronil reduced the parasitoid populations when applied in rice.

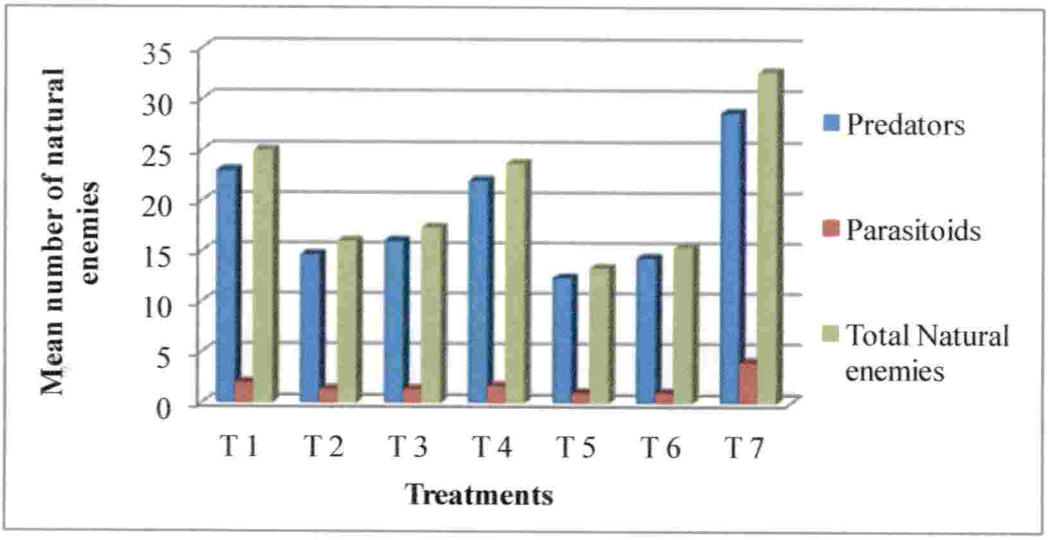


Fig.11 Impact of new generation granular insecticides on population of natural enemies at 30 days after transplanting

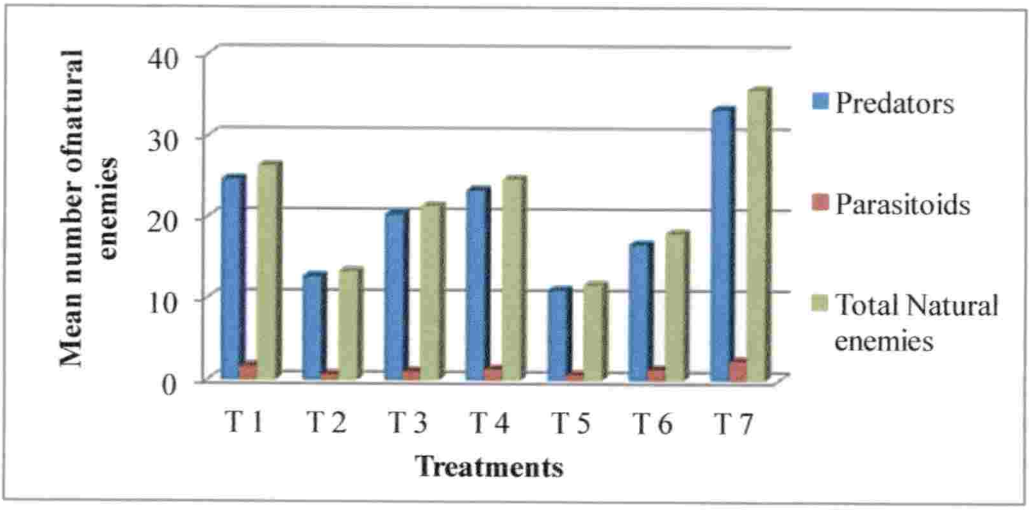


Fig.12 Impact of new generation granular insecticides on population of natural enemies at 45 days after transplanting

Treatments: T1-Chlorantraniliprole 0.4 G 10 kg ha^{-1}, T_2-Fipronil 0.3 G 10 kg ha^{-1}, T_3-Cartap hydrochloride 4 G 25 kg ha^{-1}, T_4-Chlorantraniliprole 0.4 G 20 kg ha^{-1}, T_5-Fipronil 0.3 G 20 kg ha^{-1}, T_6-Cartap hydrochloride 4 G 50 kg ha^{-1}, T_7- Untreated Control.

