# ECO-FRIENDLY MANAGEMENT OF MAJOR PESTS OF UPLAND RICE ECOSYSTEM

*by*

**SHOBHA, Y. B.**
**(2016-11-099)**

**THESIS**

**Submitted in partial fulfilment of the**
**requirements for the degree of**

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**2018**

# DECLARATION

I, hereby declare that this thesis entitled **"Eco-friendly management of major pests of upland rice 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 of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

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# CERTIFICATE

Certified that this thesis entitled **"Eco-friendly management of major pests of upland rice ecosystem"** is a record of research work done independently by Ms. Shobha Y. B. (2016-11-099) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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| | |
|---|---|
| @ | At the rate of |
| > | More than |
| % | Per cent |
| ANOVA | Analysis of Variance |
| a.i | Active ingredient |
| B:C | Benefit cost ratio |
| CD | Critical difference |
| cm | Centimetre |
| Cry | Crystal protein |
| DAS | Days after sowing |
| DAT | Days after treatment |
| *et al.* | and co-workers/co-authors |
| etc. | etsetra |
| EC | Emulsifiable concentrate |
| Fig. | Figure |
| G | Granule |
| g | Gram |
| g $kg^{-1}$ | Gram per kilogram |
| g $L^{-1}$ | Gram per litre |
| ha | Hectare |
| $ha^{-1}$ | Per hectare |
| *i.e.* | That is |
| kg | Kilogram |
| kg $ha^{-1}$ | Kilogram per hectare |
| KAU | Kerala Agricultural University |
| L | Litre |
| L $ha^{-1}$ | Litre per hectare |
| $LC_{50}$ | Lethal dose required for killing 50 per cent of test insect |
| $L^{-1}$ | Per litre |
| m-$^{1}$ | Per meter |

| | |
|---|---|
| $m^{-2}$ | Per meter square |
| mg | Milli gram |
| µg | Micro gram |
| mg $L^{-1}$ | Milligram per litre |
| mL | Millilitre |
| mL $acre^{-1}$ | Millilitre per acre |
| $mL^{-1}$ | Per millilitre |
| No. | Number |
| NS | Non significant |
| POP | Package of Practices |
| ppm | Parts per million |
| RBD | Randomised Block Design |
| SC | Soluble concentrate |
| Sl. No | Serial number |
| sp. | Species |
| *viz.* | Namely |

# INTRODUCTION

# 1. INTRODUCTION

In Asia, commonly cultivated rice *Oryza sativa* L. occupies more than one third of the world area. Rice is the chief and principal food crop supporting food security for more than half of the population (FAO, 2004) and livelihood security in India (Mondal and Chakraborty, 2016). In Asia, about 2.5 billion people depend on rice as the dominant food source. In the world, rice occupies a place in an area of 160.75 m ha with the production of 488.23 mMt (USDA, 2018). India occupies second place in area and production of rice after China with an area of 433.88 lakh ha and production of 104.32 m t. In Kerala rice is cultivated in an area of 1.71 lakh ha with production of 4.36 lakh t (GOI, 2017).

The wet land paddy area of Kerala has been reduced considerably during the previous years, thereby reducing rice production of the state. Recently as the farmers are getting assistance from various agencies and experiencing scarcity of food grains they are coming forward for cultivating rice both in wetland and uplands.

Rice fields are rapidly changing dynamic ecosystem with plenty of biodiversity of pests and natural enemies. There are reports of more than 128 insect pests infesting rice crop, out of which 15-20 are major. From sowing to harvesting rice crop is liable to be attacked by different pests. Every part of the crop is infested and in every stage from seedling to harvesting (Kalode, 2005). In upland rice, crop is commonly ravaged by major chewing and borer pests *viz.*, stem borer *Scirpophaga incertulas* (Walker) (Pyralidae), leaf roller *Cnapalocrosis medinalis* (Guenee) (Pyralidae) and hispa *Dicladispa armigera* (Oliver) (Chrysomelidae), blue beetle *Leptispa pygmaea* Baly. (Chrysomelidae) etc. and sucking pests like thrips *Stenchaetothrips biformis* (Bagnall) (Thripidae), rice bug *Leptocorisa acuta* (Fabricius) (Alydidae) and brown plant hopper *Nilaparvata lugens* (Stal)

(Delphacidae). The minor pests *viz.*, rice grass hopper *Hieroglyphus banian* Krauss (Acrididae), rice black bug *Scotinophora* sp. (F.) (Pentatomidae) etc. are also present. The yield loss due to the rice insect pests is about 27.99 per cent (Mondal and Chakraborty, 2016)

As rice is a commercial crop, farmers rely on chemical insecticides for the control of the insect pests. However, continuous use of the chemicals cause ecological imbalance (Tuan, 2014) by assassinating living organisms and their negative impingement is represented by 4 R's, i.e. residue, resurgence, resistance and risk. To come out of these problem, the best solution is use of eco-friendly methods of pest control including botanicals and microbial pesticides. The application of bio pesticides is the vital component in sustainable agriculture and greatest tactic in IPM due to ecofriendly nature and economic viability (David, 2008). In fact, botanical pesticides are well known from centuries and are emerging as prominent now a days.

In eco-friendly management of pests, botanicals are essential component and worthwhile due to low mammalian toxicity. Botanicals are the best alternative to conventional chemicals in pest management. Use of botanicals is now emerging as an important means of protection to crop produce and the environment from pesticidal pollution, which is a globally facing problem (Prakash *et al.*, 2008). Botanicals are either naturally occurring plant materials or products derived from such plant material. Neem is an efficient botanical in which whole plant is having toxic effect. Azadirachtin is the most efficacious compound in pest control and quite safer to natural enemies in paddy field (Samiayyan and Chandrasekharan, 1998). Dasagavya is an organic pesticide prepared from five cow products (Panchagavya) and extracts from five plants. It enhances the plant growth as well as effective in pest management particularly against sap feeders *viz.*, homopterans and thrips, leaf diseases *viz.*, leaf spot, blight, rust, powdery mildew etc (Prabhu, 2006). Cashew nut shell liquid (CNSL) is a phenolic compound resulted in growth deformities and delayed development of larva and pupa (Mahapatro, 2011). There is no risk of developing resistance as these pesticides are used in the natural forms. These are safer to non target organisms or less harmful as compared to synthetic insecticides.

Microbial agents have different mode of action and more effective as compared to botanicals. *Beauveria bassiana* Vuill. is an efficient entomopathogen which can be mass produced and safer to non- target organisms. It has well developed chitinolytic system necessary for pathogenicity of most lepidopteran pests (Coudron *et al.*, 1989). *Pseudomonas fluorescens* (Flugge) is the antagonistic bacteria, which also enhances plant growth (Commare *et al.*, 2002). *Bacillus thuringiensis* Berliner is the endospore forming bacteria with Cry toxin causing septicaemia of insect blood leading to death of the pest within 3-4 days of application.

Looking for the above mentioned facts and benefits, it is imperative to study and evaluate the bio pesticides in the field condition for management of major pests in upland rice.

In the above circumstances, the present study "Eco-friendly management of major pests of upland rice ecosystem" was carried out with the **objective to document the insect pests and natural enemies of upland rice and to develop an eco-friendly management strategy against major pests.**

# REVIEW OF LITERATURE

# 2. REVIEW OF LITERATURE

Rice is a fundamental food crop cultivated in India. Earlier, most of the agricultural area was covered with wetland rice. Now farmers are switching over to upland rice. Upland rice is a great niche for pest as well as natural enemies. Due to use of synthetic chemicals, the outbreak of minor pests and wiping out of beneficial fauna from biodiversity is emanating as new problem. So, to get rid of all this, safe way of pest management and conservation of biodiversity is foremost important. Literature on distribution and occurrence of different pests and natural enemies and efficacy of bio pesticides on pest and effect on natural enemies under upland cultivation are reviewed

## 2.1. SURVEY AND DOCUMENTATION OF PESTS AND NATURAL ENEMIES OF RICE

### 2.1.1. Insect pests documented from rice

Edirisinghe and Bambaradeniya (2006) studied the biodiversity of rice ecosystem and documented 10 phyla with 495 invertebrate species. From vertebrates, he recorded 103 species belongs to 5 classes and 53 families. The arthropods constituted 82% of terrestrial invertebrates, dominated with insects followed by spiders. All stages of rice attracted insects including leaf feeders, sap feeders, gall makers and borers.

There are five different stem borer species distributed throughout India. These are yellow stem borer (YSB), *Scirpophaga incertulas* (Walker), Pink Stem borer (PSB), *Sesamia inferens* (Walker), White stem borer (WSB), *Scirpophaga innotata* (Walker), Dark headed borer (DHB), *Chilo polychrysus* (Meyrick), Striped stem borer (SSB), *Chilo supressalis* (Meyrick). Among them, Stem borer *S. incertulus* was predominant, widespread and destructive in India. Other than that, Pink stem borer *Sesamia inferens* (Walker) was confined to rice wheat cropping system of North-west part. South Kerala was the chief habitat for white borer *Scirpophaga innotata* (Walker), dark headed borer *Chilo polychrysa* Meyr. and striped stem borer *Chilo suppressalis* Meyr. were distributed in West Bengal and Assam (Krishnaiah and Varma, 2011).

Pasalu in 2011 surveyed and documented hispa *D. armigera* from India and it was considered as major pests of rice from states of Assam, Bihar and Andra Pradesh.

Rahaman *et al.* (2014) examined the abundance of stem borers, natural enemies and their interaction at 3 different stages of crop at Bangladesh. There were five species of stem borer such as yellow stem borer *S. incertulas*, dark headed stem borer *C. polychrysa*, striped stem borer *C. supressalis,* pink stem borer *S. inferens*, and white stem borer *S. innotata* and nine natural enemies collected from the rice field. Higher incidence of stem borer and natural enemy population observed from tillering stage and the lowest was noticed from seedling stage. Yellow stem borer *S. Incertulas* was the abundant species from all. Rice bug *L. acuta* reported as major threat to rice crop under upland cultivation from Kerala (Mohan, 2014). Saini *et al.* (2017) documented six species of leaf roller from Tamil nadu of which *Cnaphalocrocis patnalis* Bradley, *C. medinalis* and *Cnaphalocrocis ruralis* (Walker) were more prevalent and destructive.

**2.1.2. Natural enemies documented from rice**

Way *et al.* (2002) studied the role of ants in controlling pests in upland rice. In upland rice, ants were found omnipresent. Fourteen species of ants were identified to be predating on rice pests of which *Solenopsis geminata* (F.) and *Tapinoma* sp. Forel were prominent. These ants commonly predate on BPH adults and eggs. Other than BPH, predation was noticed on leaf folder causing mortality of 97%.

Lekha (2003) documented the natural enemies of rice pests distributed in Thiruvananthapuram district of Kerala. Predators *viz., Micraspis crocea* Mulsant, *Paederus fuscipes* Curtis, *Ophionea nigrofasciata* Schmidt-Goebel, *Cyrtorhinus lividipennis* Reuter, *Polytoxus fuscovitattus* (Stal) and *Conocephalus* sp. Thunberg were documeneted from Kalliyoor panchayath of Thiruvananthapuram. There were three predatory spiders reported during survey includes *Tetragnatha* maxillosa Thorell, *Lycosa pseudoannulata* (Boesenberg and Strand) and *Oxyopes javanus* Thorell, Parasitoids *viz., Goniozus triangulifer* Kieffer, *Xanthopimpla flavolineata* Cameron and *Cotesia* sp. were documented. Among all, *G. triangulifer* was specific on rice leaf roller

The natural enemies of rice insect pest comprise 90 predatory species and 30 parasitoid species which maintained the natural balance between different organisms and played a crucial role in reducing pest damage and incidence (Edirisinghe and Bambaradeniya, 2006).

Gahari *et al.* (2008) conducted a survey in Iran to know the contribution of predators and parasitoids in controlling rice pests and saving biodiversity. About 25 predator species recorded from 7 orders and 11 families, 37 parasitoids from 2 orders and 8 families, of which 11 genera and 23 species were newly reported. Predator families includes Mantidae and Empusidae (Order: Mantodea), Gryllidae and Tettigonidae (Order: Orthoptera), Staphylinidae and Malachiidae (Order: Coleoptera), Forficulidae and Anisolabiidae (Order: Dermaptera), Chrysopidae (Order: Neuroptera) and Sphecidae (Order: Hymenoptera) and Macrochelidae (Order: Prostigmata, class: Acari). Parasitoids like Braconidae, Ichneumonidae, Chalcididae, Bethylidae and Trichogrammatidae from Hymenoptera and Phoridae, Sarcophagidae and Tachinidae

Ueno (2012) evaluated the abundance and biodiversity of natural enemies in Japanese rice ecosystem that natural enemies were bio indicators under rice ecosystem and observed that, judicious or less use of chemical pesticides is needed for conserving natural enemies in rice ecosystem. Insect natural enemies inhabiting rice paddies have an important function for rice production as agents of 'ecosystem services' because they play a major role in suppressing rice pests.

From the results of survey conducted by Rahaman *et al.* (2014),it has been proved that coccinellids were the abundant predators from rice field followed by long jawed spider, wolf spider, damselfly, carabids, green mirid bug, lynx spider, dragonfly and earwig. There was a positive correlation of stem borer and natural enemy population except carabids and earwig.

The abundance of spider in rice ecosystem from Thiruvananthapuram (Kerala) was studied by Anis and Premila (2016). About 65 species of spiders reported from families Tetragnathidae, Araenidae, Salticidae, Oxyopidae, Lycosidae etc., which include both hunters and web spinners. These were the chief predators in rice during whole crop period.

## 2.2. MANAGEMNETOF MAJOR PESTS OF RICE

### 2.2.1. Biopesticides

#### *2.2.1.1. Beauveria bassiana* Vuill.

Nghiep *et al.* (1999) tested entomophagous fungi on Brown plant hopper (BPH). They collected several isolates from *B. bassiana* and *Metarhizium anisopliae* Butt. infected on BPH and purified from different sites. From pathogenesity test, the yconcluded that *B. bassiana* at $6\times10^{12}$ spore $ha^{-1}$ was the most effective one against BPH at 7 days after application.

Loc and Chi (2005) isolated *B. bassiana* and *M. anisopliae* from naturally infected insects and tested pathogenicity on rice bug, *L. acuta.* At 14 days after application, field mortality ranged from 45.3-74.9 and 63.6-86.6 per cent from *B. bassiana* and *M. anisopliae* respectively.

Pathogenesity of *B. bassiana* to the *S. incertulas* under laboratory condition was reported by Dhuyo and Soomro (2008). Two isolates of *B. bassiana* (274 and 373) with spore count of $10^5$ to $10^9$ spore's $mL^{-1}$ were tested against stem borer recorded higher mortality and reduced fecundity. The isolate No.274 was more pathogenic than the isolate No.373 to control of larva and adult of *S. Incertulas* as well as egg hatching.

Isolation of 13 strains of *B.bassiana* from soil and infected insects was done by Sivasundaram *et al.* (2008). From all the 13 strains, B2 strain significantly reduced the leaf folder incidence (76.6 %) with conidial concentration of $1\times10^8$ c.f.u $mL^{-1}$ under laboratory condition. The effects showed altered feeding behaviour, pupal weight, prolonged pupation period, malformed pupa and adult under *in vitro* condition. Talc based formulation of *B. bassiana* also increased the concentration of peroxidase, polyphenol oxidase, phenylalanine ammonia-lyase, chitinase, and phenolics which were known to be defence related enzymes from rice.

The compatibility of *B. bassiana* (isolates BbCm KKL1100) along with 12 insecticides and 3 neem formulations was examined by Ambethgar *et al.* (2009). They had grown the culture on agar plate to develop suitable combination for control of rice insect pests in field. At 1X concentration carbofuran totally inhibited the mycelia growth. 0.1X concentration of NSKE, chlorpyriphos and dimethoate exhibited less mycelia inhibition. Hence, these could be used in combination with *B. bassiana* in field for pest control in rice.

The virulence of 2 isolates of *M. anisopliae* and 6 isolates of *B. bassiana* to BPH *N. lugens* eggs were tested by Li *et al.* (2012). One day old eggs were most sensitive to *B. bassiana* at standard concentration of $1\times10^8$ conidia $mL^{-1}$. The symptoms observed as shrunken egg, then changed to orange brown (*B. bassiana*) after 12 days of spraying.

An experiment was conducted by Tuan (2014) to evaluate the infection of *B. bassiana* on *L. acuta*. The population was significantly affected by *B. bassiana* at $1\times10^{12}$ conidia $ha^{-1}$ recorded 2.26 bugs $m^{-1}$, $1\times10^{13}$ conidia $ha^{-1}$ recorded 1.39 bugs $m^{-1}$. Malathion recorded 1.15 bugs $m^{-1}$ at 7days after treatment.

Talc formulated *B. bassiana* strain Bb5 was found to be effective against *C. medinalis* and *L. acuta* at $10^{10}$ spores $mL^{-1}$ was proven by (Nilamudeen, 2015). She proved that *B. bassiana* (Bb5 and Bb21) is compatible with chlorantraniliprole at different concentration *viz.*, 0.004, 0.006 and 0.008 %.

Sustainable management of leaf folder with *B. bassiana* ($1.3\times10^{6}$ conidia $mL^{-1}$), potassium silicate (50mg $L^{-1}$) and imidacloprid (75 mL $acre^{-1}$) were done by Shakir *et al.* (2015). Specific mode of action made all the treatments effective in elimination of pests. However, maximum mortality of 61.91 per cent was noted on combined application of potassium silicate, imidacloprid and *B. bassiana* after 20th day of application.

### *2.2.1.2. Pseudomonas fluorescens* Flugge.

Commare *et al.* (2002) tested the efficacy of *P. fluorescens* (12 g $kg^{-1}$) seeds against rice leaf folder of rice by different strains including PF1, FP7 (fluorescent pseudomonas strains) and its mixture with and without chitin. The population of leaf folder was reduced under field and green house condition by seed, root, soil and foliar application. There was a reduction in leaf folder incidence by 47.7–56.1 per cent, altered feeding behaviour and reduced larval and pupal weight in the mixture treatment of PF1 and FP7 strains containing chitin was noticed.

Plant growth promoting *P. fluorescens* strains Pt-1, TDK-1 and PY-15 were evaluated for their efficacy against leaf folder of rice by Sarankumar *et al.* (2008).

Applications of all three strains in combination significantly affected the leaf folder survival and also increased natural enemies population.

Saveetha *et al.* (2010) studied the interaction of *P. fluorescens* with leaf folder *C. medinalis* and rice plant. *P. fluorescens* TDK 1 was found to induce high degree of resistance in rice plant against leaf folder. Annotation and mapping of differentially expressed genes onto metabolic pathways revealed the interaction. The expression gene regulated the diverse metabolic processes by selective integration of defensive signals in rice plant.

### *2.2.1.3. Azadirachtin*

Kumar (2004) tried organic pest management in rice. He tested bio pesticides against major pests of rice. Among all, Neem seed kernal extract (NSKE 5%) reduced insect damage significantly such as silver shoot (6.92 %), dead heart (1.8 %), white ear head (6.28 %), leaf folder (6.23 %), hispa (6.2 %), caseworm (5.12 %), green leaf hopper (4.93 %) at 50 days after treatment. Finally results indicated that NSKE 5% provided most effective results in reducing pest complex incidence and recorded highest yield of 28.32 per cent. The B: C ratio recorded from NSKE was 2.5:1.

Gut enzyme activity of the leaf folder larva was affected by neem limonoids, azadirachtin, deacetylgedunin, gedunin17, hydroxyl adiradione and deacetylnimbin (Nathan *et al.*, 2005). Among all the alkaloids tested, azadirachtin was the most potent one by reducing weight of leaf folder by 59-89 per cent.