DAT: Days after transplanting

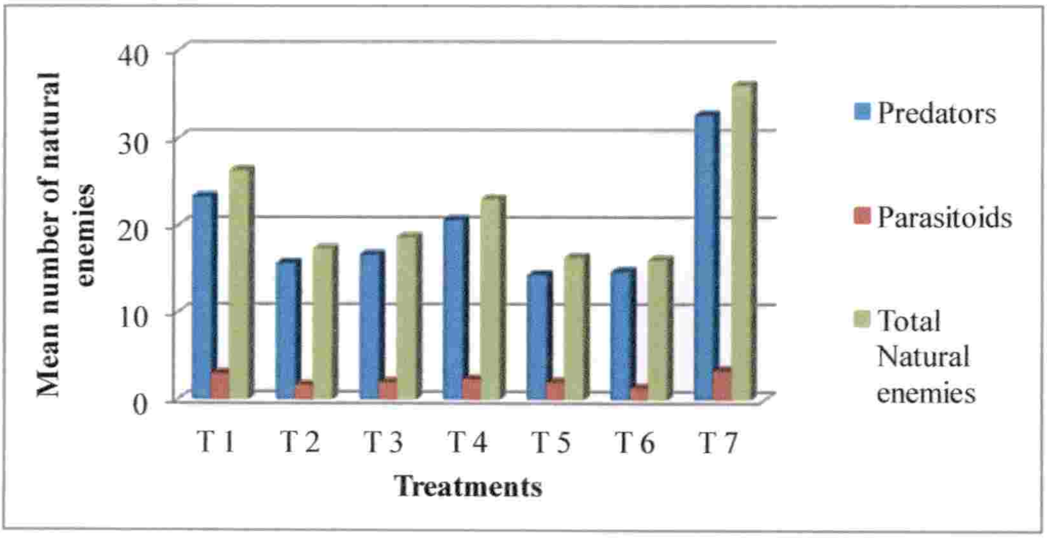


Fig.13 Impact of new generation granular insecticides on population of natural enemies at 60 days after transplanting

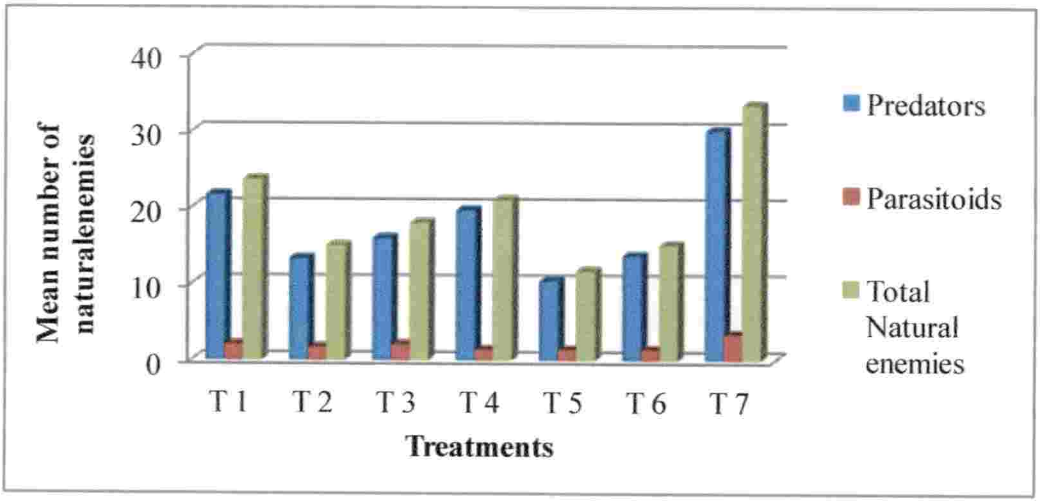


Fig.14 Impact of new generation granular insecticides on population of natural enemies at 75 days after transplanting

Treatments: T1-Chlorantraniliprole 0.4 G 10 kg ha^{-1}, T_2-Fipronil 0.3 G 10 kg ha^{-1}, T_3-Cartap hydrochloride 4 G 25 kg ha^{-1}, T_4-Chlorantraniliprole 0.4 G 20 kg ha^{-1}, T_5-Fipronil 0.3 G 20 kg ha^{-1}, T_6-Cartap hydrochloride 4 G 50 kg ha^{-1}, T_7- Untreated Control.

DAT: Days after transplanting

5.3 PEST: DEFENDER RATIO

Chlorantraniliprole 0.4 G (10 and 20 kg ha^{-1}) at both doses were reported to be safe in the case of natural enemy population in the present study and also confirmed with the recorded least value P: D ratio of 0.59 to 0.93 for 10 kg ha^{-1} and 0.54 to 0.92 for 20 kg ha^{-1} respectively in both doses (4.3). Hence chlorantraniliprole can be recommended as a component in the integrated pest management programs (Brugger *et al.*, 2010 and Jia *et al.*, 2011).

5.4. EFFECT OF NEW GENERATION GRANULAR INSECTICIDES ON EARTHWORMS, NEMATODES AND SOIL ARTHROPODS AT DIFFERENT GROWTH STAGES OF THE CROP

About 50 per cent of the applied pesticides reach soil during applications which lead to pollution of soil and water bodies (Aswathi *et al.*, 2002). Besides management of pests, the adverse effects of insecticides on soil fauna fetches a vital significance in the conservation of non target soil fauna to sustain the ecological balance and in maintenance of the physical properties of soil and soil heath. The present study mainly focus on the effect of new generation granular insecticides on beneficial soil fauna and the results presented in 4.4.

In the case of soil fauna *viz.,* earthworms, spiders, snails and soil arthropods, all the treatments significantly reduced its population compared to control. The treatment chlorantraniliprole 0.4 G at 10 and 20 kg ha^{-1} recorded the highest population of soil fauna among the treatments and was on par with control (Fig. 15 and 16) and the treatment fipronil 0.3 G at 10 and 20 kg ha^{-1} recorded the lowest population of soil fauna followed by cartap hydrochloride 4 G at 25 and 50 kg ha^{-1}. This indicates the toxicity of both fipronil 0.3 G and cartap hydrochloride 4G to soil fauna.

Findings of present experiment were in agreement with the studies on the toxic effects of fipronil and cartap hydrochloride to soil fauna by various

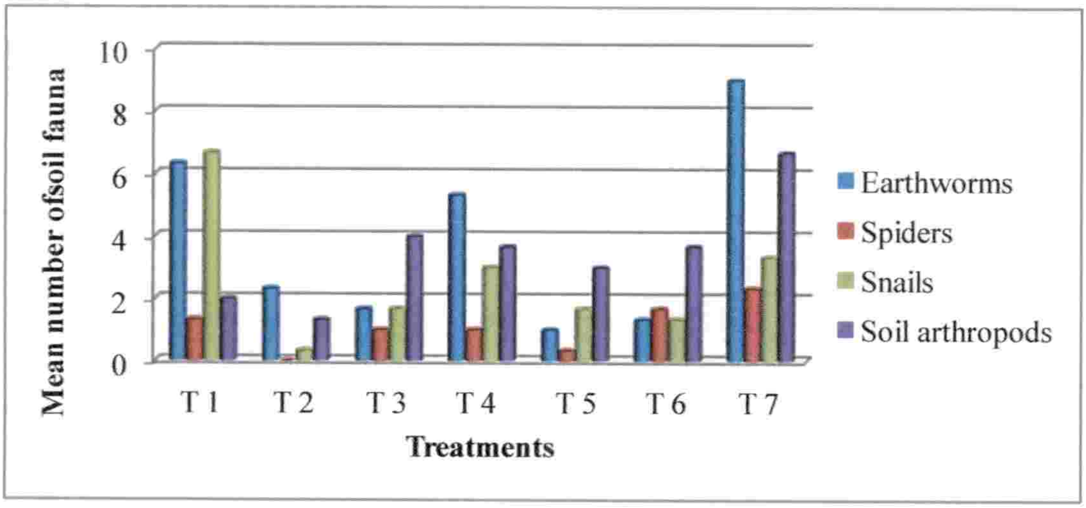


Fig.15 Impact of new generation granular insecticides on population of soil fauna at 50 days after transplanting

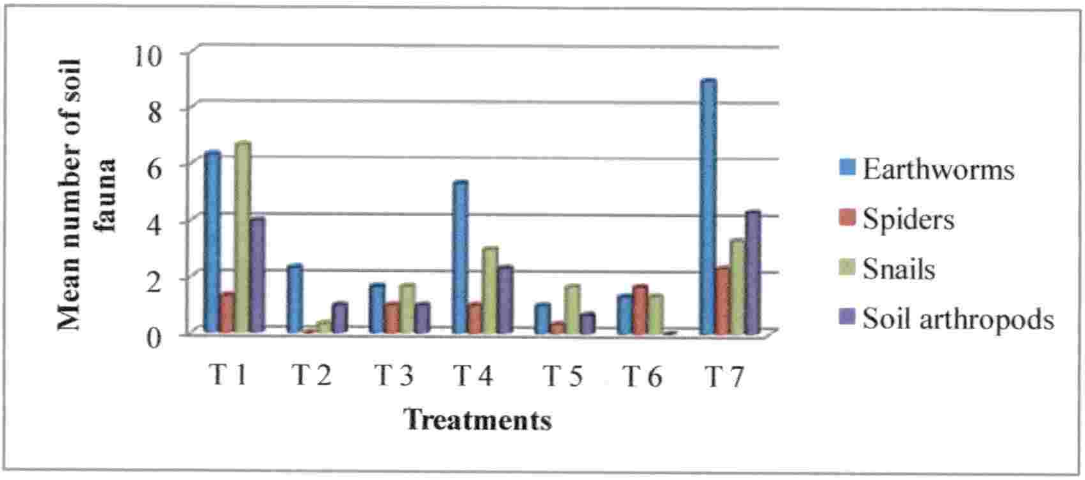


Fig.16 Impact of new generation granular insecticides on population of soil fauna at 70 days after transplanting