Prakash *et al.* (2008) assayed botanicals against some major pests of rice such as pink borer (*Chilo partellus* Swinhoe), rice ear head bug (*L. acuta*), leaf folder (*C. medinalis*) and white backed plant hopper (*Sogatella furcifera* Horvath). NSKE 4 % +Teepol 0.16 % inhibited the development of leaf folder and WBPH due to juvenile activity in immature stage. Neem oil reduced the leaf folder incidence and recommended soaking of rice seedling in NSKE for WBPH control. Antifeedent activity of neem cake 5% reduced the emergence of WBPH adults.

Chakraborty (2011) selected neem formulations against rice ear head bug, *L. acuta*. All the treatments significantly suppressed the incidence and extent of grain damage. Nimbidine 5 % reduced greater damage followed by neem oil 2 %, NSKE 5%, neem leaf extract 5 %, neem root extract 5% and neem bark extract 5 %.

Chakraborty (2012) estimated the efficacy of some selected insecticidal formulations on yellow stem borer *S. incertulas* and its natural enemies. Combined effect of flubendiamide 480SC, NSKE 5%, neem leaf extract 5%, deltamethrin1% and triazophos 35% showed best results.

Ogah *et al.* (2011) studied the effect of NSKE and Carbofuran in the management of stem borers in rice. Results showed that both the formulation significantly reduced the dead heart and white ear head damage. But the population of natural enemies was significantly more in the NSKE treated plots. Hence, NSKE was considered as a suitable alternative for the synthetic insecticides in order to increase the yield by reducing the pest infestation and increase the natural enemy population.

Reddy *et al.* (2013) conducted a field experiment to determine the comparative efficacy of leaf extracts of pongamia, custard, calotropis, NSKE and panchagavya at 5 and 7.5 % each and Acephate 75 SP at 1.5 gm $L^{-1}$ against hoppers in rice. Among the botanicals NSKE at 7.5 % showed higher efficacy in controlling rice hoppers.

The incidence of stem borer, *S. incertulas* was assessed with the relative efficacy of three selected plant extracts which included neem, tobacco, akando and two chemical insecticides dimethoate and fipronil by Mondal and Chakraborty (2016). There was a reduction in dead heart and white ear incidence by 38.33 and 48.14 per cent respectively in the neem extract applied plants. The result indicated that plant based formulation of insecticide especially neem effectively reduced *S. incertulas* infestation compared to chemical insecticides.

Ashly *et al.* (2017) studied the ecofriendly products against rice pests. Azadirachtin 1% at 750 mL $ha^{-1}$ at 70DAS furnished a good control of stem borer. This was followed by Bt 200 g $ha^{-1}$. Azadirachtin 1% was superior in control of case worm and leaf folder also followed by fish amino acid 3 L $ha^{-1}$.

### *2.2.1.4. Dasagavya*

Dasagavya was found to be effective in controlling sucking pests like aphids, white flies, thrips and mites and some foliage feeders (Prabhu, 2006).

Dasagavya 3 per cent was effective in controlling the pests and diseases in floral crops (POP KAU, 2016).

### *2.2.1.5. Bacillus thuringiensis* **Berliner**

Saika *et al.* (2002) released egg parasitoid *Trichogramma chilonis* Ishii *at* 50,000 $ha^{-1}$ and applied *Bacillus thuringiensis* var. *galleriae* (1 kg $ha^{-1}$) Buprofezin 25WP (200 g a.i. $ha^{-1}$), Neem seed kernal extract (NSKE 5%) and Monocrotophos 36 SL (0.5 g a.i. $L^{-1}$) to test the efficacy against rice leaf folder *C. medinalis.* Good results delivered from 4 inundative releases of *T. chilonis* followed by spraying monocrotophos 3 times. But natural enemies were adversely affected due to monocrotophos toxicity and hence recommended inundative release of *T. Chilonis* followed by Bt, NSKE and Buprofezin alone or combination in reducing the leaf folder incidence.

Singh (2005) studied the bio efficacy of native isolates of *B. thuringiensis* against leaf folder *C. medinalis*. From 22 isolates selected, 3 isolates such as BtK4, BtC5 and BtJ showed higher mortality (more than 55%) and reduced weight of larva and pupa. This was also effective in suppressing fecundity of female at higher concentration.

Chen *et al.* (2008) assayed the effect of *B. thuringiensis* against rice stem borers by selecting genes Cry IAc-2, Cry 2A-3 and Cry 9c-5 with 10 lines. Yellow stem borer *S. incertulas* and Asiatic stem borer *C. supressalis* were affected by all the 10 lines. Feeding behaviour of 7 days old larva of *C. supressalis* was affected.

Singh *et al.* (2008) investigated synthetic insecticides, bio pesticides, botanicals and their combination on yellow stem borer and leaf folder. Minimum incidence of both yellow stem borer and leaf folder was noted in the treatments cartap hydrochloride 4G at 0.75 kg a.i. $ha^{-1}$ and Imidacloprid 17.8 SL at 0.05%. But these insecticides adversely affected the spider survival. So, Bt and *B. bassiana* were considered to be effective in controlling pests and conserving spider population.

Chakraborty and Rath (2011) tested the efficacy of some bio pesticides against rice leaf folder. The leaf folder incidence from different treatments ranged from 0.2-1.5 larva $hill^{-1}$ and 0.2-5.9 per cent damaged leaves. Larval population of 0.2 larva $hill^{-1}$ and 0.2 per cent damage was observed on spraying Bt formulation Dipel 3.5% at 4 mL $ha^{-1}$ followed by neem formulation nimbecidine 2% at 4 mL $L^{-1}$ (0.3 larva $hill^{-1}$ and 1.7 per cent damage ), NSKE 5% (0.4 larva $hill^{-1}$ and 2.1 per cent damage) and neem leaf extract 2% (0.5 larva $hill^{-1}$ and 2.8 per cent damage). The percentage increase in yield from Bt was 36.6.

### *2.2.1.6. Cashew nut shell liquid*

Effect of CNSL on coconut root grub *Leucopolis coneophora* Bur. was studied by John *et al.* (2008). He used different concentration of CNSL (5, 10, 20 and 25%) and followed drenching of soil having root grubs. All treatments of CNSL from 5 -25 % resulted in cent per cent mortality of grubs.

Olotuah and Ofuya (2010) tested ethanolic extract of cashew nut shell liquid against cowpea pests like *Maruca testulalis* (F.), *Aphis craccivora* Koch. and *Ootheca mutabilis* (Schonherr) by comparing with insecticide Cypermethrin. CNSL 1% was proved to be more effective as Cypermethrin (Cymbush), showing comparatively protective ability against pest attack by reducing pest population and flower infestation and recorded high yield.

Mahapatro (2011) tested the insecticidal properties of CNSL against *Helicoverpa armigera* (Hubner) and *Spilarctia oblique* (Walker) in laboratory. CNSL 1% was effective against *H. armigera* with deformed larva. Delayed larval and pupal development was also observed.

***2.2.1.7. Fish jaggery extract***

Fish jaggery extract at 6 mL $L^{-1}$ was found to be effective in controlling rice bug *L. acuta* in rice (KAU, 2016).

**2.2.2. Synthetic pesticides**

***2.2.2.1. Chlorantraniliprole***

The control effect of chlorantraniliprole 20 SC on *C. medinalis* and its safety to beneficial arthropods were studied by Fang *et al.* (2009). A mortality of 40 and 100 per cent was observed at 24 and 96 hours after treatment. Under plot and field experiment mortality of leaf roller recorded from chlorantraniliprole reached 90.59 and 97.07 per cent respectively within 14 days after treatment.

LianWei *et al.* (2010) studied the effect of diamides against rice leaf folder *C. medinalis* at booting stage. The results indicated that application of chlorantraniliprole 20SC at 150 mL $ha^{-1}$ reduced the leaf folder population by 75.2 per cent after 3 days and 91.2 per cent after 15 days of application.

Efficacy of chlorantraniliprole was evaluated at 10, 20, 30 and 40 g a.i. ha$^{-1}$ and comparison was made with thiocyclam hydrogen oxalate at 400 g a.i. ha$^{-1}$ and the check insecticide chlorpyrifos 25 WP at 500 g a.i. ha$^{-1}$ against stem borers and leaf folder infesting rice and the results showed that chlorantraniliprole provided an effective control of stem borers at concentration of 40 g a.i. ha$^{-1}$ (1.62% dead hearts and 2.00% white-ears) (Suri, 2011).

Zhao *et al.* (2012) studied the effect of chlorantraniliprole against predatory mirid bug *C. lividipennis* by rice stem dipping method. From the results, it was seen that amount of predation reached 163.03, 104.21 and 102.45 per cent of egg, first instar and second instar nymph respectively proved to be safe to predator.

Suri and Brar (2013) reported that chlorantraniliprole at 40 g ha$^{-1}$ provided an effective control of stem borers (1.48 per cent dead hearts and 2.05 per cent white ear heads), which was on par with its higher dose of 50 g a.i. ha$^{-1}$ (1.36 per cent dead hearts and 1.88 per cent white ear heads).

Kartikeyan and Christy (2014) tested the efficacy of chlorantraniliprole 18.5 EC (150 mL ha$^{-1}$) against rice pests along with Triazophos (750 and 250 ml ha$^{-1}$), Sulfoxyflor (313 and 375 mL ha$^{-1}$), buprofezin (800 mL ha$^{-1}$), acephate (660g ha$^{-1}$) and monocrotophos (1390 mL ha$^{-1}$). The pooled results of two crop seasons revealed that chlorantraniliprole at 150 mL ha$^{-1}$ was the most effective treatment against major rice pests like yellow stem borer, leaf folder and case worm by reducing damage and increasing grain yield.

Sarao and Kaur, (2014) conducted a field experiment to test the efficacy of chlorantraniprole 0.4% G (Ferterra) against stem borer and leaf folder of basmati rice. At 70 days after transplanting (DAT) the concentration of 40 and 50 g a.i ha$^{-1}$ significantly reduced the dead heart and leaf folder symptoms. At 80 DAT at the same concentration reduced the white ear head damage effectively.

Efficacy of new insecticide chlorantraniliprole 0.4 G and 18.5 SC (Rynaxypyr) against rice leaf folder was compared with emamectin benzoate 5 SG along with recommended insecticides like fipronil, carbofuran and profenophos. Rynaxypyr 0.4 G at 50 g a.i. $ha^{-1}$ presented the best result by minimizing the damage (80.27 and 86.12 per cent reduction over control) with increased grain yield (51and 55 q $ha^{-1}$). (Chanu and Sontakke, 2015).

Chlorantraniliprole exhibited better control of stem borer at vegetative stage from both granular and spray formulations. Application at peak activity of borers reduced the dead heart incidence to 8.33-9.05 per cent against 24.57 per cent in control. At panicle initiation stage, it was highly effective in reducing white ear head damage with 2.62 and 3.73 per cent respectively. Sprayable formulation of chlorantraniliprole had least adverse effect on natural enemies like spiders (Sahu, 2016).

Saini *et al.* (2016) tested the efficacy of chlorantraniliprole 20 SC against yellow stem borer, *S. incertulas* at different concentrations. Superior results were obtained from the concentration of chlorantraniprole 20 SC at 180 mL $ha^{-1}$ with infestation of 0.47 per cent and 40.35 q $ha^{-1}$ grain yield. This was followed by chlorantraniprole 20 SC at 150 mL $ha^{-1}$. Hence Chlorantraniprole 20 SC at 180 mL $ha^{-1}$ can be used for the management of yellow stem borer.

Omprakash *et al.* (2017) evaluated the comparative efficacy of insecticides against yellow stem borer. He observed 1.9 and 2.5 per cent dead heart and 0.7 and 1.0 per cent white ear heads from chlorantraniliprole 0.4G at 10 kg $ha^{-1}$ and chlorantraniliprole 18.5 SC at 150 mL $ha^{-1}$ respectively. However, the highest yield was recorded from the treatment chlorantraniliprole 0.4G at 10 kg $ha^{-1}$.

#### *2.2.2.2. Malathion*

Jena *et al.* (1999) selected 12 new insecticides to control rice bug, *L. acuta*. The experiment was conducted both in field and green house. From the treatment selected Malathion caused good knock down effect followed by methyl parathion, quinalphos etc. He also observed non persistency of Malathion in the environment.

Dey *et al.* (2012) studied the effectiveness of different pesticides *viz.*, carbofuran 3 G at 9 kg acre$^{-1}$, monocrotophos 40 WSC at 1.25 L ha$^{-1}$, phorate 10 G at 9 kg acre$^{-1}$, Malathion 57 EC at 2.5 L acre$^{-1}$, dimethoate 40 EC at 0.875 L ha$^{-1}$, chlorpyriphos 40 EC at 500 mL acre$^{-1}$ and cypermethrin 10 EC at 0.625 L acre$^{-1}$ and botanicals like NSKE 5% and neem oil 0.5% against leaf folder. All insecticides showed mortality of leaf folder ranging from 71.22 to 96.62 per cent after 24 hrs of spray. From all, Malathion was the best treatment in controlling pest effectively.

Gupta and Kumar (2017) studied the efficacy of Malathion against rice bug. From the treatment, population of 2.84 bugs per hill was recorded in the treatment Malathion 50 EC as against 3.51 bugs per hill.

### 2.2.3. Effect of bio pesticides on natural enemies of rice pests

Pathogenicity of *B. bassiana* (9.471 spore mL$^{-1}$) was studied by Pingel and Lewis, 1996. He had proven that *B. Bassiana* was non-pathogenic and safer to natural enemies of *S. Incertulus* present in field.

Commercial neem pesticides *viz.*, Neemax, Rakshak and Fortune Aza were safer to predators of BPH (Jhansilakshmi *et al.*, 1997) and egg parasitoids in rice (Srinivasan *et al.*, 2001). Crude extracts of neem *viz.*, neem oil and neem cake had been safer to natural enemies of rice pests compared to synthetic insecticides (Dash *et al.*, 2001).

Commare *et al.*, 2002 proven that population of natural enemies of rice leaf folder including hymenopteran parasitoids (*Goniozus* sp. Forster, *Brachymeria* sp. Westwood and *Apanteles* sp. Foerster) and spiders (Wolf and Lynx spider) were enhanced with talc formulated *P. fluorescens*.

Natural enemies of BPH like *C. lividipennis* and *Anagrus nilaparvatae* (Pang et Wang) showed the least mortality of 6.67 per cent from chlorantraniliprole 20 SC and safer to beneficial arthropods in rice ecosystem than conventional chemicals (Fang *et al.*, 2009).

Joseph *et al.* (2010) evaluated the safety of neem products and chemical pesticides to tetragnathid spiders *Tetragnatha mandibulata* Walckenaer and *T. maxillosa* in rice ecosystem. Among neem products NSKE was the best with less mortality of predatory spider. Neem oil 50 mL $L^{-1}$ in combination with neem leaf extract (5%) and Novuluron (50 g a.i. $ha^{-1}$) were found to be less harmful to predatory bugs, odonata and coccinellids. This was followed by NSKE 5% (Chakraborty, 2011).

NSKE 5% supported highest number of natural enemies viz., *Conocephalus* sp., *O. javanus*, *Goniozus indicus* (Ashmead), *Bracon* sp. (F.) and *Trichogramma japonicum* Ashmead etc. in rice ecosystem (Ogah *et al.* 2011).

*B. thuringiensis* at 1kg a.i. $ha^{-1}$ treatment in rice crop recorded the highest and superior population of natural enemies *viz.*, coccinellids, chrysopids. odonata and spiders (Chormule *et al.*, 2014).

# MATERIALS AND METHODS

# 3. MATERIALS AND METHODS

The present study entitled "Eco-friendly management of major pests of upland rice ecosystem" has been carried out in Onattukara Regional Agricultural Research Station, Kayamkulam and farmers fields in Alapuzha district.

As part of the programme, the following studies were made.

1. Detailed survey to document the pests and natural enemies of upland rice in Alapuzha district

2. A field experiment to study the eco-friendly management of stem bore, leaf roller and gall midge in upland rice ecosystem

3. A field experiment to study the eco-friendly management of BPH and rice bug in upland rice

## 3.1 SURVEY AND DOCUMENTATION OF PESTS AND NATURAL ENEMIES OF UPLAND RICE IN ALAPUZHA DISTRICT.

A survey was conducted during first crop season of 2017 in the major areas of Alapuzha district where upland cultivation of rice is being carried out. Six fields each having an area not less than 0.5 acre of rice under upland cultivation were selected for the survey. The six selected locations include Charumoodu, Chennithala, Haripad, Muthukulum, Oachira and Thazhakkara.

The survey was conducted at two stages of the crop *viz.,* tillering (40-45 DAS) and flowering (70-75 DAS) stages. Standard sampling procedures were followed for recording the incidence of pests and natural enemies. The mean per cent of damage caused by major pests *viz.,* stem borer, leaf roller and sweep net collection of pests and natural enemies were taken from each plot. Ten sweeps each were taken from each plot. Observations like per cent damage by stem borer and leaf roller and population of pests and natural enemies per ten sweeps were recorded.

The methodology adopted for recording observations of pests and their associated natural enemies is given in Table 1 and their scoring is given in Table 2.

## 3.2. MANAGEMENT OF STEM BORER, LEAF ROLLER AND GALL MIDGE IN UPLAND RICE

A field experiment was conducted in the upland of Onattukara Regional Agricultural Research Station, Kayamkulam for drawing out an eco-friendly management strategy against stem borer, leaf roller and gall midge in upland rice. The experiment was conducted during first crop season of 2017.

The experiment was laid out in a randomised block design using the short duration variety Bhagya with nine treatments replicated thrice. A spacing of 15cm between rows and 10 cm between plants was adopted with a plot size of 5Mx2 M. All the other agronomic practices were followed according to the Package of Practices recommendations of Kerala Agricultural University (KAU, 2016). General view of experimental plot is given in Plate 1

**Treatments**

**$T_1$**-Talc formulated *B. bassiana* ITCC 6063 – 2 %

**$T_2$**-1% Azardirachtin 0.003 %

**$T_3$**-Cashewnut shell liquid 0.1 %

**$T_4$**-Fish jaggery extract 0.6 %

**$T_5$**-Dasagavya 3 %

**$T_6$**-Chitin based Pseudomonas 2.5 kg $ha^{-1}$

**$T_7$**- *Bacillus thuringiensis* 0.04 %

**$T_8$**- Chlorantraniliprole 18.5 SC 0.005 % (Insecticide check)

**$T_9$**-Untreated control


**Plate 1. Field view of experiment on management of stem borer, leaf roller and gall midge in upland rice**

**Plate 2. Field view of experiment on management of BPH and rice bug in upland rice**

Table 1. Method for recording observations on pests and associated natural enemies

| Pests/natural enemies | Method of observation |
|---|---|
| Rice stem borer | 1. Number of dead heart/white ear head out of ten hills selected at random and arriving at the mean percent damage<br>2. Number of adult moths per ten sweeps |
| Rice leaf roller | 1. Number of damaged leaves out of ten hills selected at random and arriving at the mean percent damage<br>2. Mean number of adult moths per ten sweeps |
| Rice bug | Number of adults and nymphs per ten sweeps |
| Rice hispa and Rice leptispa, | Number of adults per ten sweeps |
| Predators | Number of adults per ten sweeps |
| Parasitoids | Number of adults per ten sweeps |

Table 2. Score on population/level of damage by the pests and associated natural enemies

| Name of the pest/damage/natural enemy | Scale/score | | | |
|---|---|---|---|---|
| | Nil (0) | Low (1) | Medium (2) | High (3) |
| Rice stem borer | No incidence | 0.1 to 25 per cent dead heart/white ear head | 25 to 50 per cent dead heart/white ear head | >50 per cent dead heart/white ear head |
| Rice leaf roller | No incidence | 0.1 to 25 per cent damaged leaves | 25 to 50 per cent damaged leaves | >50 per cent damaged leaves |
| Rice stem borer and Leaf roller adults | No population | 0.1to 2.5 adults | 2.6 to 5 adults | >5 adults |
| Rice bug | No population | 0.1to 2.5 adults and nymphs | 2.6 to 5 adults and nymphs | >5 adults and nymphs |
| Rice hispa and leptispa | No population | 0.1to 2.5 adults | 2.6 to 5 adults | >5 adults |
| Predators | No population | 0.1to 2.5 adults | 2.6 to 5 adults | >5 adults |
| Parasitoids | No population | 0.1 to 2.5 adults | 2.6 to 5 adults | >5 adults |

The treatments were applied at three intervals *viz.*, 30, 50 and 70 days after sowing.

**3.2.1. Preparation of organic pesticides**

***3.2.2.1. Talc formulated B. bassiana ITCC 6063 -2 %***

The talc based formulation of *Beauveria bassiana* ITCC 6063 from Kerala Agricultural University was used for the experiment. The commercial formulation contains spore count of $1\times10^{8}$ cfu $g^{-1}$ $mL^{-1}$ for effective control of pest (Sudharma, 2011). Twenty gram *B. bassiana* was dissolved in one litre water along with 1 mL Teepol was applied as spreader.

***3.2.2.2. 1% Azadirachtin - 0.003%***

The commercial product Econeem Plus, the neem based EC formulation contain 1% (1000 ppm) Azadirachtin was used for the experiment at 3mL $L^{-1}$ of water.

***3.2.2.3. Cashew nut shell liquid (CNSL) 0.1%***

CNSL is a natural resin prepared by cold press or solvent extraction from cashew nut shell. For spray application 1 mL of CNSL was dissolved in 1L water. Teepol 1% was added to improve efficacy.

***3.2.2.4. Fish jaggery extract 0.6%***

Fish jaggery extract was prepared using sardine fish and jaggery (1:1 wt). This was prepared by keeping fish and jaggery in alternate layers for 20 days. The spray fluid was prepared by diluting 6 mL of extract in 1L water.

*3.2.2.5. Dasagavya 3%*

Dasagavya was prepared by mixing panchagavya with 5 plant extracts. Panchagavya was prepared by mixing fresh cow dung (700 g) with ghee (100 g) in a plastic bucket. One litre of Cow urine and water each were added after 2 days and kept for incubation under room temperature for 13 days. Cow milk (300 mL), curd (200 mL), tender coconut water 300 mL, jaggery 300 g and ripen banana (1 No.) were added. Allowed all the ingredients to ferment for 6 days. Chopped leaves (200 g each) of five plants *viz., Lantana camara* L., *Datura stramonium* L., *Calotropis gigantia* L., *Azadirachta indica* L., and *Ocimum basilicum* L. were soaked in cow urine in 1:1 ratio for 10 days. The extract was filtered and mixed with 10 L of water. This plant extract was mixed with panchagavya at 5:1 ratio (Chandrashekaraiah and Sannaveerappanava, 2013). The spray fluid was prepared by mixing 30 mL in 1 L water.

***3.2.2.6. Chitin based Pseudomonas 2.5 kg ha$^{-1}$***

The Chitin based Pseudomonas at 2% concentration was used for spraying (KAU, 2016). The commercial formulation of Chitin based Pseudomonas (Pseudo chitinase plus) was used in this experiment.

***3.2.2.7. Bacillus thurengensis 0.04%***

The commercial formulation of Bt (Mahastra 0.5WP) containing 2.5 $\times 10^{11}$ viable spores per gram was used in this experiment. The spray fluid was prepared by diluting 4g B.t. in 1 L water.

***3.2.2.8. Chlorantraniliprole 0.005%***

The commercial formulation Coragen 18.5SC was taken as insecticide check treatment. Dissolving 0.3 mL of chlorantraniliprole in 1 L of water was done to obtain 0.005% spray liquid.

### 3.2.3. Observations of per cent damage and population of stem borer, leaf roller and gall midge

Post treatment observations were recorded at 5, 7 and 10 days after each application. Both the observations of damage and population were recorded at each occasion as explained in Table 1 and 2. From the data the per cent damage calculated as given below

1. Dead heart / white ears (%) = $\frac{\text{Total number of dead hearts/white ears}}{\text{Total number of tillers/panicles}} \times 100$

2. Leaf roller (%) = $\frac{\text{Number of leaves rolled in a hill}}{\text{Total number of leaves from hill}} \times 100$

3. Silver shoot (%) = $\frac{\text{Total number of silver shoot}}{\text{Total number of tillers}} \times 100$

From sweeping, observations were recorded by counting the number of insect pests and natural enemies by taking 10 sweeps diagonally.

### 3.2.4. Yield

The crop was harvested at 90 days after sowing. The harvested crop was threshed, cleaned and weighed. After 3 days of drying, dry weight of straw and grain was taken and expressed in t $ha^{-1}$.

### 3.2.5. Analysis and assessment of results

The data generated through field experiment were transformed and statistically analyzed by using software WASP.

3.3. MANAGEMNET OF BROWN PLANT HOPPER (BPH) AND RICE BUG IN UPLAND RICE.

A second field experiment was conducted in Onnatukara Regional Agricultural Research Station, Kayamkulam for studying eco-friendly management strategy against brown plant hopper and rice bug of upland rice during Rabi season of 2017.

The experiment was laid out in randomized block design with seven treatments and three replications. Variety and all agronomic practices followed were as same as mentioned in 3.2. General view of experimental plot is given in Plate 2. The treatments were applied twice at 50 and 70 days after sowing.

**Treatments**

**$T_1$**-1% Azadirachtin 0.003%

**$T_2$**-Chitin based Pseudomonas 2.5 kg $ha^{-1}$

**$T_3$**-Cashewnut shell liquid 0.1%

**$T_4$**-Fish jaggery extract 0.6%

**$T_5$**- Dasagavya 3%

**$T_6$**-Malathion 50 EC @ 0.1%

**$T_7$**-Untreated control

Malathion 50 EC @ 0.1% was prepared by dissolving 2 mL in 1L of water. Preparation of other treatments were same as mentioned in 3.2.3.

**3.3.2. Observations of per cent damage and population of brown plant hopper and rice bug**

Post treatment observations were recorded at 5, 7 and 10 days after each application. Both the observations of damage and population were recorded. At each occasion as explained in Table 1 and 2. From the data the per cent damage calculated as given below.

$$\% \text{ Rice bug} = \frac{\text{Number of grains infected in a panicle}}{\text{Total number of grains in a panicle}} \times 100$$

From sweeping, observations were recorded by counting the number of insect pests and natural enemies by taking 10 sweeps diagonally.

### 3.3.3. Yield

The same procedure explained in 3.2.5 was followed for recording yield.

### 3.3.4. Analysis and assessment of results

For analysis of data, same procedure followed as in 3.2.5.

# RESULTS

# 4. RESULTS

The results of the research work entitled "Ecofriendly management of major pests of upland rice ecosystem" carried out during 2016-18 in Onnatukara Regional Agricultural Research Station, Kayamkulam are presented below.

## 4.1. SURVEY AND DOCUMENTATION OF PESTS AND NATURAL ENEMIES OF UPLAND RICE IN ALAPUZHA DISTRICT.

### 4.1.1. Information on the varieties cultivated by farmers under upland rice in Alapuzha district

The data revealed that four varieties *viz.,* Onam, Bhagya, Uma and Jyothi were grown by the farmers in the six locations under this study. Bhagya and Jyothi were grown in two locations each while Onam and Uma were grown in one location each. Among the six locations, Bhagya was grown in Haripad and Thazhakkara, while Jyothi was grown in Chennithala and Muthukulum. Onam was grown in Oachira, while Uma was grown in Charumoodu (Table 3).

### 4.1.2. Incidence of pests observed in upland rice ecosystem in Alapuzha

The data on the insect pests observed in upland rice is given in Table 4. During early stages of crop growth (40-45 DAS) infestation of leaf roller (*C. medinalis*) and stem borer (*S. incertulas*) were observed (Plate 3 and 4). Adult moths of *S. incertulas, C. medinalis*, rice hispa *D. armigera* and blue beetle *L. pygmaea* were also observed from the fields surveyed.

Of the six locations surveyed, damage by leaf roller was recorded from all the six locations. Stem borer was the second major one having infestation in 5 locations followed by minor pests *viz.,* rice hispa in two locations and leptispa in one location.

a. Larva

b. Adult

c. Dead heart

d. White ear head

**Plate 3. Stem borer, *Scirpophaga incertulas***

a. Larva

b. Adult

c. Leaf damage

**Plate 4. Leaf roller *Cnaphalocrocis medinalis***

Table 3. Rice varieties cultivated by farmers under upland rice in Alapuzha district

| Variety | Number of locations | Name of locations |
|---|---|---|
| Onam | 1 | Oachira |
| Bhagya | 2 | Haripad and Thazhakkara |
| Uma | 1 | Charumoodu |
| Jyothi | 2 | Chennithala and Muthukulum |

Table 4. Insect pests observed in upland rice from six locations of Alapuzha district

| Stage of the crop | Name of the pest | Number of locations | Percentage |
|---|---|---|---|
| 40-45 DAS | *Scirpophaga incertulas* | 5 | 83.0 |
| | *Cnaphalocrocis medinalis* | 6 | 100.0 |
| | *Dicladispa armigera* | 2 | 33.3 |
| | *Leptispa pygmaea* | 1 | 17.0 |
| 70-75 DAS | *Scirpophaga incertulas* | 6 | 100.0 |
| | *Cnaphalocrocis medinalis* | 6 | 100.0 |
| | *Leptocorisa acuta* | 5 | 83.0 |
| | *Dicladispa armigera* | 2 | 33.3 |
| | *Leptispa pygmaea* | 1 | 17.0 |

During flowering stage (70-75 DAS) also stem borer and leaf roller infestation were noticed from all the six locations followed by rice bugs from 5 locations (Plate 6). Leptispa was recorded from single location. Hispa was not recorded at reproductive stage in any of the locations.

The predominance of pests and natural enemies were categorised into four groups *viz.*, no incidence, low, medium and high. Data on the occurrence of insect pests in upland rice fields in Alapuzha district is presented in the Table 5.

### *4.1.2.1. Incidence of pests at 40-45 DAS*

The data presented in Table 5 revealed that no infestation was observed in one location, while five locations recorded mild infestation of stem borer. However, none of the locations recorded medium or high infestation.

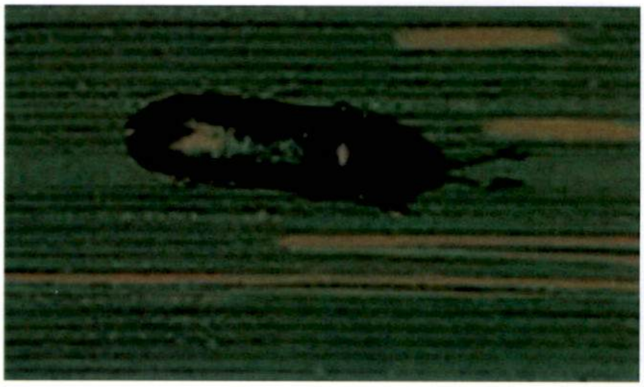
The infestation by leaf roller was observed in low intensities in all the six locations surveyed. None of the locations escaped from leaf roller infestation. As in the case of stem borer, none of the locations recorded medium or high infestation. Adult leaf roller population was recorded in low intensities only in two locations.

The population of rice hispa was observed only in two locations each with low and medium intensities. Only one location out of six recorded blue beetle (Leptispa) population in low intensity. Rice bug population was not recorded in any of the location at 40-45 DAS.

### *4.1.2.2. Incidence of pests at 70-75 DAS*

At 70-75 DAS, infestation by stem borer and leaf roller was observed in low intensities in all the six locations. Adult stem borer population was observed in two locations in low intensities, while adult leaf roller population observed in five out of six locations in low intensities.

*Dicladispa armigera*



*Leptispa pygmaea*

**Plate 5. Minor pests in upland rice ecosystem of Alapuzha district**

*Leptocorisa acuta*

**Plate 6. Rice bug and its infestation in field**

Table 5. Damage/Population of pests at intervals after sowing in upland rice of Alapuzha district

| Pest/Damage | Population /Damage intensity | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 40-45 DAS | | | | 70-75 DAS | | | |
| | Nil | Low | Medium | High | Nil | Low | Medium | High |
| Stem borer damage (%) | 1 | 5 | 0 | 0 | 0 | 6 | 0 | 0 |
| Leaf roller damage (%) | 0 | 6 | 0 | 0 | 0 | 6 | 0 | 0 |
| *Stem borer | 6 | 0 | 0 | 0 | 4 | 2 | 0 | 0 |
| *Leaf roller | 4 | 2 | 0 | 0 | 1 | 5 | 0 | 0 |
| *Rice bug | 6 | 0 | 0 | 0 | 1 | 3 | 2 | 0 |
| *Hispa | 4 | 1 | 1 | 0 | 6 | 0 | 0 | 0 |
| *Leptispa | 5 | 1 | 0 | 0 | 5 | 1 | 0 | 0 |

* adults 10 $sweeps^{-1}$

Percentage stem borer and leaf roller damage incidence: Nil: 0, Low: 0.1-25%, Medium: 26-50% and High: >50%

No. of adults per 10 sweeps (Stem borer, Leaf roller, Rice bug, Hispa and Leptispa); Nil: 0,

Low: 0.1-2.5, Medium: 2.6-5.0, High: >5.0

DAS: Days after sowing

Rice bug population was recorded in five out of six locations surveyed. Three locations recorded rice bug population in low intensities and two in medium intensities. The population of blue beetle was recorded from single location in low intensities. However, hispa infestation was recorded from any of the locations.

### 4.1.3. Incidence of natural enemies associated with upland rice pests in Alapuzha district

The incidence of natural enemies associated with pests of upland rice in farmers fields of Alapuzha district were recorded during two growth stages *viz.*, 40-45 DAS and 70-75 DAS. Spiders, dragonflies, damselflies, *Ophionea nigrofasciata, Paederus* sp. and *Micraspis* sp. were observed to be the predominant predators in the fields surveyed. Among them, spiders were the major ones followed by dragon flies, damsel flies, gryllids, *Ophionea* sp. and *Paederus* sp. (Plate 7).

Among the parasitoids, *Tetrastichus* sp. was the predominant one. *Goniozus nephantidis* and *Cotesia* sp. were the other parasitoids (Plate 8).

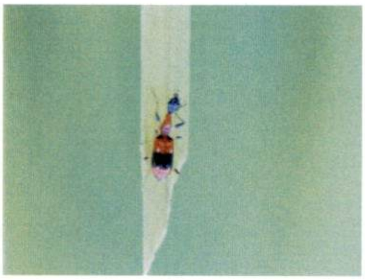
Data on the natural enemies associated with pests of upland rice in Alapuzha district are presented in the Table 6.

#### *4.1.3.1. Incidence of natural enemies at 40-45 DAS*

At early stage, no spider population was observed in one location. Spiders were observed in low intensities in three locations and medium intensities in two locations out of six locations surveyed. High population was recorded in none of the locations surveyed.

Regarding the incidence of dragonflies, no incidence was recorded in 4 locations, low and medium population was observed in one and two locations respectively. However, high population was recorded in none of the fields.

*Paederus* sp.



*Ophionea nigrofasciata*

*Micraspis discolor*

*Tetragnatha* sp.

*Argiope* sp.

*Argiope* sp.

**Plate 7. Predators recorded from upland rice in Alapuzha district**

*Cotesia* sp.

*Goniozus nephantidis*

*Tetrastichus* sp.

**Plate 8. Parasitoids recorded from upland rice in Alapuzha district**

Table 6. Population of natural enemies at intervals after sowing in upland rice of Alapuzha district

| Natural enemy | Population intensity at intervals | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | 40-45 DAS | | | | 70-75 DAS | | | |
| | Nil | Low | Medium | High | Nil | Low | Medium | High |
| **1. Predators** Spiders | 1 | 3 | 2 | 0 | 1 | 5 | 0 | 0 |
| Dragonflies | 3 | 1 | 2 | 0 | 4 | 2 | 0 | 0 |
| Damselflies | 4 | 2 | 0 | 0 | 4 | 2 | 0 | 0 |
| *Ophionea* sp. | 4 | 2 | 0 | 0 | 4 | 2 | 0 | 0 |
| *Paederus* sp. | 5 | 1 | 0 | 0 | 6 | 0 | 0 | 0 |
| *Micraspis* sp. | 6 | 0 | 0 | 0 | 2 | 4 | 0 | 0 |
| Gryllids | 5 | 1 | 0 | 0 | 6 | 0 | 0 | 0 |
| **2.Parasitoids** | 6 | 0 | 0 | 0 | 0 | 0 | 1 | 5 |

Predators / Parasitoids (Adults 10 $sweeps^{-1}$); Nil: 0, Low: 0.1-2.5, Medium: 2.6-5.0, High: >5.0
DAS: Days after sowing

In case of damselflies, two locations recorded low population and no incidence was recorded from the remaining 4 locations. Only one location recorded the low incidence of *Paederus* sp. and gryllids.

All the six locations recorded no population of parasitoids.

#### *4.1.3.2. Incidence of natural enemies at 70-75 DAS*

At flowering stage also the same species of natural enemies recorded at 40-45 DAS were present. Spiders were present from five locations in low intensities. None of the fields recorded the spider population in medium and high intensities. No spider population at all was recorded in one location.

Dragon flies, damsel flies and *Ophionea* sp. were recorded from two locations in low intensities and no incidence was recorded from remaining four locations. The population of *Micraspis* sp. was recorded from four locations in low intensities and no population recorded in two locations. *Paederus* sp. was absent in all the locations surveyed. There was high incidence of parasitoids in five locations surveyed and medium incidence from remaining one location.

## 4.2. MANAGEMENT OF STEM BORER, LEAF ROLLER AND GALL MIDGE IN UPLAND RICE

The different eco-friendly pesticides were tested against yellow stem borer *S. incertulas* and leaf roller *C. medinalis.*

### 4.2.1. Efficacy of different organic pesticides in management of stem borer at different growth stages of the crop

Per cent dead heart incidence by stem borer was recorded and given in Table 7.