Treatments: T1-Chlorantraniliprole 0.4 G 10 kg ha^{-1}, T_2-Fipronil 0.3 G 10 kg ha^{-1}, T_3-Cartap hydrochloride 4 G 25 kg ha^{-1}, T_4-Chlorantraniliprole 0.4 G 20 kg ha^{-1}, T_5-Fipronil 0.3 G 20 kg ha^{-1}, T_6-Cartap hydrochloride 4 G 50 kg ha^{-1}, T_7- Untreated Control.

DAT: Days after transplanting

scientists. Ferido *et al.* (1991) from Philippines who reported that snails, *Pomacea sp* which infest the transplanted and direct seeded rice can be efficiently managed by cartap hydrochloride i.e. Dimotrin 50% SP at 500 g L^{-1} soluble powder and 4 G at 40 g kg^{-1} granule. Karanjkar (2009) reported the highest reduction of earthworms up to 96.7 per cent on application of fipronil even after an exposure period of one month. Fipronil was reported to be highly toxic to the freshwater invertebrates, especially molluscs. Leaf dipping bioassay technique in a period of 48 to 90 hours of treatment the lethal toxicity (LC_{50}) of fipronil against three land snail species *E. vermiculata, T. pisana* and *H. vestalis*, were in the array of (0.073-0.014), (0.032-0.0073) and (0.019-0.0049) respectively (Varro *et al.*, 2009). Chlorantraniliprole appeared to be the least hazardous insecticide for non target beneficial arthropod species as reported by Jaafar *et al.* (2013) and Maria *et al.* (2016). Salokhe *et al.* (2014) and Adarsha *et al.* (2015) also reported that the population of earthworm is significantly reduced in fipronil treated soil. The present findings were also supported by Sandeep *et al.* (2017) who found that cartap 4 G had more toxic effects on earthworm's biochemical composition when used alone as well as in combination with phorate.

In the case of nematodes, population of parasitic nematodes were not recorded in the field. All the treatments significantly reduced the total nematode population including free living and predatory species except chlorantraniliprole 0.4 G 10 kg ha^{-1} which was found to be less harmful to nematodes and recorded significantly high population both at 50 and 70 DAT (Fig. 17). Fipronil 0.3 G at both doses (10 and 20 kg ha^{-1}) recorded the lowest population of nematodes at 50 DAT and it was slightly recovered at 70 DAT (Fig. 17). Mamun *et al.* (2014) reported that both chlorantraniliprole 0.4 G (Rynaxypyr) and fipronil 3 G caused the maximum reduction of 85.80 and 82.00 per cent mortality of nematodes respectively. He also reported chlorantraniliprole and fipronil granules to be toxic to nematode population in tea in Bangladesh.