Table 7. Damage by stem borer at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean per cent damage 10 hills$^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Dead heart (%)- 30 DAS | | | Dead heart (%)- 50 DAS | | | White ear head (%)-70 DAS | | |
| | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10 DAT |
| Talc formulated *B. bassiana* 2% | 0.86 (1.05) | 1.06 (1.12) | 0.98 (1.09) | 1.28[b] (1.17) | 1.06[b] (1.12) | 0.69[b] (1.01) | 1.30[b] (1.18) | 1.52[b] (1.34) | 1.58[b] (1.34) |
| Azadirachtin 0.003% | 0.44 (0.92) | 2.12 (1.51) | 0.62 (0.98) | 1.46[b] (1.21) | 1.61[b] (1.36) | 0.50[b] (0.95) | 2.07[b] (1.49) | 1.48[b] (1.33) | 0.07[b] (0.75) |
| Cashew nut shell liquid 0.1% | 0.0 (0.70) | 0.0 (0.70) | 0.68 (1.01) | 0.26[b] (0.85) | 0.22[b] (0.83) | 0.16[b] (0.80) | 0.26[b] (0.85) | 0.58[b] (0.96) | 0.18[b] (0.81) |
| Fish jaggery extract 0.6% | 0.21 (0.82) | 0.42 (0.91) | 0.58 (0.96) | 0.43[b] (0.91) | 0.34[b] (0.89) | 0.43[b] (0.91) | 0.23[b] (0.83) | 0.90[b] (1.14) | 0.32[b] (0.88) |
| Dasagavya 3% | 0.0 (0.70) | 0.07 (0.75) | 0.83 (1.05) | 0.29[b] (0.86) | 0.51[b] (0.94) | 0.29[b] (0.87) | 0.34[b] (0.88) | 0.28[b] (0.85) | 0.44[b] (0.92) |
| Chitin based pseudomonas 2.5 kg ha$^{-1}$ | 0.42 (0.92) | 0.45 (0.92) | 0.56 (0.97) | 0.41[b] (0.91) | 0.41[b] (0.91) | 0.22[b] (0.82) | 0.92[b] (1.11) | 0.77[b] (1.03) | 0.53[b] (0.97) |
| *B. thuringiensis* 0.04% | 0.25 (0.84) | 0.66 (0.99) | 0.72 (1.07) | 0.71[b] (1.02) | 1.33[b] (1.18) | 0.85[b] (1.12) | 1.2[b] (1.14) | 1.34[b] (1.29) | 1.0[b] (1.21) |
| Chlorantraniliprole 0.005% | 0.0 (0.70) | 0.0 (0.70) | 0.71 (1.02) | 0.41[b] (0.91) | 0.78[b] (1.03) | 0.33[b] (0.87) | 0.40[b] (0.90) | 0.20[b] (0.81) | 0.24[b] (0.84) |
| Untreated control | 1.82 (1.40) | 2.07 (1.50) | 3.56 (2.02) | 5.53[a] (2.43) | 6.32[a] (2.58) | 3.27[a] (1.94) | 11.69[a] (3.45) | 8.36[a] (2.97) | 4.18[a] (2.15) |
| CD (0.05%) | NS | NS | NS | 0.845 | 0.845 | 0.589 | 1.018 | 0.771 | 0.606 |

Figures in parenthesis are $\sqrt{x+1}$ transformed values, DAS- Days after sowing, DAT- Days after treatment

#### *4.2.1.1. Per cent dead heart incidence at 30 DAS*

The mean per cent of dead hearts at 5, 7 and 10 days after first spray at 30 DAS is given in Table 7. However, statistical analysis of the data revealed that, no significant difference was observed among treatments at 5, 7 and 10 days after first spray at 30 DAS. No dead heart symptom was observed in the treatments cashew nut shell liquid 0.1% and chlorantraniliprole 0.005% at 5 and 7 days after treatment.

#### *4.2.1.2. Per cent dead heart incidence at 50 DAS*

At five days after treatment, significant reduction in dead heart symptom was observed in all the treatments compared to control. The lowest incidence was observed in the treatment cashew nut shell liquid 0.1% with 0.26 per cent damage which was on par with the treatments dasagavya 3%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, chlorantraniliprole 0.005%, fish jaggery extract 0.6%, *B. thuringiensis* 0.04%, talc formulated *B. bassiana* ITCC 6063-2% and azadirachtin 0.003% with 0.29, 0.41, 0.41, 0.43, 0.71, 1.28 and 1.46 per cent damage respectively.

Similar trend was observed at 7 DAT also. Cashew nut shell liquid 0.1% recorded significantly low incidence over control and was on par with treatments fish jaggery extract 0.6% (0.34%), chitin based Pseudomonas 2.5 kg $ha^{-1}$(0.41%), dasagavya 3% (0.51%), chlorantraniliprole 0.005% (0.78%), talc formulated *B. bassiana* ITCC 6063-2% (1.06%), *B. thuringiensis* 0.04% (1.33%) and azadirachtin 0.003% (1.61%). The highest incidence was recorded in control with 6.32% incidence.

At 10 DAT also cashew nut shell liquid 0.1% recorded significantly low dead heart incidence (0.16%) over control (3.27%) and which was on par with all the treatments *viz.,* chitin based Pseudomonas 2.5 kg $ha^{-1}$(0.22%), dasagavya 3% (0.29%), chlorantraniliprole 0.005% (0.33%), fish jaggery extract 0.6% (0.43%), azadirachtin 0.003% (0.50%), talc formulated *B. bassiana* ITCC 6063-2% (0.69%) and *B. thuringiensis* 0.04% (0.85%).

#### *4.2.1.3. Per cent white ear head incidence at 70 DAS*

At 5 DAT, although all the treatments recorded significantly low incidence of white ear head symptoms over control (11.69), the treatment fish jaggery extract 0.6% recorded the lowest incidence of white ear head (0.23%).This was on par with cashew nut shell liquid 0.1%, dasagavya 3%, chlorantraniliprole 0.005%, chitin based Pseudomonas 2.5 kg ha$^{-1}$, *B. thuringiensis* 0.04%, talc formulated *B. bassiana* ITCC 6063-2% and azadirachtin 0.003% with 0.26, 0.34, 0.40, 0.92, 1.30 and 2.07 per cent white ear head incidence.

At 7 DAT also significant reduction in white ear head damage was observed in all the treatments over control (8.36%). The treatment chlorantraniliprole 0.005% recorded the lowest damage of 0.20% which was on par with dasagavya 3% (0.28%), cashew nut shell liquid 0.1% (0.58%), chitin based Pseudomonas 2.5 kg ha$^{-1}$ (0.77%), fish jaggery extract 0.6% (0.90%), *B. thuringiensis* 0.04% (1.34%), azadirachtin 0.003% (1.48%) and talc formulated *B. bassiana* ITCC 6063-2% (1.52%). Control plot recorded the 8.36% white ear head incidence.

Similarly at 10 DAT, all the treatments were significantly superior over control (4.18%). However, the lowest white ear head incidence was observed in the treatment azadirachtin 0.003% with 0.07% incidence which was on par with cashew nut shell liquid 0.1%, chlorantraniliprole 0.005%, fish jaggery extract 0.6%, dasagavya 3%, chitin based Pseudomonas 2.5 kg ha$^{-1}$, *B. thuringiensis* 0.04% and talc formulated *B. bassiana* ITCC 6063-2% with damage of 0.18, 0.24, 0.32, 0.44, 0.53, 1.00 and 1.58% respectively.

### 4.2.2. Efficacy of organic pesticides in management of leaf roller at different growth stages of the crop

The data on mean per cent of damage by leaf roller at different intervals after treatment are presented in Table 8.

#### *4.2.2.1. Per cent of leaf roller damage at 30 DAS*

At five days after treatment, all the treatments recorded significantly low incidence of leaf roller damage over control (4.39%). However, the lowest damage of 0.31 per cent was recorded in the treatments *B. thuringiensis* 0.04% and chlorantraniliprole 0.005%. These treatments were on par with cashew nut shell liquid 0.1%, talc formulated *B. bassiana* ITCC 6063- 2%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, azadirachtin 0.003%, dasagavya 3% and fish jaggery extract 0.6% with per cent damage of 0.45, 0.55, 1.21, 1.32, 1.85 and 1.91 respectively.

At seven days after treatment, there was significant reduction in leaf roller damage in all the treatments over control. The treatment fish jaggery extract 0.6% recorded 0.33 per cent reduction in damage which was on par with chlorantraniliprole 0.005%, azadirachtin 0.003%, talc formulated *B. bassiana* ITCC 6063-2%, cashew nut shell liquid 0.1% with per cent damage of 0.31, 0.32, 0.75 and 0.78 respectively. Untreated control recorded the highest damage of 5.67 per cent.

All the treatments recorded significant reduction in leaf roller damage over control (6.86%) at 10 days after treatment. However, the lowest damage of 0.43% was observed in the treatment fish jaggery extract 0.6% which was on par with *B. thuringiensis* 0.04% (0.72%), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (0.84%), azadirachtin 0.003% (0.92%), talc formulated *B. bassiana* ITCC 6063-2% (1.05%), cashew nut shell liquid 0.1% (1.11%), dasagavya 3% (1.42%) and chlorantraniliprole 0.005% (1.38%).

Table 8. Damage by leaf roller at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean per cent damage 10 hills$^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 50 DAS | | | 70 DAS | | |
| | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10 DAT |
| Talc formulated *B. bassiana* 2% | $0.55^{b}$ (0.96) | $0.75^{bcd}$ (1.09) | $1.05^{b}$ (1.16) | $1.18^{b}$ (1.26) | $2.29^{bc}$ (1.60) | $10.94^{a}$ (3.38) | $2.07^{b}$ (1.50) | $2.65^{b}$ (1.76) | $2.57^{b}$ (1.73) |
| Azadirachtin 0.003% | $1.32^{b}$ (1.36) | $0.32^{bcd}$ (0.89) | $0.92^{b}$ (1.15) | $1.57^{b}$ (1.43) | $0.32^{c}$ (0.89) | $1.63^{b}$ (1.42) | $2.19^{b}$ (1.59) | $2.23^{bc}$ (1.66) | $2.03^{bc}$ (1.59) |
| Cashew nut shell liquid 0.1% | $0.45^{b}$ (0.87) | $0.78^{bcd}$ (1.10) | $1.11^{b}$ (1.20) | $0.92^{b}$ (1.16) | $1.11^{bc}$ (1.24) | $1.14^{b}$ (1.22) | $1.69^{b}$ (1.48) | $1.18^{bcd}$ (1.30) | $1.05^{cd}$ (1.10) |
| Fish jaggery extract 0.6% | $1.91^{b}$ (1.50) | $0.33^{d}$ (0.87) | $0.43^{b}$ (0.92) | $0.51^{b}$ (0.99) | $0.35^{c}$ (0.92) | $0.84^{b}$ (1.10) | $1.53^{b}$ (1.42) | $0.47^{cd}$ (0.98) | $0.37^{d}$ (0.93) |
| Dasagavya 3% | $1.85^{b}$ (1.43) | $1.00^{bc}$ (1.22) | $1.42^{b}$ (1.28) | $1.23^{b}$ (1.31) | $2.08^{b}$ (1.55) | $2.07^{b}$ (1.55) | $1.24^{b}$ (1.32) | $0.30^{d}$ (0.9) | $1.62^{bcd}$ (1.45) |
| Chitin based pseudomonas2.5 kg ha$^{-1}$ | $1.21^{b}$ (1.12) | $1.07^{bc}$ (1.24) | $0.84^{b}$ (1.12) | $1.54^{b}$ (1.35) | $2.35^{b}$ (0.67) | $1.42^{b}$ (1.38) | $2.05^{b}$ (1.56) | $1.26^{bcd}$ (1.32) | $2.07^{bc}$ (1.59) |
| *B. thuringiensis* 0.04% | $0.31^{b}$ (0.87) | $1.69^{b}$ (1.38) | $0.72^{b}$ (1.01) | $1.55^{b}$ (1.35) | $1.54^{bc}$ (1.33) | $0.95^{b}$ (1.16) | $2.19^{b}$ (1.61) | $1.08^{bcd}$ (1.27) | $1.12^{bcd}$ (1.22) |
| Chlorantraniliprole 0.005% | $0.31^{b}$ (0.87) | $0.31^{cd}$ (0.87) | $1.38^{b}$ (1.28) | $0.64^{b}$ (1.04) | $0.66^{bc}$ (1.04) | $1.27^{b}$ (1.30) | $0.74^{b}$ (1.08) | $1.35^{bcd}$ (1.35) | $1.16^{bcd}$ (1.23) |
| Control | $4.39^{a}$ (2.20) | $5.67^{a}$ (2.47) | $6.86^{a}$ (2.66) | $6.43^{a}$ (2.63) | $6.37^{a}$ (2.6) | $10.81^{a}$ (3.36) | $12.63^{a}$ (3.60) | $13.98^{a}$ (3.76) | $11.76^{a}$ (3.48) |
| CD (0.05) | 0.750 | 0.496 | 0.606 | 0.730 | 0.658 | 1.582 | 0.627 | 0.716 | 0.537 |

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

#### *4.2.2.2. Per cent of leaf roller damage at 50 DAS*

At five days after second treatment, there was significant reduction of leaf roller damage in all the treatments compared to control. Fish jaggery extract 0.6% recorded the least damage of 0.51% followed by chlorantraniliprole 0.005%, cashew nut shell liquid 0.1%, talc formulated *B. bassiana* ITCC 6063-2%, dasagavya 3%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, *B. thuringiensis* 0.04% and azadirachtin 0.003% which were found to be on par and with damage of 0.64, 0.92, 1.18, 1.23, 1.54, 1.55 and 1.57% respectively. The maximum damage of 6.43% was recorded from control.

At 7 DAT the treatment azadirachtin 0.003% (0.32%) was significantly superior over control (6.37%) and on par with other treatments *viz.,* fish jaggery extract 0.6% (0.35%), chlorantraniliprole 0.005% (0.66%), cashew nut shell liquid 0.1% (1.11%), *B. thuringiensis* 0.04% (1.54%) and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (2.35%).

Significant reduction in leaf roller damage over control (10.81%) at ten days after treatment was recorded from the treatment fish jaggery extract 0.6% (0.84%) and found to be on par with *B. thuringiensis* 0.04%, cashew nut shell liquid 0.1%, chlorantraniliprole 0.005%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, azadirachtin 0.003% and dasagavya 3% with 0.95, 1.14, 1.27, 1.42, 1.63 and 2.07% incidence respectively.

#### *4.2.2.3. Per cent of leaf roller damage at 70 DAS*

At five days after treatment, though significant reduction in leaf roller incidence was observed in all the treatments, chlorantraniliprole 0.005% was the one with the lowest incidence of 0.74 per cent damage. This was on par with the treatments dasagavya 3%, fish jaggery extract 0.6%, cashew nut shell liquid 0.1%, talc formulated *B. bassiana* ITCC 6063-2%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, azadirachtin 0.003% and *B. thuringiensis* 0.04% which recorded 1.24, 1.53, 1.69, 2.07, 2.19 and 2.19 % damage respectively. The highest incidence was recorded in control with 12.63% damage.

There was significant reduction in leaf roller incidence over control (13.98%) at seven days after treatment. The lowest incidence was observed in the treatment dasagavya 3% (0.30%) which was on par with fish jaggery extract 0.6% (0.47%), *B. thuringiensis* 0.04% (1.08%), cashew nut shell liquid 0.1% (1.18%), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.26%) and chlorantraniliprole 0.005% (1.35%).

At ten days after treatment, the per cent damage by leaf roller was significantly reduced in the treatment fish jaggery extract 0.6% with damage of 0.37%. This was found to be on par with cashew nut shell liquid 0.1%, *B. thuringiensis* 0.04%, chlorantraniliprole 0.005% and dasagavya 3% with damage of 1.05, 1.12, 1.16 and 1.62 per cent respectively. No significant reduction over control was observed in treatments *viz.*, azadirachtin 0.003%, chitin based Pseudomonas 2.5 kg $ha^{-1}$ and talc formulated *B. bassiana* ITCC 6063-2% with 2.03, 2.07 and 2.57% incidence. Untreated control plot recorded the highest damage of 11.7% and all other treatments superior over control.

### 4.2.3. Efficacy of organic pesticides in management of gall midge at different growth stages of the crop

There was no incidence of gall midge in the experiment.

### 4.2.4. Efficacy of organic pesticides on population of pests and natural enemies at different growth stages of the crop

#### *4.2.4.1. Stem borer*

The population of adult stem borer was recorded by counting the number in 10 sweeps. The result is presented in Table 9.

#### 4.2.4.1.1. Stem borer (Treatment at 30 DAS)

At 5 days after treatment zero population of adult stem borer was observed in the treatment cashew nut shell liquid 0.1%. There was significant reduction in stem borer population in the treatments azadirachtin 0.003%, fish jaggery extract 0.6%, dasagavya 3% and chlorantraniliprole 18.5 SC 0.005% (0.67), talc formulated *B. bassiana* ITCC 6063-2% and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.0) compared to control. No significant reduction in population was recorded by the treatment *B. thuringiensis* 0.04% (1.33) and was on par with control (2.67).

Chlorantraniliprole 18.5 SC 0.005% and *B. thuringiensis* 0.04% recorded significantly low population of adult stem borer (0.33) at seven days after treatment. This was on par with the treatments fish jaggery extract 0.6% (0.67) and cashew nut shell liquid 0.1% (0.67). No significant reduction in population was recorded in treatments *viz.,* dasagavya 3%, talc formulated *B. bassiana* ITCC 6063-2% and azadirachtin 0.003% with mean population of 1.67, 1.67 and 2.0 respectively. Control plot recorded the highest mean population of 4.33.

At ten days after treatment, significant reduction in adult stem borer was observed in the treatment cashew nut shell liquid 0.1% (0.33). This was on par with the treatments *B. thuringiensis* 0.04% (0.67), chlorantraniliprole 18.5 SC 0.005%, fish jaggery extract 0.6% and dasagavya 3% (1.0). The treatments *viz.,* talc formulated *B. bassiana* ITCC 6063-2% (1.67) and azadirachtin 0.003% (2.0)

Table 9. Population of adult stem borer at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean population of adult stem borer 10 sweeps $^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 50 DAS | | | 70 DAS | | |
| | 5DAT | 7DAT | 10 DAT | 5DAT | 7DAT | 10DAT | 5DAT | 7DAT | 10DAT |
| Talc formulated *B. bassiana* 2% | 1.0$^{bc}$ (1.18) | 1.67$^{bc}$ (1.46) | 1.67$^{b}$ (1.46) | 0.67$^{b}$ (1.05) | 1.67$^{bc}$ (1.46) | 2.0$^{bc}$ (1.56) | 3.33$^{ab}$ (1.93) | 3.33$^{b}$ (1.93) | 2.33$^{b}$ (1.68) |
| Azadirachtin 0.003% | 0.67$^{bc}$ (1.05) | 2.00$^{b}$ (1.56) | 2.00$^{ab}$ (1.56) | 1.00$^{b}$ (1.18) | 1.33$^{bc}$ (1.35) | 2.33$^{bc}$ (1.68) | 1.67$^{bcd}$ (1.46) | 2.67$^{bc}$ (1.76) | 2.00$^{b}$ (1.56) |
| Cashew nut shell liquid 0.1% | 0.0$^{c}$ (0.70) | 0.67$^{bcd}$ (1.05) | 0.33$^{c}$ (0.88) | 0.33$^{b}$ (0.88) | 0.67$^{c}$ (1.05) | 0.67$^{c}$ (1.05) | 0.67$^{d}$ (0.99) | 0.67$^{c}$ (1.05) | 1.00$^{b}$ (1.18) |
| Fish jaggery extract 0.6% | 0.67$^{bc}$ (1.05) | 0.67$^{bcd}$ (1.05) | 1.00$^{bc}$ (1.18) | 0.33$^{b}$ (0.88) | 1.00$^{bc}$ (1.18) | 0.33$^{bc}$ (0.88) | 0.67$^{cd}$ (1.05) | 1.00$^{bc}$ (1.18) | 1.33$^{b}$ (1.27) |
| Dasagavya 3% | 0.67$^{bc}$ (1.05) | 1.67$^{bc}$ (1.46) | 1.00$^{bc}$ (1.23) | 1.00$^{b}$ (1.18) | 1.33$^{bc}$ (1.35) | 0.67$^{c}$ (0.99) | 1.67$^{bcd}$ (1.44) | 1.33$^{bc}$ (1.29) | 1.67$^{b}$ (1.46) |
| Chitin based pseudomonas 2.5kg ha-1 | 1.00$^{bc}$ (1.18) | 0.60$^{cd}$ (1.0) | 1.33$^{bc}$ (1.35) | 1.33$^{b}$ (1.35) | 1.33$^{bc}$ (1.35) | 1.33$^{bc}$ (1.29) | 2.00$^{cd}$ (1.58) | 1.67$^{bc}$ (1.38) | 1.67$^{b}$ (1.44) |
| *B. thuringiensis* 0.04% | 1.33$^{ab}$ (1.35) | 0.33$^{d}$ (0.88) | 0.67$^{bc}$ (1.05) | 0.67$^{b}$ (1.05) | 2.00$^{b}$ (1.58) | 1.33$^{bc}$ (1.35) | 2.33$^{bc}$ (1.68) | 2.67$^{bc}$ (1.74) | 1.67$^{b}$ (1.44) |
| Chlorantraniliprole 0.005% | 0.67$^{b}$ (1.05) | 0.33$^{d}$ (0.88) | 1.00$^{bc}$ (1.18) | 0.33$^{b}$ (0.88) | 0.67$^{c}$ (1.0) | 0.67$^{c}$ (1.0) | 0.67$^{d}$ (1.0) | 1.67$^{bc}$ (1.38) | 1.33$^{b}$ (1.29) |
| Control | 2.67$^{a}$ (1.77) | 4.33$^{a}$ (2.18) | 3.67$^{a}$ (2.03) | 3.33$^{a}$ (1.95) | 4.33$^{a}$ (2.18) | 4.33$^{a}$ (2.19) | 5.67$^{a}$ (2.42) | 11.33$^{a}$ (3.44) | 11.33$^{a}$ (3.43) |
| CD (0.05) | 0.530 | 0.539 | 0.522 | 0.578 | 0.516 | 0.564 | 0.661 | 0.782 | 0.641 |

Figures in parenthesis are $\sqrt{x+1}$ transformed values, DAS- Days after sowing, DAT- Days after treatment recorded no significant reduction in population of adult stem borer. Control recorded the highest mean population of 3.67.