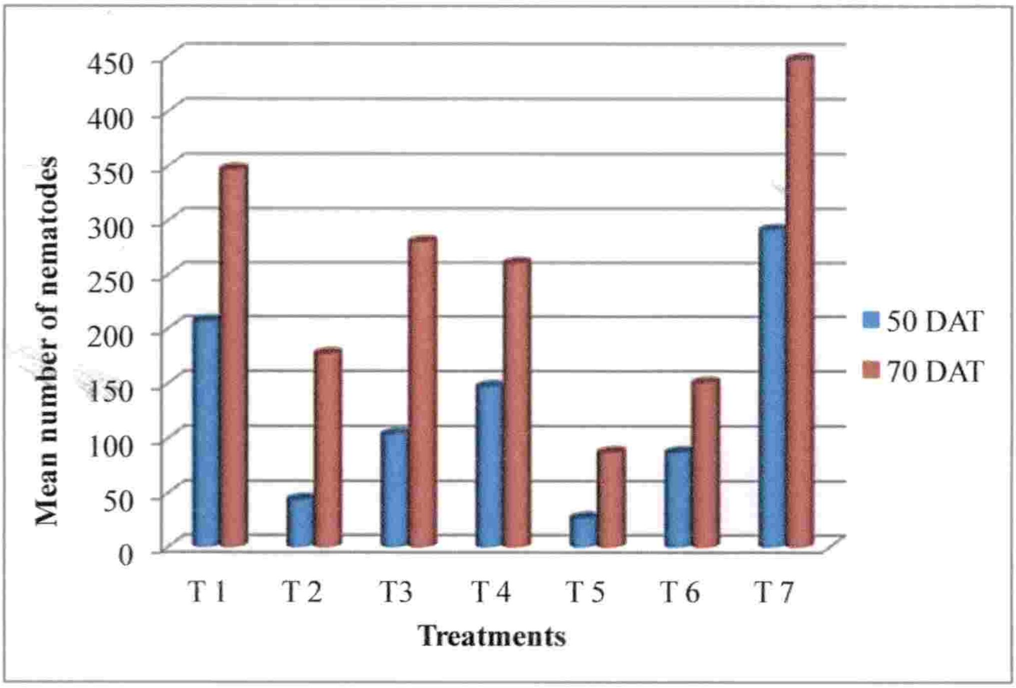


Fig.17 Impact of new generation granular insecticides on population of nematodes at 50 and 70 days after transplanting

Treatments: T1-Chlorantraniliprole 0.4 G 10 kg ha^{-1}, T_2-Fipronil 0.3 G 10 kg ha^{-1}, T_3-Cartap hydrochloride 4 G 25 kg ha^{-1}, T_4-Chlorantraniliprole 0.4 G 20 kg ha^{-1}, T_5-Fipronil 0.3 G 20 kg ha^{-1}, T_6-Cartap hydrochloride 4 G 50 kg ha^{-1}, T_7- Untreated Control.

DAT: Days after transplanting

5.5. EFFECT OF NEW GENERATION GRANULAR INSECTICIDES ON GRAIN AND STRAW YEILD

Results of 4.5 represent the yield of rice which showed increase in grain yield with tested granular insecticides. The highest yield of 5.43 t ha^{-1} was recorded from the plots treated with chlorantraniliprole 0.4 G at 10 kg ha^{-1}. Similarly no significant differences were noticed in straw yield also. Chlorantraniliprole 0.4G 10kg ha^{-1} recorded the highest straw yield of 12.83 t ha^{-1}.

5.6. ESTIMATION OF PESTICIDE RESIDUE IN SOIL AND WATER

Over 50 per cent of the applied pesticide reaches the soil and contaminate the soil and water bodies during application (Aswathi *et al.*, 2002). In irrigated crops such as rice, pesticides applied may be more mobile than dry land crops, because of saturated soil which potentially provides a channel between surface and ground waters (Doran *et al.*, 2008). Generally, the impact of pesticides on the paddy field ecosystem is assessed mainly on the basis of acute toxicity tests in laboratory conducted on the commonly found test species in the paddy field.

The indiscriminate use of pesticides and the introduction of granular formulations resulted in high accumulation of residues in the soil and water bodies of paddy ecosystem which showed toxic to non target organisms including beneficial fauna of paddy ecosystem. In paddy fields the pesticides were detected at the point of application or as a result of spray drift in aerial spraying, runoff due to rain, drainage and water ways of paddy ecosystem. In this context dissipation studies of two insecticides proved as the best in the management of major pests of rice *viz.,* fipronil 0.3 G and chlorantraniliprole 0.4 G at the rate of 10 and 20 kg ha^{-1} respectively were conducted in IFSRS, Karamana. The results of the dissipation studies are presented in Table 24 to 27.

Present study revealed that after the second application of treatments at 30 DAT, residues could be detected only in the chlorantraniliprole 0.4 G treatment at both doses (10 and 20 ka ha^{-1}) of application in soil up to 3 days after treatment

(0.07 mg kg^{-1}), thereafter the residues were BDL from 5 days after treatment. The residues of fipronil 0.3 G was BDL in soil at both doses (10 and 20 ka ha^{-1}). No residues of fipronil 0.3 G and chlorantraniliprole 0.4 G at both doses (10 and 20 kg ha^{-1}) could be detected in water during the study. The results of present study in water are not supported by Doran *et al.* (2008). In their study on the mobility of the pesticides in water in rice fields revealed that with leakage rates of 10 mm per day from the base of the soil cores and due to rapid transfer to the soil phase only less than 20 per cent of applied pesticides (thiobencarb and fipronil) remained in the water column after 10 days in green house under flooded condition.

Watanable *et al.* (2006) suggested the water management practices by extension of water holding up to 10 days to reduce the herbicide effluents in paddy fields of Japan. Anasco *et al.* (2010) found the pesticide residues in fresh water areas which are directly influenced from the paddy effluents, out of which herbicides had relatively higher concentrations in early stages of crop and insecticides and fungicides were higher at later stages.