**4.2.4.1.2. Stem borer (Treatment at 50 DAS)**

At 5 days after treatment, all the treatments recorded significant reduction in population of adult stem borer over control (3.33). However the lowest population was recorded in the treatments fish jaggery extract 0.6%, cashew nut shell liquid 0.1% and chlorantraniliprole 18.5 SC 0.005% with 0.33 adults which were on par with treatments talc formulated *B. bassiana* ITCC 6063-2% and *B. thuringiensis* 0.04% (0.67), azadirachtin 0.003% and dasagavya 3% (1.0) and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.33).

At seven days after treatment, though all the treatments recorded significant reduction in population of adult stem borer, chlorantraniliprole 18.5 SC 0.005% and cashew nut shell liquid 0.1%, recorded the lowest population (0.67). This was on par with the treatments fish jaggery extract 0.6% (1.00), azadirachtin 0.003% (1.33), dasagavya 3% (1.33), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.33), talc formulated *B. bassiana* ITCC 6063-2% (1.67) and *B. thuringiensis* 0.04% (2.00). The highest population was recorded by control (4.33).

At ten days after treatment, all the treatments recorded significant reduction in population over control except azadirachtin 0.003%. Significantly low population was recorded from the treatments fish jaggery extract 0.6% (0.33) which was on par with the treatments dasagavya 3%, chlorantraniliprole 18.5 SC 0.005%, and cashew nut shell liquid 0.1% with population of 0.67 and chitin based Pseudomonas 2.5 kg $ha^{-1}$ and *B. thuringiensis* 0.04% with 1.33. The treatments, talc formulated *B. bassiana* ITCC 6063-2% and azadirachtin 0.003% recorded no significant reduction in population, with mean population of 2.0 and 2.33 respectively. Control plot recorded a mean population of 4.3

#### 4.2.4.1.3. Stem borer (Treatment at 70 DAS)

At five days after treatment, all the treatments recorded significant reduction in population of adult stem borer compared to control (5.67) except talc formulated *B. bassiana* ITCC 6063-2% (3.33) and *B. thuringiensis* 0.04% (2.33). However the lowest mean population of 0.67 was recorded from the treatments chlorantraniliprole 18.5 SC 0.005%, cashew nut shell liquid 0.1% and fish jaggery extract 0.6%. This was found to be on par with dasagavya 3%, azadirachtin 0.003% (1.67) and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (2.0).

All the treatments except talc formulated *B. bassiana* ITCC 6063-2% (3.33) recorded significantly low population of stem borer adults over control (11.33) at seven days after treatment. The lowest population was observed in the treatment cashew nut shell liquid 0.1% (0.67) which was on par with fish jaggery extract 0.6%, dasagavya 3%, chlorantraniliprole 18.5 SC 0.005%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, *B. thuringiensis* 0.04% and azadirachtin 0.003% with mean population of 1.0, 1.33, 1.67, 1.67, 2.67 and 2.67 respectively..

At ten days after treatment, significant population reduction was observed in all the treatments with least record from cashew nut shell liquid 0.1% (1.00) which was on par with fish jaggery extract 0.6% and chlorantraniliprole 18.5 SC 0.005% (1.33), *B. thuringiensis* 0.04%, chitin based Pseudomonas 2.5 kg $ha^{-1}$ and dasagavya 3% (1.67), azadirachtin 0.003% (2.00) and talc formulated *B. bassiana* ITCC 6063-2% (2.33). The highest population was recorded from untreated control (11.33).

### 4.2.4.2. Leaf roller

The population of adult leaf roller was recorded and represented in Table 10.

Table 10. Population of adult leaf roller at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean population of adult leaf roller 10 sweeps $^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 50 DAS | | | 70 DAS | | |
| | 5DAT | 7DAT | 10 DAT | 5DAT | 7DAT | 10DAT | 5DAT | 7DAT | 10DAT |
| Talc formulated *B. bassiana* | $1.00^{bc}$ (1.18) | $2.0^{ab}$ (1.56) | $3.00^{a}$ (1.86) | $0.67^{bc}$ (1.0) | $1.00^{bc}$ (1.18) | $2.67^{ab}$ (1.77) | $2.33^{b}$ (1.68) | $4.00^{b}$ (2.11) | $2.00^{b}$ (1.556) |
| Azadirachtin | $2.33^{ab}$ (1.68) | $1.0^{bc}$ (1.18) | $2.00^{ab}$ (1.56) | $1.00^{ab}$ (1.29) | $0.33^{bc}$ (0.88) | $1.33^{bcd}$ (1.35) | $1.67^{b}$ (1.38) | $2.00^{cd}$ (1.56) | $1.00^{bc}$ (1.23) |
| Cashew nut shell liquid | $0.33^{c}$ (0.88) | $0.33^{c}$ (0.88) | $1.00^{b}$ (1.23) | $0.67^{cd}$ (1.05) | $1.00^{bc}$ (1.18) | $0.67^{cd}$ (1.05) | $1.00^{b}$ (1.18) | $1.00^{de}$ (1.18) | $0.67^{c}$ (1.05) |
| Fish jaggery extract | $0.33^{c}$ (0.88) | $0.67^{bc}$ (1.05) | $0.67^{b}$ (1.05) | $0.33^{d}$ (0.88) | $0.67^{bc}$ (1.05) | $0.33^{d}$ (0.88) | $1.00^{b}$ (1.28) | $0.67^{e}$ (1.05) | $1.0^{bc}$ (1.23) |
| Dasagavya | $0.6^{bc}$ (1.05) | $1.33^{abc}$ (1.29) | $1.00^{b}$ (1.18) | $0.0^{cd}$ (0.70) | $0.0^{c}$ (0.70) | $1.00^{cd}$ (1.18) | $1.33^{b}$ (1.35) | $2.33^{bcd}$ (1.64) | $1.33^{bc}$ (1.35) |
| Chitin based pseudomonas 2.5 kg ha-1 | $1.00^{bc}$ (1.18) | $1.33^{abc}$ (1.27) | $1.00^{b}$ (1.18) | $1.00^{bcd}$ (1.18) | $0.67^{bc}$ (1.05) | $1.67^{abc}$ (1.46) | $2.00^{b}$ (1.58) | $3.00^{bc}$ (1.86) | $1.67^{bc}$ (1.46) |
| *B. thuringiensis* 0.04% | $1.33^{bc}$ (1.27) | $1.00^{bc}$ (1.18) | $1.33^{ab}$ (1.35) | $0.33^{bcd}$ (0.88) | $1.33^{b}$ (1.35) | $1.33^{bcd}$ (1.35) | $2.33^{b}$ 1.68) | $1.67^{bc}$ (1.46) | $1.67^{bc}$ (1.46) |
| Chlorantraniliprole 0.005% | $0.67^{c}$ (1.0) | $0.0^{c}$ (0.70) | $1.00^{b}$ (1.18) | $0.67^{cd}$ (1.0) | $0.33^{bc}$ (0.88) | $0.33^{d}$ (0.88) | $1.00^{b}$ (1.18) | $0.67^{e}$ (1.05) | $1.33^{bc}$ (1.29) |
| Control | $4.33^{a}$ (2.20) | $3.0^{a}$ (1.86) | $3.33^{a}$ (1.93) | $2.67^{a}$ (2.03) | $3.33^{a}$ (1.95) | $3.67^{a}$ (2.00) | $5.00^{a}$ (2.34) | $10.00^{a}$ (3.24) | $4.67^{a}$ (2.25) |
| CD (0.05) | 0.674 | 0.637 | 0.595 | 0.658 | 0.543 | 0.566 | 0.564 | 0.506 | 0.447 |

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

#### 4.2.4.2.1. Leaf roller (Treatment at 30 DAS)

At 5 DAT, all the treatments except azadirachtin 0.003% recorded significant reduction in population of adult leaf roller. However the lowest mean population of 0.33 was recorded by the treatments fish jaggery extract 0.6% and cashew nut shell liquid 0.1% with mean population of 0.33. This was on par with chlorantraniliprole 18.5 SC 0.005% (0.67), dasagavya 3% (0.67), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.00), talc formulated *B. bassiana* ITCC 6063-2% (1.00) and *B. thuringiensis* 0.04% (1.33). The maximum incidence was recorded by untreated control (4.33).

At seven days after treatment, there was significant reduction in leaf roller population in all the treatments except talc formulated *B. bassiana* ITCC 6063-2%. The treatment chlorantraniliprole 18.5 SC 0.005% recorded cent per cent reduction in population. This was on par with the treatments *viz.,* cashew nut shell liquid 0.1%, fish jaggery extract 0.6%, *B. thuringiensis* 0.04%, azadirachtin 0.003%, chitin based Pseudomonas 2.5 kg $ha^{-1}$ and dasagavya 3% with a mean population of 0.33, 0.67, 1.00, 1.00, 1.33 and 1.33 respectively The mean population of untreated control was 3.0.

At ten days after treatment, the lowest mean population of about 0.67 was recorded from fish jaggery extract 0.6% which was significantly superior over control (3.33). This was on par with chitin based Pseudomonas 2.5 kg $ha^{-1}$, dasagavya 3%, chlorantraniliprole 18.5 SC 0.005% and cashew nut shell liquid 0.1% (1.0), *B. thuringiensis* 0.04% (1.33) and azadirachtin 0.003% (2.00). The mean population in control was 3.33, which was on par with talc formulated *B. bassiana* ITCC 6063-2% (3.00).

#### 4.2.4.2.2. Leaf roller (Treatment at 50 DAS)

At five days after treatment, although all the treatments recorded significant reduction in population of adult leaf roller compared to control (2.67), zero population was recorded in the treatment dasagavya 3%. This was on par with the treatments, *B. thuringiensis* 0.04% (0.33), fish jaggery extract 0.6% (0.33), talc formulated *B. bassiana* ITCC 6063-2% (0.67), cashew nut shell liquid 0.1% (0.67), chlorantraniliprole 18.5 SC 0.005% (0.67) and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.00).

At seven days after treatment, there was cent per cent reduction in population of adult leaf roller in the treatment dasagavya 3%. All the other treatments except *B. thuringiensis* 0.04% *viz.,* talc formulated *B. bassiana* ITCC 6063-2% (1.0), chlorantraniliprole 18.5 SC 0.005%(0.33), azadirachtin 0.003% (0.33), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (0.67), fish jaggery extract 0.6% (0.67) and cashew nut shell liquid 0.1% and (1.0) recorded significant reduction in population. The control recorded the highest population of 3.33.

All the treatments except chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.67) and talc formulated *B. bassiana* ITCC 6063-2% (2.67) recorded significant reduction in leaf roller population at ten days after treatment. However the lowest population was observed in the treatments *viz.,* fish jaggery extract 0.6% and chlorantraniliprole 18.5 SC 0.005% with a mean population of 0.33. These treatments were on par with cashew nut shell liquid 0.1% (0.67), dasagavya 3% (1.0), *B. thuringiensis* 0.04% (1.33) and azadirachtin 0.003% (1.33). Control recorded the highest population of 3.67.

**4.2.4.2.3. Leaf roller (Treatment at 70 DAS)**

At 5 DAT all the treatments recorded significant reduction in population of adult leaf roller. The treatments cashew nut shell liquid 0.1%, fish jaggery extract 0.6% and chlorantraniliprole 18.5 SC 0.005% recorded the lowest population (1.00). These were on par with the treatments dasagavya 3% (1.33), azadirachtin 0.003% (1.67), chitin based Pseudomonas 2.5 kg $ha^{-1}$(2.00), *B. thuringiensis* 0.04% (2.33) and talc formulated *B. bassiana* ITCC 6063-2% (2.33). Control recorded the highest population of 5.00.

At 7 DAT, the treatments cashew nut shell liquid 0.1% (1.00), *B. thuringiensis* 0.04% (1.67), azadirachtin 0.003% (2.00), dasagavya 3% (2.33) and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (3.00) recorded significant reduction in population of adult leaf roller over control (10.00). The other treatments viz. *B. bassiana* ITCC 6063-2 % (4.00), dasagavya 3% (2.333) and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (3.00) were on par with control.

At ten days after treatment, significant reduction in population was observed in all the treatments except talc formulated *B. bassiana* ITCC 6063-2% (2.00). However the lowest population was recorded in the treatment cashew nut shell liquid 0.1% (0.67) which was on par with azadirachtin 0.003%(1.00), fish jaggery extract 0.6% (1.00), chlorantraniliprole 18.5 SC 0.005% (1.33) and dasagavya 3% (1.33), *B. thuringiensis* 0.04% (1.67) and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.67). Untreated control recorded a population of 4.67.

**4.2.4.3. Rice hispa**

The population of adult hispa was recorded and the result was presented in Table 11.

**4.2.4.3.1. Rice hispa (Treatment at 30 DAS)**

At five days after treatment, all the treatments except azadirachtin 0.003% (3.00) recorded significant reduction in population of rice hispa. However the lowest population was recorded in the treatment cashew nut shell liquid 0.1% (0.33) which was on par with fish jaggery extract 0.6% (0.67), dasagavya 3% (0.67), *B. thuringiensis* 0.04% (1.00), chlorantraniliprole 18.5 SC 0.005% (1.00), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.67) and talc formulated *B. bassiana* ITCC 6063-2%(2.00). The highest population of 5.33 was recorded in control.

Table 11. Population of hispa at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean population of hispa 10 $sweeps^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 50 DAS | | | 70 DAS | | |
| | 5DAT | 7DAT | 10 DAT | 5DAT | 7DAT | 10DAT | 5DAT | 7DAT | 10DAT |
| Talc formulated *B. bassiana* 2% | $2.00^{bc}$ (1.56) | $3.33^{ab}$ (1.68) | $2.00^{b}$ (1.56) | $1.33^{b}$ (1.29) | $3.00^{a}$ (1.86) | $2.00^{b}$ (1.38) | $0.67^{b}$ (1.05) | $1.67^{abc}$ (1.43) | $0.33^{b}$ (0.88) |
| Azadirachtin 0.003% | $3.00^{ab}$ (1.82) | $3.33^{ab}$ (1.93) | $1.67^{b}$ (1.38) | $1.33^{b}$ (1.35) | $0.33^{b}$ (0.88) | $1.67^{bc}$ (1.27) | $0.67^{b}$ (1.05) | $2.00^{ab}$ (1.53) | $1.67^{b}$ (1.39) |
| Cashew nut shell liquid 0.1% | $0.33^{c}$ (0.88) | $0.67^{b}$ (1.05) | $1.00^{b}$ (1.23) | $1.00^{b}$ (1.18) | $1.00^{b}$ (1.18) | $1.00^{c}$ (1.00) | $0.67^{b}$ (1.05) | $1.33^{abc}$ (1.35) | $0.67^{b}$ (1.05) |
| Fish jaggery extract 0.6% | $0.67^{bc}$ (1.0) | $0.67^{b}$ (1.0) | $0.33^{b}$ (0.88) | $0.67^{b}$ (1.05) | $1.00^{b}$ (1.18) | $1.33^{bc}$ (1.13) | $0.33^{b}$ (0.88) | $0.33^{bc}$ (0.88) | $1.0^{b}$ (1.18) |
| Dasagavya 3% | $0.67^{bc}$ (1.00) | $1.33^{b}$ (1.18) | $1.33^{b}$ (1.27) | $1.00^{b}$ (1.18) | $0.67^{b}$ (1.0) | $2.00^{b}$ (1.41) | $0.67^{b}$ (1.05) | $2.00^{ab}$ (1.56) | $1.33^{b}$ (1.35) |
| Chitin based pseudomonas 2.5 kg $ha^{-1}$ | $1.67^{bc}$ (1.38) | $3.33^{ab}$ (1.93) | $1.67^{b}$ (1.38) | $1.33^{b}$ (1.35) | $1.33^{ab}$ (1.35) | $1.67^{bc}$ (1.27) | $0.33^{b}$ (0.88) | $0.0^{c}$ (0.70) | $1.67^{b}$ (1.38) |
| *B. thuringiensis* 0.04% | $1.00^{bc}$ (1.18) | $1.67^{b}$ (1.25) | $1.33^{b}$ (1.27) | $1.33^{b}$ (1.35) | $0.67^{b}$ (1.05) | $1.33^{bc}$ (1.13) | $0.67^{b}$ (1.05) | $2.00^{ab}$ (1.44) | $0.33^{b}$ (0.88) |
| Chlorantraniliprole 0.005% | $1.00^{bc}$ (1.18) | $1.67^{b}$ (1.38) | $1.00^{b}$ (1.18) | $1.33^{b}$ (1.35) | $0.33^{b}$ (0.88) | $1.33^{bc}$ (1.13) | $0.0^{b}$ (0.70) | $1.33^{abc}$ (1.35) | $1.33^{b}$ (1.29) |
| Control | $5.33^{a}$ (2.41) | $6.33^{a}$ (2.60) | $5.33^{a}$ (2.41) | $4.00^{a}$ (2.11) | $3.33^{a}$ (1.93) | $3.33^{a}$ (1.81) | $4.33^{b}$ (2.2) | $3.67^{a}$ (2.04) | $5.33^{a}$ (2.41) |
| CD (0.05) | 0.816 | 0.978 | 0.731 | 0.549 | 0.641 | 0.382 | 0.479 | 0.719 | 0.649 |

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

All the treatments recorded significant reduction in population of adult hispa at seven days after treatment and the lowest population recorded from fish jaggery extract 0.6% and cashew nut shell liquid 0.1% (0.67). This was on par with dasagavya 3% (1.33), *B. thuringiensis* 0.04%(1.67), chlorantraniliprole 18.5 SC 0.005% (1.67), talc formulated *B. bassiana* ITCC 6063-2% (3.33), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (3.33) and azadirachtin 0.003% (3.33). Untreated control recorded a mean population of 6.33.

At ten days after treatment also all the treatments recorded significant reduction in hispa population over control. The lowest population was observed in the treatment fish jaggery extract 0.6% with a mean population of 0.33. This was on par with the treatments cashew nut shell liquid 0.1% (1.00), chlorantraniliprole 18.5 SC 0.005% (1.00), dasagavya 3% (1.33), *B. thuringiensis* 0.04% (1.33), azadirachtin 0.003% (1.67), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.67) and talc formulated *B. bassiana* ITCC 6063-2% (2.00). Control recorded the highest population of 5.33.

**4.2.4.3.2. Rice hispa (Treatment at 50 DAS)**

At five days after treatment, all the treatments recorded significant reduction in the population of rice hispa adults. However the lowest population was recorded in the treatment fish jaggery extract 0.6% (0.67) which was on par with cashew nut shell liquid 0.1% (1.00), dasagavya 3% (1.00), talc formulated *B. bassiana* ITCC 6063-2% (1.33), *B. thuringiensis* 0.04% (1.33), azadirachtin 0.003% (1.33), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.33) and chlorantraniliprole 18.5 SC 0.005% (1.33). Control recorded the highest population of 4.00.

All the treatments recorded significant reduction in hispa population at seven days after treatment compared to control (3.33). Azardirachtin 0.003% and chlorantraniliprole 18.5 SC 0.005% recorded the lowest population of 0.33. This was on par with dasagavya 3% (0.67) and *B. thuringiensis* 0.04% (0.67), fish jaggery extract 0.6% (1.00) and cashew nut shell liquid 0.1% (1.0) and chitin based

Pseudomonas 2.5 kg ha$^{-1}$ (1.33). The treatments *viz.,* talc formulated *B. bassiana* ITCC 6063-2% and control was on par with a mean population of 3.00 and 3.33 respectively.

At 10 DAT, all the treatments recorded significant reduction in hispa population over control (3.33). However the lowest population was recorded from cashew nut shell liquid 0.1% (1.00) followed by fish jaggery extract 0.6% (1.33), *B. thuringiensis* 0.04%(1.33), chlorantraniliprole 18.5 SC 0.005% (1.33), azadirachtin 0.003% (1.67), chitin based Pseudomonas 2.5 kg ha$^{-1}$(1.67), talc formulated *B. bassiana* ITCC 6063-2% (2.00) and dasagavya 3% (2.00) which were on par.

**4.2.4.3.3. Rice hispa (Treatment at 70 DAS)**

At five days after treatment, all the treatments were found to be significantly superior over control (4.33). No population was observed in the treatment chlorantraniliprole 18.5 SC 0.005%. This was on par with the treatments chitin based Pseudomonas 2.5 kg ha$^{-1}$ (033), fish jaggery extract 0.6% (0.33), cashew nut shell liquid 0.1% (0.67), azadirachtin 0.003% (0.67), dasagavya 3% (0.67), talc formulated *B. bassiana* ITCC 6063-2% (0.67) and *B. thuringiensis* 0.04% (0.67)

There was zero population of adult hispa at seven days after treatment. Chitin based Pseudomonas 2.5 kg ha$^{-1}$ recorded zero population of hispa. This was on par with fish jaggery extract 0.6% (0.33), chlorantraniliprole 18.5 SC 0.005% (1.33), cashew nut shell liquid 0.1% (1.33), talc formulated *B. bassiana* ITCC 6063-2%(1.67). Control recorded the highest population of 3.67 which was on par with the treatments *B. thuringiensis* 0.04% (2.00), azadirachtin 0.003% (2.00) and dasagavya 3% (2.00).

At ten days after treatment, all the treatments recorded significant reduction in population of hispa over control (5.33). However the lowest mean population of 0.33 was recorded in the treatments talc formulated *B. bassiana* ITCC 6063-2% and *B.*

*thuringiensis* 0.04%. These treatments were on par with azadirachtin 0.003% (1.67), cashew nut shell liquid 0.1% (0.67), fish jaggery extract 0.6% (1.0), dasagavya 3% (1.33), chitin based Pseudomonas 2.5 kg ha$^{-1}$(1.67) and chlorantraniliprole 18.5 SC 0.005% (1.33).

**4.2.4.4. Rice blue beetle (Leptispa)**

The population of adult blue beetles was presented in table 12.

**4.2.4.4.1. Rice blue beetle (Treatment at 30 DAS)**

At five days after treatment, all the treatments except chlorantraniliprole 18.5 SC 0.005% and cashew nut shell liquid 0.1% recorded significantly low population of blue beetles compared to control (5.60). The lowest population was observed in the treatment fish jaggery extract 0.6% (1.00) which was on par with chitin based Pseudomonas 2.5 kg ha$^{-1}$ (1.33), talc formulated *B.bassiana* ITCC 6063-2% (1.67), dasagavya 3% (2.00), *B. thuringiensis* 0.04% (2.33) and azadirachtin 0.003% (2.33)

At 7 days after treatment also similar trend was observed. There was significant reduction in population over untreated control (5.67) in the treatments fish jaggery extract 0.6% (1.00), chitin based Pseudomonas 2.5 kg ha$^{-1}$(1.33), talc formulated *B. bassiana* ITCC 6063-2% (1.67), azadirachtin 0.003% (2.00), dasagavya 3% (2.00) and *B. thuringiensis* 0.04% (2.33). The treatments chlorantraniliprole 18.5 SC 0.005% (3.00) and cashew nut shell liquid 0.1% (3.00) were on par with control.

At ten days after treatment, the lowest population of 0.67 was observed both in the treatments fish jaggery extract 0.6% and cashew nut shell liquid 0.1%. These were on par with chlorantraniliprole 18.5 SC 0.005% (1.00), azadirachtin 0.003% (1.00), talc formulated *B. bassiana* ITCC 6063-2% (1.33), chitin based Pseudomonas 2.5 kg ha$^{-1}$ (1.33) and dasagavya 3% (1.67). The treatment *B. thuringiensis* 0.04%

Table 12. Population of blue beetle at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean population of blue beetle 10 sweeps$^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 50 DAS | | | 70DAS | | |
| | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10 DAT |
| Talc formulated *B. bassiana* 2% | $1.67^{bcd}$ (1.27) | $1.67^{bc}$ (1.27) | $1.33^{bcd}$ (1.29) | $1.33^{ab}$ (1.35) | $1.33^{ab}$ (1.35) | $1.33^{b}$ (1.35) | $3.00^{ab}$ (1.81) | $3.33^{bc}$ (1.91) | $2.33^{b}$ (1.68) |
| Azadirachtin 0.003% | $2.33^{bcd}$ (1.48) | $2.00^{bc}$ (1.38) | $1.00^{bcd}$ (1.23) | $1.33^{ab}$ (1.35) | $1.00^{bc}$ (1.18) | $1.67^{b}$ (1.44) | $3.33^{ab}$ (1.94) | $3.33^{b}$ (1.93) | $3.00^{b}$ (1.82) |
| Cashew nut shell liquid 0.1% | $3.00^{b}$ (1.71) | $3.00^{b}$ (1.71) | $0.67^{cd}$ (1.05) | $1.00^{bc}$ (1.23) | $0.33^{bc}$ (0.88) | $0.67^{b}$ (1.0) | $1.33^{bc}$ (1.29) | $1.33^{bc}$ (1.29) | $1.33^{b}$ (1.29) |
| Fish jaggery extract 0.6% | $1.00^{d}$ (1.0) | $1.00^{c}$ (1.0) | $0.67^{d}$ (0.88) | $2.00^{ab}$ (1.58) | $0.33^{bc}$ (0.88) | $1.00^{b}$ (1.179) | $1.33^{bc}$ (1.35) | $1.00^{c}$ (1.18) | $1.33^{b}$ (1.35) |
| Dasagavya 3% | $2.00^{bcd}$ (1.38) | $2.00^{bc}$ (1.38) | $1.67^{abc}$ (1.53) | $1.33^{ab}$ (1.2) | $0.33^{bc}$ (0.88) | $1.00^{b}$ (1.18) | $2.67^{ab}$ (1.77) | $2.00^{bc}$ (1.58) | $1.67^{b}$ (1.46) |
| Chitin based pseudomonas 2.5 kg ha$^{-1}$ | $1.33^{cd}$ (1.13) | $1.33^{c}$ (1.13) | $1.67^{abcd}$ (1.35) | $1.33^{c}$ (1.35) | $0.0^{c}$ (0.70) | $1.67^{b}$ (1.46) | $3.33^{ab}$ (1.93) | $2.67^{bc}$ (1.77) | $2.67^{b}$ (1.71) |
| *B. thuringiensis* 0.04% | $2.33^{bcd}$ (1.47) | $2.33^{bc}$ (1.47) | $1.67^{ab}$ (1.58) | $1.00^{b}$ (1.23) | $0.33^{bc}$ (0.88) | $1.33^{b}$ (1.35) | $0.67^{c}$ (1.05) | $1.67^{bc}$ (1.44) | $2.00^{b}$ (1.56) |
| Chlorantraniliprole 0.005% | $3.00^{bc}$ (1.68) | $3.00^{b}$ (1.68) | $1.00^{bcd}$ (1.18) | $1.33^{b}$ (1.35) | $0.33^{bc}$ (0.88) | $0.33^{b}$ (0.88) | $1.33^{bc}$ (1.29) | $1.33^{bc}$ (1.29) | $1.33^{b}$ (1.35) |
| Control | $5.60^{a}$ (2.36) | $5.67^{a}$ (2.36) | $1.88^{a}$ (1.88) | $5.33^{a}$ (2.41) | $2.67^{a}$ (1.77) | $5.67^{a}$ (2.47) | $5.00^{a}$ (2.34) | $8.33^{a}$ (2.97) | $6.67^{a}$ (2.67) |
| CD (0.05) | 0.560 | 0.530 | 0.528 | 0.370 | 0.5 | 0.608 | 0.661 | 0.751 | 0.663 |

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

(1.67) and control (2.33) recorded significantly high population of blue beetles compared to the other treatments.

**4.2.4.4.2. Blue beetle (Treatment at 50 DAS)**

At 5 days after treatment, all the treatments except fish jaggery extract 0.6% (2.00) recorded significantly low population of blue beetles over control. The treatment cashew nut shell liquid 0.1% (1.00) recorded the lowest population and was on par with *B. thuringiensis* 0.04% (1.0), dasagavya 3% (1.33), chlorantraniliprole 18.5 SC 0.005% (1.33), azadirachtin 0.003% (1.33), talc formulated *B. bassiana* ITCC 6063-2% (1.33) and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.33) . Control recorded the highest population of 5.33 beetles.

At seven days after treatment, all the treatments except talc formulated *B. bassiana* ITCC 6063-2% (1.33) recorded significantly low population of blue beetles compared to control (2.67). Cent per cent reduction in the population was observed in the treatment chitin based Pseudomonas 2.5 kg $ha^{-1}$ and was on par with *B. thuringiensis* 0.04%, fish jaggery extract 0.6%, cashew nut shell liquid 0.1%, dasagavya 3% and chlorantraniliprole 18.5 SC 0.005% with population of 0.33 and azadirachtin 0.003% (1.00).

All the treatments recorded significantly low population of blue beetles compared to control at ten days after treatment. However the lowest population was observed in the treatment chlorantraniliprole 18.5 SC 0.005% (0.33) which was on par with cashew nut shell liquid 0.1% (0.67), fish jaggery extract 0.6% (1.00), dasagavya 3% (1.00), *B. thuringiensis* 0.04% (1.33), talc formulated *B. bassiana* ITCC 6063-2% (1.33), azadirachtin 0.003% (1.67), and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.67). Control recorded the highest population of 5.67 beetles.

#### 4.2.4.4.3. Blue beetle (Treatment at 70 DAS)

At five days after treatment the treatment *B. thuringiensis* 0.04% (0.67) recorded significantly low population of blue beetles compared to control and was on par with cashew nut shell liquid 0.1%, fish jaggery extract 0.6% and chlorantraniliprole 18.5 SC 0.005% with population of 1.33. The treatments *viz.*, dasagavya 3%, talc formulated *B. bassiana* ITCC 6063-2%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, azadirachtin 0.003% and untreated control were found to be on par with mean population of 2.67, 3.00, 3.33, 3.33 and 5.00 respectively.

All the treatments except azadirachtin 0.003% (3.33) recorded significantly low population of blue beetles compared to control (8.33) at seven days after treatment. The lowest incidence was observed in fish jaggery extract 0.6% (1.00) which was on par with cashew nut shell liquid 0.1% (1.33), chlorantraniliprole 18.5 SC 0.005% (1.33), *B. thuringiensis* 0.04% (1.67), dasagavya 3% (2.00), Chitin based Pseudomonas 2.5 kg $ha^{-1}$ (2.67) and talc formulated *B. bassiana* ITCC 6063-2% (2.67).

At ten days after treatment all the treatments recorded significantly low population of blue beetles over control (6.67). However the treatments cashew nut shell liquid 0.1%, fish jaggery extract 0.6% and chlorantraniliprole 18.5 SC 0.005% recorded the lowest population of 1.33 which were on par with dasagavya 3% (1.67), *B. thuringiensis* 0.04% (2.00), talc formulated *B. bassiana* ITCC 6063-2% (2.33), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (2.67) and azadirachtin 0.003% (3.00).

#### 4.2.4.5. Grass hoppers

The population of grass hoppers was presented in Table 13.

Table 13. Population of grass hopper at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean population of grass hoppers 10 sweeps$^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 50 DAS | | | 70DAS | | |
| | 5DAT | 7DAT | 10 DAT | 5DAT | 7DAT | 10 DAT | 5DAT | 7DAT | 10DAT |
| Talc formulated *B. bassiana* 2% | $1.33^{b}$ (1.35) | 1.33 (1.35) | $2.00^{abcd}$ (1.58) | $1.33^{b}$ (1.35) | $2.67^{ab}$ (1.77) | $0.33^{b}$ (0.88) | $1.67^{b}$ (1.47) | $1.00^{c}$ (1.18) | $1.67^{b}$ (1.38) |
| Azadirachtin 0.003% | $1.33^{b}$ (1.29) | 2.33 (1.64) | $2.33^{abc}$ (1.64) | $1.00^{b}$ (1.23) | $1.33^{bc}$ (1.29) | $3.33^{a}$ (1.93) | $2.00^{b}$ (1.56) | $1.33^{ab}$ (1.35) | $1.67^{b}$ (1.46) |
| Cashew nut shell liquid 0.1% | $1.33^{b}$ (1.27) | 1.33 (1.35) | $0.33^{d}$ (0.88) | $1.00^{b}$ (1.23) | $0.67^{c}$ (1.00) | $0.67^{b}$ (1.05) | $0.67^{b}$ (1.05) | $0.0^{c}$ (0.70) | $0.67^{b}$ (1.05) |
| Fish jaggery extract 0.6% | $0.67^{b}$ (1.05) | 0.67 (1.05) | $0.67^{bcd}$ (1.38) | $1.33^{b}$ (1.35) | $0.67^{c}$ (1.00) | $0.33^{b}$ (0.88) | $1.00^{b}$ (1.18) | $0.33^{bc}$ (0.88) | $1.00^{b}$ (1.18) |
| Dasagavya 3% | $1.00^{b}$ (1.18) | 1.67 (1.44) | $0.67^{cd}$ (1.05) | $1.33^{b}$ (1.35) | $0.67^{c}$ (1.05) | $0.67^{b}$ (1.05) | $1.33^{b}$ (1.27) | $1.00^{ab}$ (1.23) | $1.33^{b}$ (1.35) |
| Chitin based pseudomonas 2.5 kg ha$^{-1}$ | $0.67^{b}$ (1.44) | 1.67 (1.38) | $3.00^{ab}$ (1.82) | $1.00^{b}$ (1.23) | $0.67^{c}$ (1.00) | $0.67^{b}$ (1.05) | $1.67^{b}$ (1.46) | $1.00^{bc}$ (1.18) | $1.67^{b}$ (1.46) |
| *B. thuringiensis* 0.04% | $2.00^{b}$ (1.49) | 2.00 (1.56) | $1.67^{bcd}$ (1.38) | $1.00^{b}$ (1.23) | $1.67^{bc}$ (1.46) | $1.00^{b}$ (1.18) | $2.00^{b}$ (1.56) | $0.67^{bc}$ (1.00) | $0.67^{b}$ (1.00) |
| Chlorantraniliprole 0.005% | $0.67^{b}$ (1.0) | 1.00 (1.23) | $0.67^{cd}$ (1.05) | $1.00^{b}$ (1.18) | $0.33^{c}$ (0.88) | $0.33^{b}$ (0.88) | $0.67^{b}$ (1.05) | $0.67^{bc}$ (1.05) | $1.33^{b}$ (1.27) |
| Control | $5.33^{a}$ (2.41) | 3.33 (1.93) | $4.67^{a}$ (2.28) | $5.33^{a}$ (2.41) | $5.33^{a}$ (2.41) | $3.67^{a}$ (2.03) | $5.00^{a}$ (2.31) | $2.33^{a}$ (1.68) | $5.00^{a}$ (2.31) |
| CD (0.05) | 0.584 | NS | 0.739 | 0.385 | 0.636 | 0.597 | 0.593 | 0.495 | 0.627 |

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

**4.2.4.5.1. Grass hoppers (Treatment at 30 DAS)**

At 5 days after treatment, the treatments chlorantraniliprole 18.5 SC 0.005% and fish jaggery extract 0.6% recorded the lowest population of 0.67 which was on par with the treatments dasagavya 3%, cashew nut shell liquid 0.1%, azadirachtin 0.003%, talc formulated *B. bassiana* ITCC 6063-2%, chitin based Pseudomonas 2.5 Kg $ha^{-1}$ and *B. thuringiensis* 0.04% with a population of 1.00, 1.33, 1.33, 1.33, 1.67 and 2.00 respectively. The highest population was recorded in control (5.33).

At 7 DAT all the treatments were non significant. However, the lowest pest population was recorded from the treatment fish jaggery extract 0.6% (0.67) followed by chlorantraniliprole 18.5 SC 0.005% (1.00), talc formulated *B. bassiana* ITCC 6063-2% and cashew nut shell liquid 0.1% (1.33), dasagavya 3%, chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.67), *B. thuringiensis* 0.04% (2.00), azadirachtin 0.003% (2.33) and control (3.33).

At ten days after treatment, significant reduction in population over control was recorded in treatments cashew nut shell liquid 0.1% (0.33) and was on par with dasagavya 3% and chlorantraniliprole 18.5 SC 0.005% (0.67), fish jaggery extract 0.6% (1.67), *B. thuringiensis* 0.04% (1.67) and talc formulated *B. bassiana* ITCC 6063-2% (2.00). The treatments *viz.,* azadirachtin.003%, chitin based Pseudomonas 2.5 Kg $ha^{-1}$ and control were on par with mean population of 2.33, 3.00 and 4.67 respectively.

**4.2.4.5.2. Grass hoppers (Treatment at 50 DAS)**

At 5 DAT all the treatments recorded significantly low population of grass hoppers compared with control. The treatments chlorantraniliprole 18.5 SC 0.005%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, *B. thuringiensis* 0.04%, cashew nut shell liquid 0.1% and azadirachtin 0.003% recorded the lowest population of 1.00. This was on par with all other treatments viz. dasagavya 3%, fish jaggery extract 0.6% and talc formulated *B. bassiana* ITCC 6063-2% (1.33 each). The highest population of 5.33 was recorded in control plot.

At 7 DAT, all the treatments except talc formulated *B. bassiana* ITCC 6063-2% (2.67) recorded significantly low population of grass hopper over control (5.33). The treatments chlorantraniliprole 18.5 SC 0.005% (0.33) , chitin based Pseudomonas 2.5 Kg $ha^{-1}$(0.67), fish jaggery extract 0.6% (0.67), cashew nut shell liquid 0.1% (0.67), dasagavya 3% (0.67), azadirachtin 0.003% (1.33) and *B. thuringiensis* 0.04% (1.67) were on par.