The faster degradation of insecticides may be due to higher rate of photolysis, hydrolysis and volatilization or may be due to the activity of microbes which degraded the insecticides in to its metabolites. Fipronil rapidly photolyzed to desthiofipronil in deionised water in the laboratory, photolysis of fipronil was still faster in the existence of water with half life of 0.874 to 4.51 h (Ngim and Crosby, 2001) which is in coherence with our study where fipronil 0.3G at both doses dissipated within 2 h after treatment in water (Table 26). Zhu *et al.* (2004) also showed that presence of soil microbes influence the faster degradation of fipronil in clay loam soils forming a metabolite MB45950.

The faster degradation of insecticides in water in the present study is also in agreement with the studies of Zhang *et al.* (2012) who revealed that the rate of degradation of chlorantraniliprole in water was the fastest followed by soil with the average recoveries of 95.20 to 103.10 and 76.90 to 82.40 per cent respectively and Jinguji *et al.* (2013) who reported that fipronil dissipated quickly in paddy water, with half-lives of 5.40 days and reached BDL (< 0.50 μg L^{-1}) exponentially at 7 days after treatment. The results of the study on dissipation of insecticides suggest that application of new generation granular insecticides *viz.*, fipronil 0.3 G and chlorantraniliprole 0.4 G are safe to soil fauna of paddy ecosystems as the residues were not detected in water and not remained in soil for a longer period.

In the current study even though residues of fipronil 0.3 G seemed to possess no harm to soil fauna in both water and soil, it found to cause highest reduction of natural enemies (Fig. 11 to 14). The reduction of natural enemies in fipronil 0.3 G at both doses may be due to the decline in host population or some of the metabolites of fipronil 0.3 G showed strong acute toxicity in respective treatments. Ngim and Crosby (2001) reported that metabolite desthiofipronil which was formed photo-chemically from fipronil in rice field water was more stable to photolysis than fipronil ($t_{½}$ 120 to 149 h). The major degraded products of fipronil were desthiofipronil in water and fipronil-sulfide in soils (Jinguji *et al.*, 2013).

Only lesser amount of chlorantraniliprole 0.4 G residues were detected up to 3 days after treatment (0.07 μg kg^{-1}), which is reported to be less harm to soil fauna and natural enemies at this concentration in soil and no residues were detected in water of paddy ecosystems during this study. The previous works related to chlorantraniliprole which was reported to be the safest and harmless insecticide to egg parasitoid *T. chilonis* with LC_{50} 1.9530 mg a.i L^{-1} (Preetha *et al.*, 2009).

Though these test consequences are comparatively easy to evaluate and compare they are not suitable to assess seasonality of the effects or the preservation of neighbouring biodiversity since the following three factors are ignored:

1. Dissimilarity in sensitivity amongst the species in the field (Straalen, 2002),

2. Inter specific relations within the community structure (Liess, 2002) and

3. The variation in exposure that occurs in the field, which depends basically on the physicochemical characteristics of each pesticide, like adsorption, water solubility and hydrolytic and photolytic properties (Hayasaka *et al.*, 2012a and b).

As conclusion of the study on impact of new generation granular insecticides on beneficial fauna of paddy ecosystem revealed that all the tested insecticides found effective in controlling the damage of rice crop due to pests by recording higher yields and lesser pest incidence over control. All the tested insecticides were found to be toxic to beneficial fauna which includes earthworms, nematodes, soil arthropods, predators and parasitoids of the ecosystem, while in case of dissipation studies both chlorantraniliprole 0.4 G and fipronil 0.3 G were found to be safe since their residues were BDL after fifth day in soil and two hours after application in water. The overall study revealed that chlorantraniliprole 0.4 G was found to be comparatively safer among the tested insecticides by recording the highest number of natural enemies and beneficial soil fauna; hence, chlorantraniliprole 0.4 G has to be emphasized in this context that can be recommended as the part of IPM programmes. Need based use of chemical insecticides or pocket/spot application is preferred and comparatively safe insecticide should be selected in order to conserve the beneficial fauna of the ecosystem to keep the biodiversity under safety and to avoid the contamination of soil and waters of the ecosystem. In future, further studies have to be taken up on the effect of the recommended new generation insecticides on soil micro arthropods and microbes to ensure ecological safety.

SUMMARY

6. SUMMARY

Widespread cultivation of high yielding and fertilizer responsive varieties over the decades have provoked the pest problems and altered the status of pests in rice. Screening is necessary to select the best and safe insecticide which could effectively smother the pests without affecting the natural enemies and beneficial soil fauna. The present study was carried out to assess the effect of recommended new generation granular insecticides on beneficial fauna of paddy ecosystem at recommended dose and double the recommended doses to ensure the ecological safety of these granular insecticides. The major findings of the study are summarized here.