At 10 DAT also all the treatments except the treatment azadirachtin 0.003% (3.33) recorded significantly low population of grass hoppers. The other treatments *viz*. talc formulated *B. bassiana* ITCC 6063-2% (0.33), fish jaggery extract 0.6% (0.33), chlorantraniliprole 18.5 SC 0.005% (0.33), dasagavya 3% (0.67), chitin based Pseudomonas 2.5 kg $ha^{-1}$(0.67) and *B. thuringiensis* 0.04% (1.00) were on par. The highest population of 3.67 was observed in control.

#### 4.2.4.5.3. Grass hoppers (Treatment at 70 DAS)

All the treatments recorded significantly low population of grass hoppers compared to control at 5 DAT. The treatments *viz.,* cashew nut shell liquid 0.1% (0.67), chlorantraniliprole 18.5 SC 0.005%(0.67), fish jaggery extract 0.6% (1.00), dasagavya 3% (1.33), chitin based Pseudomonas 2.5 kg $ha^{-1}$(1.67), talc formulated *B. bassiana* ITCC 6063-2% (1.67), *B. thuringiensis* 0.04% (2.00) and azadirachtin 0.003% (2.00) were on par. Control recorded the highest population of 5.00.

At 7 DAT, also the same trend was observed. All the treatments recorded significant reduction in population of grass hoppers over control except azadirachtin 0.003%. However the treatment cashew nut shell liquid 0.1% recorded cent per cent reduction in population.

At ten days after treatment, all the treatments recorded significantly low population of grass hopper over control (5.00). However both the treatments cashew nut shell liquid 0.1% and *B. thuringiensis* 0.04% recorded the lowest population of 0.67 which were on par with the treatments *viz.* fish jaggery extract 0.6% (1.00), chlorantraniliprole 18.5 SC 0.005% and dasagavya 3% (1.33), talc formulated *B. bassiana* ITCC 6063-2% (1.67), chitin based Pseudomonas 2.5 kg $ha^{-1}$(1.67) and azadirachtin 0.003% (1.67).

**4.2.5. Effect of organic pesticides on population of natural enemies at different growth stages of the crop**

***4.2.5.1. Parasitoids***

The population of adult parasitoids was recorded and represented in Table 14.

**4.2.5.1.1. Parasitoids (Treatment at 30 DAS)**

At five days after treatment, no significant difference between population of parasitoids in different treatments including control was observed. However, the highest population was recorded from cashew nut shell liquid 0.1% (23.33) followed by fish jaggery extract 0.6% and control (21.67), dasagavya 3% (20.33), azadirachtin 0.003% (19.00), talc formulated *B. bassiana* ITCC 6063-2% (17.67), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (17.33), chlorantraniliprole 18.5 SC 0.005% (15.33) and *B. thuringiensis* 0.04% (14.67).

The highest population of 22.33 was recorded in control plot at seven days after treatment. This was on par with cashew nut shell liquid 0.1% and fish jaggery extract 0.6% (21.33), dasagavya 3% (19.67), azadirachtin 0.003% (18.67), talc formulated *B. bassiana* ITCC 6063-2% (16.67) and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (16.00). The population was significantly reduced in the treatments chlorantraniliprole 18.5 SC 0.005% and *B. thuringiensis* 0.04% with a mean of 8.00 and 9.00 respectively.

Table 14. Population of parasitoids at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean population of parasitoids 10 sweeps$^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 50 DAS | | | 70 DAS | | |
| | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10 DAT | 5DAT | 7 DAT | 10 DAT |
| Talc formulated *B. bassiana* 2% | 17.67 (4.16) | 16.67$^{a}$ (4.02) | 8.00$^{c}$ (2.80) | 8.00$^{bc}$ (2.83) | 11.33$^{c}$ (3.36) | 12.33$^{b}$ (3.5) | 11.67$^{bc}$ (3.391) | 8.67$^{c}$ (2.93) | 8.67$^{b}$ (3.5) |
| Azadirachtin 0.003% | 19.0 (4.36) | 18.67$^{a}$ (4.23) | 12.67$^{bc}$ (3.50) | 10.67$^{bc}$ (3.27) | 14.0$^{bc}$ (3.74) | 14.00$^{b}$ (3.70) | 12.33$^{bc}$ (3.5) | 8.00$^{cd}$ (2.7) | 8.00$^{b}$ (3.70) |
| Cashew nut shell liquid 0.1% | 23.33 (4.81) | 21.33$^{a}$ (4.59) | 21.0$^{ab}$ (4.55) | 11.00$^{bc}$ (3.31) | 20.33$^{ab}$ (4.51) | 18.00$^{b}$ (4.24) | 15.67$^{b}$ (3.92) | 13.33$^{ab}$ (4.15) | 17.33$^{b}$ (4.24) |
| Fish jaggery extract 0.6% | 21.67 (4.64) | 21.33$^{a}$ (4.61) | 13.67$^{bc}$ (3.62) | 13.00$^{ab}$ (3.61) | 21.0$^{ab}$ (4.55) | 17.33$^{b}$ (4.11) | 15.00$^{b}$ (3.86) | 11.67$^{bc}$ (3.31) | 10.33$^{b}$ (4.11) |
| Dasagavya 3% | 20.33 (4.50) | 19.67$^{a}$ (4.43) | 12.33$^{bc}$ (3.41) | 13.00$^{ab}$ (3.59) | 19.00$^{ab}$ (4.33) | 14.00$^{b}$ (3.71) | 10.33$^{bc}$ (3.21) | 10.33$^{c}$ (3.14) | 10.00$^{b}$ (3.71) |
| Chitin based pseudomonas 2.5 kg ha$^{-1}$ | 17.33 (4.15) | 16.00$^{a}$ (3.99) | 14.33$^{abc}$ (3.76) | 11.67$^{bc}$ (3.37) | 20.33$^{ab}$ (4.48) | 13.00$^{b}$ (3.59) | 13.67$^{bc}$ (3.67) | 8.33$^{c}$ (2.85) | 8.33$^{b}$ (3.59) |
| *B. thuringiensis* 0.04% | 14.67 (3.76) | 9.00$^{b}$ (2.94) | 13.33$^{abc}$ (3.61) | 12.33$^{bc}$ (3.37) | 21.00$^{ab}$ (4.58) | 13.33$^{b}$ (3.61) | 11.33$^{bc}$ (3.33) | 7.33$^{cd}$ (2.7) | 7.33$^{b}$ (3.61) |
| Chlorantraniliprole 0.005% | 15.33 (3.90) | 8.00$^{b}$ (2.83) | 6.67$^{c}$ (2.55) | 7.67$^{c}$ (2.69) | 16.67$^{abc}$ (4.02) | 14.00$^{b}$ (3.74) | 8.67$^{c}$ (2.91) | 7.33$^{d}$ (1.75) | 8.33$^{b}$ (3.88) |
| Control | 21.67 (4.62) | 22.33$^{a}$ (4.71) | 21.33$^{a}$ (4.78) | 18.33$^{a}$ (4.28) | 23.0$^{a}$ (4.78) | 26.0$^{a}$ (5.08) | 24.0$^{a}$ (4.9) | 21.33$^{a}$ (4.75) | 19.00$^{a}$ (5.08) |
| CD (0.05) | NS | 1.027 | 1.239 | 0.780 | 0.858 | 0.750 | 0.928 | 1.002 | 0.741 |

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

At ten days after treatment, significantly high population of parasitoids was observed in untreated control (21.33) and was on par with cashew nut shell liquid 0.1% (21.00). The treatments *viz.,* chitin based Pseudomonas 2.5 kg $ha^{-1}$(14.33), *B. thuringiensis* 0.04% (13.33), fish jaggery extract 0.6% (13.67), azadirachtin 0.003% (12.67), dasagavya 3% (12.33), talc formulated *B. bassiana* ITCC 6063-2% (8.00) and chlorantraniliprole 18.5 SC 0.005% (6.67) were found to be on par.

**4.2.5.1.2. Parasitoids (Treatment at 50 DAS)**

Significantly high population of parasitoid was recorded from control (18.33) at 5 days of treatment and on par with fish jaggery extract 0.6% (13.00) and dasagavya 3% (13.00). The treatments *viz., B. thuringiensis* 0.04%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, cashew nut shell liquid 0.1 %, azadirachtin 0.003%, talc formulated *B. bassiana* ITCC 6063-2% and chlorantraniliprole 18.5 SC 0.005% were on par with mean population of 12.33, 11.67, 11.00, 10.67, 8.00 and 7.67 respectively.

At seven days after treatment also the population of parasitoids was significantly high in control (23.00) and found to be on par with *B. thuringiensis* 0.04%, fish jaggery extract 0.6%, cashew nut shell liquid 0.1 %, chitin based Pseudomonas 2.5 kg $ha^{-1}$, dasagavya 3%, and chlorantraniliprole 18.5 SC 0.005% with a mean population of 21.00, 21.00, 20.33, 20.33, 19.00 and 16.67 respectively. The mean population recorded from the treatments talc formulated *B. bassiana* ITCC 6063-2% (11.33) and azadirachtin 0.003% (14.00) were significantly low.

At ten days after treatment, significantly high population of parasitoids was observed from control (26.00) and on par with cashew nut shell liquid 0.1 % (18.00), fish jaggery extract 0.6% (17.33), chlorantraniliprole 18.5 SC 0.005% (14.00), dasagavya 3%(14.0), azadirachtin 0.003%(14.0) and *B. thuringiensis* 0.04% (13.33). The treatment talc formulated *B. bassiana* ITCC 6063-2% (12.33) recorded significantly low population compared to control and found to be on par with chitin based Pseudomonas 2.5 kg $ha^{-1}$ (13.00)

**4.2.5.1.3. Parasitoids (Treatment at 70 DAS)**

At five days after treatment the highest population of parasitoids was recorded in untreated control (24.00). The population in control was significantly high followed by cashew nut shell liquid 0.1 % (15.67) and fish jaggery extract 0.6% (15.00). The treatments viz. chitin based Pseudomonas 2.5 kg $ha^{-1}$, azadirachtin 0.003%, talc formulated *B. bassiana* ITCC 6063-2%, *B. thuringiensis* 0.04% and dasagavya 3% recorded a population of 13.67, 12.33, 11.67, 11.33 and 10.33 respectively and were on par with chlorantraniliprole 18.5 SC 0.005% which recorded the lowest population of 8.67.

At seven days after treatment also significantly high population of parasitoids was observed from control (21.33) and was on par with cashew nut shell liquid 0.1 % (13.33), fish jaggery extract 0.6% (11.67), dasagavya 3% (10.33), talc formulated *B. bassiana* ITCC 6063-2% (8.67) and chitin based Pseudomonas 2.5 kg $ha^{-1}$(8.33). The treatments azadirachtin 0.003% (8.0), *B.thuringiensis*0.04% (7.33) and chlorantraniliprole 18.5 SC 0.005% (7.33) recorded significantly low population of parasitoids and were on par.

The highest population of parasitoids was observed in control (19.00) at ten days after treatment and significantly superior over all other treatments. The treatments *viz.*, cashew nut shell liquid 0.1 % (17.33), fish jaggery extract 0.6% (10.33), dasagavya 3% (10.0), talc formulated *B. bassiana* ITCC 6063-2% (8.67), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (8.33), azadirachtin 0.003% (8.0), *B. thuringiensis* 0.04%(7.33) and chlorantraniliprole 18.5 SC 0.005% (8.33) recorded significantly low population of parasitoids and found to be on par.

*4.2.5.2. Predators*

The population of adult predators was noted and presented in Table 15.

**4.2.5.2.1. Predators (Treatment at 30 DAS)**

There was no significant difference in total predator population at five days after treatment. However, the highest population was recorded from the treatment fish jaggery extract 0.6% (5.33) followed by control, cashew nut shell liquid 0.1% and azadirachtin 0.003% with a mean population of 5.0, talc formulated *B. bassiana* ITCC 6063-2% and *B. thuringiensis* 0.04% with a mean population of 4.67, chitin based Pseudomonas 2.5 kg $ha^{-1}$(4.00), dasagavya 3% (3.66) and chlorantraniliprole 18.5 SC 0.005% (2.00). The treatment chlorantraniliprole18.5 SC 0.005% recorded the lowest predator population (2.00).

At seven days after treatment, significantly high population of predators was observed in control and the treatment cashew nut shell liquid 0.1% (6.67) and was on par with fish jaggery extract 0.6%, *B. thuringiensis* 0.04%, chlorantraniliprole 18.5 SC 0.005% and chitin based Pseudomonas 2.5 kg $ha^{-1}$ with population of 5.00, 4.67, 4.67 and 4.00 respectively. The treatments *viz.,* talc formulated *B. bassiana* ITCC 6063-2% (1.67), azadirachtin 0.003% and dasagavya 3% were on par with significantly low population of 1.67, 2.67 and 3.67 respectively.

At ten days after treatment also the same trend was noticed. Though the untreated control and the treatment cashew nut shell liquid 0.1% (2.33) recorded the highest population of predators they were on par with. *B. thuringiensis* 0.04%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, azadirachtin 0.003%, fish jaggery extract 0.6% and talc formulated *B. bassiana* ITCC 6063-2% with a mean population of 0.33, 0.67, 0.67, 1.67 and 1.67 respectively. The treatments chlorantraniliprole 18.5 SC 0.005% and dasagavya 3% recorded significantly low mean population of 0.33.

Table 15. Population of predators at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean population of predators 10 sweeps$^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 50 DAS | | | 70 DAS | | |
| | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10 DAT |
| Talc formulated *B. bassiana* 2% | 4.67 (2.15) | $1.6^{c}$ (1.27) | $1.67^{bc}$ (2.21) | $1.67^{de}$ (1.27) | $3.00^{bc}$ (1.68) | $2.00^{c}$ (1.41) | $3.33^{c}$ (1.79) | $6.00^{bc}$ (2.45) | $3.67^{c}$ (1.92) |
| Azadirachtin 0.003% | 5.00 (2.23) | $2.67^{bc}$ (1.62) | $0.67^{bc}$ (2.15) | $2.33^{bcde}$ (1.52) | $4.33^{abc}$ (2.06) | $4.00^{bc}$ (1.98) | $4.33^{abc}$ (2.03) | $4.33^{c}$ (2.06) | $4.33^{c}$ (2.06) |
| Cashew nut shell liquid 0.1% | 5.00 (2.21) | $6.67^{a}$ (2.57) | $2.33^{ab}$ (2.70) | $2.00^{cde}$ (1.38) | $5.67^{ab}$ (2.38) | $6.33^{ab}$ (2.41) | $6.67^{ab}$ (2.57) | $10.33^{ab}$ (3.11) | $7.67^{ab}$ (2.74) |
| Fish jaggery extract 0.6% | 5.33 (2.3) | $5.00^{ab}$ (2.23) | $1.67^{bc}$ (2.20) | $3.00^{bcd}$ (1.71) | $5.00^{ab}$ (2.23) | $5.67^{b}$ (2.33) | $4.00^{abc}$ (1.96) | $7.67^{bc}$ (2.74) | $6.33^{abc}$ (2.5) |
| Dasagavya 3% | 3.67 (1.8) | $3.67^{ab}$ (1.8) | $0.33^{c}$ (1.74) | $4.00^{ab}$ (1.98) | $2.33^{c}$ (1.52) | $1.33^{bc}$ (1.8) | $2.00^{c}$ (1.38) | $6.33^{bc}$ (2.5) | $5.67^{bc}$ (2.38) |
| Chitin based pseudomonas 2.5 kg ha$^{-1}$ | 4.00 (1.96) | $4.00^{ab}$ (1.96) | $0.67^{bc}$ (2.13) | $3.67^{bc}$ (1.92) | $2.33^{c}$ (1.52) | $1.67^{b}$ (2.33) | $4.00^{bc}$ (1.89) | $4.00^{c}$ (1.94) | $4.33^{c}$ (2.08) |
| *B. thuringiensis* 0.04% | 4.67 (2.25) | $4.67^{ab}$ (2.15) | $0.33^{bc}$ (2.08) | $3.00^{bcd}$ (1.68) | $3.67^{bc}$ (1.8) | $2.00^{c}$ (1.41) | $3.67^{c}$ (1.82) | $5.00^{bc}$ (2.21) | $6.00^{bc}$ (2.45) |
| Chlorantraniliprole 0.005% | 2.00 (1.38) | $4.67^{ab}$ (2.15) | $0.33^{c}$ (1.71) | $1.33^{e}$ (1.13) | $2.00^{c}$ (1.41) | $1.67^{bc}$ (2.1) | $3.33^{c}$ (1.82) | $3.67^{c}$ (1.92) | $4.00^{c}$ (1.94) |
| Control | 5.00 (2.21) | $6.67^{a}$ (2.58) | $2.33^{a}$ (3.34) | $6.33^{a}$ (2.5) | $6.33^{a}$ (2.5) | $7.33^{a}$ (3.24) | $7.00^{a}$ (2.60) | $16.00^{a}$ (3.98) | $9.33^{a}$ (3.04) |
| CD (0.05) | NS | 0.67 | 0.879 | 0.531 | 0.688 | 0.854 | 0.711 | 0.936 | 0.590 |

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

**4.2.5.2.2. Predators (Treatment at 50 DAS)**

At five days after treatment, significantly high population of predators was recorded in untreated control (6.33) which was on par with the treatment dasagavya 3% (4.00). The lowest population was recorded from the treatment chlorantraniliprole 18.5 SC 0.005% (1.33) which was on par with talc formulated *B. bassiana* ITCC 6063-2% (1.67) and azadirachtin 0.003% (2.33). The treatments *viz.,* chitin based Pseudomonas 2.5 kg $ha^{-1}$ (3.67), fish jaggery extract 0.6% (3.00), *B. thuringiensis* 0.04% (3.00) and azadirachtin 0.003% (2.33) and Cashew nut shell liquid 0.1 % (2.00) recorded significantly low population over control and were on par.

At seven days of treatment, highest population was recorded from control plot (6.33). This was on par with the treatments *viz.,* cashew nut shell liquid 0.1% (5.67), azadirachtin 0.003% (4.33) and fish jaggery extract 0.6% (5.00). The treatments *viz., B. thuringiensis* 0.04%, talc formulated *B. bassiana* ITCC 6063-2%, dasagavya 3%, chitin based Pseudomonas 2.5 kg $ha^{-1}$ and chlorantraniliprole 18.5 SC 0.005% recorded the mean population of, 3.67, 3.00, 2.33, 2.33 and 2.00 respectively and were on par.

At ten days after treatment, significantly high predator population was observed from untreated control (7.33) and was on par with cashew nut shell liquid 0.1 % (6.33). All the other treatments *viz.,* fish jaggery extract 0.6% (5.67), azadirachtin 0.003% (4.00), *B. thuringiensis* 0.04% (2.00), talc formulated *B. bassiana* ITCC 6063-2% (2.00), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.67), chlorantraniliprole 18.5 SC 0.005% (1.67) and dasagavya 3% (1.33)recorded significantly low population of predators and were on par. The lowest population was recorded by the treatment dasagavya 3% (1.33).

**4.2.5.2.3. Predators (Treatment at 70 DAS)**

The highest mean population was recorded from untreated control (7.00) at five days after treatment. This was on par with the treatments cashew nut shell liquid 0.1 % (6.67), azadirachtin 0.003% (4.33) and fish jaggery extract 0.6% (4.00). All the other treatments *viz.,* chitin based Pseudomonas 2.5 kg $ha^{-1}$ (4.00), *B. thuringiensis* 0.04%(3.67), chlorantraniliprole 18.5 SC 0.005% (3.33), talc formulated *B. bassiana* ITCC 6063-2% (3.33) and dasagavya 3% (2.00) recorded significantly low population and were on par. However, the treatment dasagavya 3% (2.00) recorded the lowest population.