Among the insect pests, stem borer, leaf folder and rice bugs were the major pests observed during the study. Fipronil 0.3 G at 10 kg ha^{-1} was found to result in lesser incidence of dead heart and white ear head followed by fipronil 0.3 G at 20 kg ha^{-1}. Fipronil 0.3 G at both the doses were found to be effective in managing stem borer infestation followed by cartap hydrochloride 4 G 50 kg ha^{-1}. Chlorantraniliprole 0.4 G at both doses (10 and 20 kg ha^{-1}) were found to be effective against leaf roller up to 45 DAT and fipronil 0.3 G (at 10 and 20 kg ha^{-1}) showed gradual reduction in leaf roller damage during the study period and was found to be effective at 60 DAT onwards at both the doses.

Chlorantraniliprole 0.4 G at both the doses (10 and 20 kg ha^{-1}) showed best results in reducing the adult stem borer population. Chlorantraniliprole 0.4 G at 20 kg ha^{-1} and cartap hydrochloride 4 G at 50 kg ha^{-1} recorded the lowest population of leaf roller at 30 DAT, but at 75 DAT cent per cent reduction in population was observed in the treatments *viz.,* chlorantraniliprole 0.4 G at 10 kg ha^{-1} and 20 kg ha^{-1} and fipronil 0.3 G 20 kg ha^{-1} which showed significant reduction in population of adult leaf roller.

At 90 DAT, chlorantraniliprole 0.4 G 20 kg ha^{-1} gave the best control of rice bugs. In case of minor pests *viz.,* grasshoppers and green leafhoppers fipronil 0.3 G at 20 kg ha^{-1} showed the best reduction followed by fipronil 0.3 G at 10 kg ha^{-1}.

The total pest population recorded in sweep net was significantly low in the treatment fipronil 0.3 G at 20 kg ha^{-1} followed by 10 kg ha^{-1}. Fipronil 0.3 G was found to be the most effective insecticide in reducing most of the rice pests at both the doses tested.

Among the new generation granular insecticides, chlorantraniliprole 0.4 G at both doses was found to be safe to natural enemies. The highest number of damselflies, ground beetles, spiders, coccinellids and other predators were recorded in the treatment chlorantraniliprole 0.4 G at 10 kg ha^{-1} followed by 20 kg ha^{-1}. The effect of treatments on parasitoids was found to be non significant throughout the period of observation and confirmed the safety of chlorantraniliprole 0.4 G to parasitoid population at both doses 10 and 20 kg ha^{-1} of application followed by cartap hydrochloride 4 G at recommended dose of 25 kg ha^{-1}.

Among the treatments chlorantraniliprole 0.4 G at 10 kg ha^{-1} recorded the highest population of soil fauna *viz.,* earthworms, free living nematodes, soil arthropods and snails followed by the same at double the recommended dose of 20 kg ha^{-1} which were on par with the control indicating the safety of chlorantraniliprole 0.4 G to soil fauna at both the doses of application. Fipronil 0.3G (10 and 20 kg ha^{-1}) and cartap hydrochloride 4 G (25 and 50 kg ha^{-1}) caused the highest reduction, indicating the toxicity of both granular insecticides on soil fauna at both the doses by recording least population of soil fauna.

Chlorantraniliprole 0.4 G at both doses (10 and 20 kg ha^{-1}) were revealed to be safe on observing the natural enemy population and also confirmed with the lowest P: D ratio of 0.59 to 0.93 and 0.54 to 0.92 respectively at both doses.

No significant difference in grain and straw yield was noticed among the treatments and control. However, the highest yield of 5.43 t ha^{-1} was recorded in the treatment chlorantraniliprole 0.4 G at 10 kg ha^{-1} followed by cartap hydrochloride 4 G at 50 kg ha^{-1} (5.42 t ha^{-1}) and fipronil 0.3 G at 20 kg ha^{-1} (5.33 t ha^{-1}). Chlorantraniliprole 0.4 G 10 kg ha^{-1} registered the highest straw yield of 12.83 t ha^{-1} followed by cartap hydrochloride 4 G and fipronil 0.3 G at double the recommended doses (12.58 and 12.17 t ha^{-1} respectively).

Results of the studies on residues revealed that the residues of the two best insecticides *viz.*, fipronil 0.3 G and chlorantraniliprole 0.4 G at the rate of 10 and 20 kg ha^{-1} respectively were found to be less toxic, as the residues of fipronil 0.3 G dissipated to below detectable limits (BDL) within 2 h after application indicating the less hazardous nature of its residues in both soil and water when applied in the form of granules. The residues of chlorantraniliprole 0.4 G dissipated to BDL at 2 h after treatment in water and 5 days after treatment in soil.

In conclusion, chlorantraniliprole 0.4 G was found to be comparatively safer among the tested insecticides and thus can be included as a component in IPM programmes. Need based use of chemical insecticides as pocket/spot application is preferred and comparatively safe insecticide should be selected in order to conserve the beneficial fauna of the ecosystem to keep the biodiversity under safety and to avoid the contamination of soil and waters of the ecosystem. As future line of work, further studies have to be taken up on the effect of the recommended new generation insecticides on soil micro arthropods and microbes to ensure ecological safety.

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ABSTRACT

IMPACT OF NEW GENERATION GRANULAR INSECTICIDES ON BENEFICIAL FAUNA OF PADDY ECOSYSTEM

by

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ABSTRACT

The research on "Impact of new generation granular insecticides on beneficial fauna of paddy ecosystem" was carried out at College of Agriculture, Vellayani during 2016-18 to study the effect of newly recommended granular insecticides on the non-target organisms *viz.,* parasitoids, predators and soil fauna of paddy ecosystem at recommended and double the recommended doses. The field experiment was done at Integrated Farming System Research Station (IFSRS), Karamana. Soil and water samples were tested to estimate residues and the degradation studies of the granular insecticides were also conducted.

A field experiment was conducted with the rice variety Uma. The treatments were chlorantraniliprole 0.4 G at 10 and 20 kg ha^{-1}, fipronil 0.3 G at 10 and 20 kg ha^{-1} and cartap hydrochloride 4 G at 25 and 50 kg ha^{-1}. Major pests *viz.,* stem borer, leaf roller and rice bug were recorded during the study. Among natural enemies major predators like damselflies, dragonflies, ground beetles, coccinellids and spiders were recorded and parasitoids of the order hymenoptera were observed. Soil fauna like ground beetles, water scavenger, ants, snails, spiders, nematodes and earthworms were recorded.

Results revealed that, among the new generation granular insecticides fipronil 0.3 G at both 10 kg ha^{-1} and 20 kg ha^{-1} was found to be effective and superior to other treatments in reducing the damage (2.33 and 2.79 per cent of dead hearts at 75 days and 5.63 and 4.07 per cent of white ear heads at 90 days after transplanting [DAT] respectively) and population of adult stem borer (0.67 and 0.33 at 75 DAT respectively). Leaf roller damage (2.00 and 1.85 per cent at 75 DAT respectively) and its population (0.00 and 0.00 at 75 DAT respectively) were reduced significantly with chlorantraniliprole 0.4 G at both recommended and double the recommended dose. Cartap hydrochloride 4 G at 25 kg ha^{-1} effectively reduced the rice bug population (10.63 and 6.33 at 75 and 90 DAT) among the recommended insecticides.

Among the new generation granular insecticides fipronil 0.3 G at 20 kg ha^{-1} followed by the recommended dose of 10 kg ha^{-1} was found to be toxic to natural enemies (predators of 10.33 and 13.33 at 75 days and parasitoids of 1.34 and 1.67 at 75 DAT) and soil fauna at all stages of the crop. Chlorantraniliprole 0.4 G at recommended dose of 10 kg ha^{-1} (21.67 of predators and 2.00 of parasitoids at 75 DAT) followed by double the recommended dose of 20 kg ha^{-1} (19.67 of predators and 1.34 of parasitoids at 75 DAT) were found to be safe to natural enemies and soil fauna. The P: D ratio of chlorantraniliprole 0.4 G (10 and 20 kg ha^{-1}) were 0.93 and 0.92 at 75 DAT respectively.

Dissipation of residues of selected insecticides fipronil 0.3 G and chlorantraniliprole 0.4 G was studied by analyzing the soil and water samples collected at 0, 1, 3, 5, 7, 10, 15 and 30 days after treatment with insecticides at recommended and double the recommended doses. The results revealed that fipronil 0.3 G at both doses dissipated within two hours (0 day) after treatment in both soil and water. Residues of chlorantraniliprole 0.4 G at both doses dissipated within two hours after treatment in water and five days after treatment in soil.

New generation insecticides fipronil 0.3 G (10 kg ha^{-1}), chlorantraniliprole 0.4 G (10 kg ha^{-1}) and cartap hydrochloride 4 G (25 kg ha^{-1}) were found effective against stem borer, leaf roller and rice bugs respectively. The present study revealed that among all the tested insecticides chlorantraniliprole 0.4 G at 10 kg ha^{-1} was safe to natural enemies and soil fauna with a low P: D ratio along with suppression of the insect pests.