At seven days after treatment also the highest mean population was observed in control (16.00) and it was on par with cashew nut shell liquid 0.1% (10.33). the treatments *viz.,* fish jaggery extract 0.6%, dasagavya 3%, talc formulated *B. bassiana* ITCC 6063-2%, *B. thuringiensis* 0.04%, azadirachtin 0.003%, chitin based Pseudomonas 2.5 kg $ha^{-1}$ and chlorantraniliprole 18.5 SC 0.005% were found to be on par with a mean population of 7.67, 6.33, 6.00, 5.00, 4.33, 4.00 and 3.67 respectively. The lowest population was recorded in the treatment chlorantraniliprole 18.5 SC 0.005%.

At ten days after treatment, significantly high predator population was recorded from control with a mean of 9.33. This was on par with treatments cashew nut shell liquid 0.1 % (7.67), fish jaggery extract 0.6% (6.33) and *B. thuringiensis* 0.04% (6.00). All the other treatments *viz.* dasagavya 3% (5.67), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (4.33), azadirachtin 0.003% (4.33), chlorantraniliprole 18.5 SC 0.005% (4.00) and talc formulated *B. bassiana* ITCC 6063-2% (3.67) were found to be on par. The lowest mean population was observed in the treatment talc formulated *B. bassiana* ITCC 6063-2%.

### *4.2.5.3. Spiders*

The population of spiders was noted and presented Table 16.

#### 4.2.5.3.1. Spiders (Treatment at 30 DAS)

At five days after treatment, there was no significant difference between all the treatments and control. However, the highest mean population of 2.33 was recorded from fish jaggery extract 0.6%. The lowest population was recorded in chlorantraniliprole 18.5 SC 0.005% (0.33). All the other treatments *viz., B. thuringiensis* 0.04% (1.33), azadirachtin 0.003% (1.00), dasagavya 3% (1.00), talc formulated *B. bassiana* ITCC 6063-2% (0.67), and control (1.67) were on par. Chitin based Pseudomonas 2.5 kg $ha^{-1}$ recorded no spider population.

At seven days after treatment, there was significantly high population of spider in untreated control (2.33) and was on par with cashew nut shell liquid 0.1 %, fish jaggery extract 0.6% and dasagavya 3% with a mean population of 1.67, 1.67, and 1.33 respectively. No population was recorded in chlorantraniliprole 18.5 SC 0.005%. The other treatments *B. thuringiensis* 0.04% (0.33), azadirachtin 0.003% (0.33), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (0.33), and talc formulated *B. bassiana* ITCC 6063-2% (0.33) were on par.

The same trend was observed at ten days after treatment also. Untreated control plot recorded the highest spider population (2.33) which was significantly higher compared to other treatments but on par with cashew nut shell liquid 0.1 % (2.33) and fish jaggery extract 0.6%, (1.67). The remaining treatments *viz.,* chitin based Pseudomonas 2.5 kg $ha^{-1}$ (0.67), azadirachtin 0.003% (0.67), chlorantraniliprole 18.5 SC 0.005% (0.33), dasagavya 3% (0.33), talc formulated *B. bassiana* ITCC 6063-2% (0.33) and *B. thuringiensis* 0.04% (0.33) were on par .

Table 16. Population of spiders at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean population of spiders 10 sweeps$^{-1}$ | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | 30 DAS | | | 50 DAS | | | 70 DAS | | |
| | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10DAT |
| Talc formulated *B. bassiana* 2% | 0.67 (1.0) | $0.33^{bc}$ (0.88) | $0.33^{b}$ (0.88) | $0.33^{c}$ (0.88) | $0.33^{cd}$ (0.88) | $0.67^{bc}$ (1.00) | $0.33^{c}$ (0.88) | $0.33^{cd}$ (0.87) | $1.00^{bcd}$ (1.18) |
| Azadirachtin 0.003% | 1.00 (1.09) | $0.33^{bc}$ (0.88) | $0.67^{b}$ (1.0) | $0.67^{bc}$ (1.00) | $0.33^{cd}$ (0.88) | $0.0^{c}$ (0.70) | $0.33^{c}$ (0.88) | $0.67^{bcd}$ (1.0) | $0.0^{d}$ (0.70) |
| Cashew nut shell liquid 0.1% | 1.33 (1.27) | $1.67^{a}$ (1.46) | $2.33^{a}$ (1.68) | $2.00^{ab}$ (1.58) | $1.33^{b}$ (1.35) | $1.67^{b}$ (1.38) | $1.0^{b}$ (1.23) | $1.67^{ab}$ (1.46) | $1.67^{ab}$ (1.44) |
| Fish jaggery extract 0.6% | 2.33 (1.68) | $1.67^{a}$ (1.44) | $1.67^{ab}$ (1.38) | $1.00^{bc}$ (1.18) | $1.00^{bc}$ (1.23) | $1.33^{b}$ (1.35) | $1.67^{ab}$ (1.44) | $1.67^{ab}$ (1.44) | $1.33^{abc}$ (1.35) |
| Dasagavya 3% | 1.00 (1.23) | $1.33^{a}$ (1.29) | $0.33^{b}$ (0.88) | $0.33^{c}$ (0.88) | $0.67^{bcd}$ (1.05) | $0.33^{bc}$ (0.88) | $0.0^{c}$ (0.70) | $1.33^{abc}$ (1.35) | $1.00^{bcd}$ (1.23) |
| Chitin based pseudomonas 2.5 kg ha$^{-1}$ | 0.0 (0.70) | $0.33^{bc}$ (0.88) | $0.67^{b}$ (1.05) | $0.33^{c}$ (0.88) | $0.0^{d}$ (0.70) | $0.0^{c}$ (0.70) | $0.33^{c}$ (0.88) | $0.33^{cd}$ (0.88) | $0.67^{bcd}$ (1.0) |
| *B. thuringiensis* 0.04% | 1.33 (1.18) | $0.33^{bc}$ (0.88) | $0.33^{b}$ (0.88) | $0.67^{bc}$ (1.0) | $0.33^{cd}$ (0.88) | $0.33^{bc}$ (0.88) | $0.0^{c}$ (0.70) | $0.33^{cd}$ (0.88) | $1.00^{bcd}$ (1.18) |
| Chlorantraniliprole 0.005% | 0.33 (0.88) | $0.0^{c}$ (0.70) | $0.33^{b}$ (0.88) | $0.0^{c}$ (0.70) | $0.0^{d}$ (0.70) | $0.0^{c}$ (0.70) | $0.0^{c}$ (0.70) | $0.0^{d}$ (0.70) | $0.33^{cd}$ (0.88) |
| Control | 1.67 (1.46) | $2.33^{a}$ (1.68) | $2.33^{a}$ (1.68) | $2.67^{a}$ (1.77) | $2.67^{a}$ (1.77) | $3.67^{a}$ (2.02) | $2.67^{a}$ (1.77) | $2.67^{a}$ (1.77) | $3.00^{a}$ (1.86) |
| CD (0.05) | NS | 0.533 | 0.596 | 0.583 | 0.383 | 0.547 | 0.344 | 0.530 | 0.545 |

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

#### 4.2.5.3.2. Spiders (Treatment at 50 DAS)

At five days after treatment, significantly high population of spiders was observed in control (2.67) compared to other treatments but on par with cashew nut shell liquid 0.1 % (2.00). The other treatments *viz.,* fish jaggery extract 0.6% (1.00), *B. thuringiensis* 0.04%(0.67), azadirachtin 0.003% (0.67), talc formulated *B. bassiana* ITCC 6063-2% (0.33), dasagavya 3% (0.33) and chitin based Pseudomonas 2.5 kg ha$^{-}$1(0.33) were on par. The treatment chlorantraniliprole 18.5 SC 0.005% recorded no population of spiders

Zero population of spiders was recorded in the treatments chitin based Pseudomonas 2.5 kg ha$^{-1}$ and chlorantraniliprole 18.5 SC 0.005% at seven days after treatment. The highest mean population of 2.67 was recorded in untreated control. The other treatments *viz.,* cashew nut shell liquid 0.1 % (1.33), fish jaggery extract 0.6% (1.00), dasagavya 3% (0.67), azadirachtin 0.003% (0.33), cashew nut shell liquid 0.1 % (1.33) talc formulated *B. bassiana* ITCC 6063-2% (0.33) and *B. thuringiensis* 0.04% (0.33) were on par.

At ten days after treatment also the same trend was observed. Untreated control recorded significantly high population of spiders (3.67) compared to other treatments. No population was observed in the treatments chitin based Pseudomonas 2.5 kg ha$^{-1}$, chlorantraniliprole 18.5 SC 0.005% and Azadirachtin 0.003%. All the other treatments *viz.,* cashew nut shell liquid 0.1 % (1.67), fish jaggery extract 0.6% (1.33), talc formulated *B. bassiana* ITCC 6063-2% (0.67), dasagavya 3% (0.33) and *B. thuringiensis* 0.04% (0.33) were on par .

#### 4.2.5.3.3. Spiders (Treatment at 70 DAS)

At five days after treatment there was no population of spiders in the treatments chlorantraniliprole 18.5 SC 0.005%, dasagavya 3% and *B. thuringiensis* 0.04%. Significantly high population of 2.67 was observed in control which was on par with fish jaggery extract 0.6% (1.67). The treatments cashew nut shell liquid 0.1% ( 1.00), talc formulated *B. bassiana* ITCC 6063-2% (0.33), azadirachtin 0.003% (0.33) and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (0.33) were on par.

At seven days after treatment, significantly high spider population was observed in control (2.67), which was on par with cashew nut shell liquid 0.1% (1.67), fish jaggery extract 0.6% (1.67) and dasagavya 3% (1.33). No population was observed in chlorantraniliprole 18.5 SC 0.005%. The treatments *viz.*, azadirachtin 0.003% (0.67), *B. thuringiensis* 0.04% (0.33), talc formulated *B. bassiana* ITCC 6063-2% (0.33), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (0.33) and chlorantraniliprole 18.5 SC 0.005% (0.0) were on par

Significantly high population of 3.0 spiders was observed in untreated control at ten days after treatment. This was on par with the treatments *viz.*, cashew nut shell liquid 0.1 % (1.67), and fish jiggery extract 0.6% (1.33). The treatments *viz.*, dasagavya 3% (1.0), talc formulated *B. bassiana* ITCC 6063-2% (1.00), *B. thuringiensis* 0.04% (1.00), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (0.67) and chlorantraniliprole 18.5 SC 0.005% (0.33) were on par. Azardirachtin 0.003% recorded no population.

**4.2.6. Effect of organic pesticides on yield**

The results of the effect of pesticides on grain and straw yield are presented in Table 17.

The grain yield varied from 2.01 t $ha^{-1}$ to 3.30 t $ha^{-1}$. The highest per hectare yield of 3.30 t $ha^{-1}$ was recorded in the treatment cashew nut shell liquid 0.1 % with marginal B: C ratio of 2.6 which was on par with fish jaggery extract 0.6% (3.17 t $ha^{-1}$) and chlorantraniliprole 18.5 SC 0.005% (3.05 t $ha^{-1}$). The Marginal B: C ratio of 2.1 and 2.5were obtained for fish jaggery extract 0.6% and chlorantraniliprole 0.005%.

Table 17. Grain and straw yield in upland rice treated with organic pesticides at different intervals

| Treatment | Grain yield ($t\ ha^{-1}$) | Straw yield ($t\ ha^{-1}$) | Marginal B:C Ratio |
|---|---|---|---|
| Talc formulated *B.bassiana* 2% | 2.52 | 3.17 | 1.6 |
| 1% Azadirachtin 0.003% | 2.29 | 2.71 | 1.0 |
| Cashew nut shell liquid 0.1% | 3.30 | 3.62 | 2.6 |
| Fish jaggery extract 0.6% | 3.17 | 3.50 | 2.1 |
| Dasagavya 3% | 2.64 | 2.82 | 1.4 |
| Chitin based Pseudomonas 2.5 Kg $ha^{-1}$ | 2.34 | 2.34 | 1.6 |
| *Bacillus thuringiensis* 0.04% | 2.39 | 3.17 | 1.1 |
| Chlorantraniliprole 18.5 SC 0.005% | 3.05 | 3.70 | 2.5 |
| Untreated control | 2.01 | 2.29 | - |
| CD (0.05) | 0.990 | NS | |

NS- Non significant

How ever in case of straw yield there was no significant effect among the treatments and was on par with control. Straw yield among the various treatments ranges from 2.29-3.62 t $ha^{-1}$

4.3. MANAGEMENT OF BROWN PLANT HOPPER (BPH) AND RICE BUG IN UPLAND RICE

The different Eco-friendly pesticides were tested against rice bug *L. acuta*

**4.3.1. Efficacy of organic pesticides on management of rice bug at different growth stages of the crop**

The per cent grain damage by rice bugs was recorded and presented in Table 18.

***4.3.1.1. Per cent grain damage at 50 DAS***

There was no incidence of rice bug damage at 50 DAS.

***4.3.1.2. Per cent grain damage at 70 DAS***

At five days after treatment, significant reduction in grain damage was observed in the treatment dasagavya 3% (14.75%) compared to control (29.23%). This was on par with the treatments cashew nut shell liquid 0.1% and fish jaggery extract 0.6% with incidence of 15.02 and 20.79% respectively. The treatments *viz.*, azadirachtin 0.003% (21.77), chitin based Pseudomonas 2.5 kg $ha^{-1}$(21.92) and Malathion 50 EC 0.1% (25.00) were on par with control (29.23%).

At seven days after treatment, rice bug infestation on grains reduced significantly in the treatment dasagavya 3% (14.37%) compared to all other treatments and control. The control recorded a damage of 26.63% which was on par with all the other treatments *viz.* azadirachtin 0.003% (19.99%) fish jaggery extract

Table 18. Damage by rice bug at intervals after treatment with organic pesticides under upland rice

| Treatment | Per cent grain damage - 70 DAS | | |
|---|---|---|---|
| | 5 DAT | 7 DAT | 10 DAT |
| Azadirachtin 0.003% | 21.77[ab] (4.66) | 19.99[a] (4.51) | 23.45[a] (4.83) |
| Chitin based pseudomonas 2.5 kg ha-[1] | 21.92[ab] (4.68) | 25.98[a] (5.14) | 15.75[a] (3.94) |
| Cashew nut shell liquid 0.1% | 15.02[bc] (3.87) | 23.72[a] (4.92) | 19.10[a] (4.37) |
| Fish jaggery extract 0.6% | 20.79[abc] (4.55) | 21.05[a] (4.61) | 14.09[a] (3.74) |
| Dasagavya 3% | 14.75[c] (3.64) | 14.37[b] (3.79) | 8.97[b] (2.99) |
| Malathion 0.1% | 25.00[a] (4.98) | 27.18[a] (5.27) | 20.63[a] (4.51) |
| Control | 29.23[a] (5.41) | 26.63[a] (5.20) | 26.99[a] (5.20) |
| CD (0.05) | 0.995 | 0.697 | 0.636 |

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

0.6% (21.05%), cashew nut shell liquid 0.1% (23.72%), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (25.98%) and the chemical check Malathion 50 EC 0.1% (27.18%).

Significant reduction in grain damage by rice bug was recorded in the treatment dasagavya 3% (8.97%) compared to all other treatments and control at ten days after treatment, The treatments *viz*., fish jaggery extract 0.6% (14.09%), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (15.75%), cashew nut shell liquid 0.1% (19.10%) and Malathion 50 EC 0.1% (20.63%) were on par . The treatment azadirachtin 0.003% (23.45%) was found to be on par with control (26.99%).

**4.3.2. Efficacy of different pesticides on management of BPH at different growth stages of the crop**

There was no incidence of brown plant hopper in upland rice.

**4.3.3. Efficacy of organic pesticides on population of pests and natural enemies at different growth stages of the crop**

***4.3.3.1. Rice bug***

The population of rice bugs recorded from the field and represented in Table 19.

**4.3.3.1.1. Rice bug (Treatment at 50 DAS)**

At five days after treatment, there was no significant difference in rice bug population between treatments and control. However, the lowest population was recorded from the treatment dasagavya 3% (0.33) followed by chitin based Pseudomonas 2.5 kg $ha^{-1}$ (0.67) and cashew nut shell liquid 0.1% (0.67), azadirachtin 0.003% (1.0), fish jaggery extract 0.6% (1.0) and Malathion 50 EC 0.1% (1.0). The highest population of 2.33 was recorded in control.

Table 19. Population of rice bug at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean population of rice bug 10 sweeeps$^{-1}$ | | | | | |
|---|---|---|---|---|---|---|
| | 50DAS | | | 70 DAS | | |
| | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10 DAT |
| Azadirachtin 0.003% | 1.00 (1.18) | $1.33^{b}$ (1.27) | $3.33^{b}$ (1.95) | $7.00^{bc}$ (2.62) | $10.00^{ab}$ (3.16) | $19.67^{ab}$ (4.657) |
| Chitin based pseudomonas 2.5 kg ha$^{-1}$ | 0.67 (1.00) | $1.70^{b}$ (1.38) | $2.33^{b}$ (1.54) | $8.67^{abc}$ (2.95) | $8.00^{b}$ (2.83) | $21.67^{ab}$ (4.69) |
| Cashew nut shell liquid 0.1% | 0.67 (1.05) | $0.67^{b}$ (1.05) | $1.67^{b}$ (1.46) | $7.67^{bc}$ (2.65) | $8.67^{b}$ (2.95) | $16.33^{bc}$ (4.03) |
| Fish jaggery extract 0.6% | 1.00 (1.18) | $1.00^{b}$ (1.18) | $2.33^{b}$ (1.54) | $6.00^{bc}$ (2.38) | $8.00^{b}$ (2.73) | $14.67^{bc}$ (3.79) |
| Dasagavya 3% | 0.33 (0.88) | $0.33^{b}$ (0.88) | $0.67^{b}$ (1.0) | $4.00^{c}$ (1.98) | $7.67^{b}$ (2.62) | $13.00^{c}$ (3.58) |
| Malathion 0.1% | 1.00 (1.18) | $1.00^{b}$ (1.18) | $2.66^{b}$ (1.76) | $10.00^{ab}$ (3.09) | $7.33^{b}$ (2.46) | $14.67^{bc}$ (3.79) |
| Control | 2.33 (1.68) | $5.00^{a}$ (2.34) | $7.33^{a}$ (2.8) | $16.00^{a}$ (3.98) | $16.67^{ab}$ (4.08) | $26.00^{a}$ (5.09) |
| CD (0.05) | NS | 0.790 | 0.899 | 1.089 | 0.941 | 0.940 |

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

At seven days after treatment all the treatments recorded significantly low population of rice bugs compared to control. However the lowest population was recorded in the treatment dasagavya 3% (0.33) which was on par with the other treatments *viz.*, cashew nut shell liquid 0.1% (0.67), fish jaggery extract 0.6% (1.00), Malathion 50 EC 0.1% (1.00), azadirachtin 0.003% (1.33) and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.67). The highest population of 5.00 was recorded in control.

At 10 days after treatment, all the treatments except azadirachtin 0.003% (3.33) recorded significant reduction in population over control. Among the other treatments dasagavya 3% (0.67) recorded the lowest population and was on par with cashew nut shell liquid 0.1% (1.67), chitin based Pseudomonas 2.5kg $ha^{-1}$ (2.33) , fish jaggery extract 0.6% (2.33) and Malathion 50 EC 0.1% (2.67). The untreated control recorded the highest population of 7.33.

**4.3.3.1.2. Rice bug (Treatment at 70 DAS)**

At 5 days of treatment, all the treatments except the check insecticide Malathion50 EC 0.1% recorded significant reduction in population over control (16.0). However the lowest population was observed in the treatment dasagavya 3% (4.00). This was on par with the treatments fish jaggery extract 0.6% (6.00), azadirachtin 0.003% (7.00), cashew nut shell liquid 0.1% (7.67) and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (8.67).

All the treatments recorded significantly low population of rice bug compared to control (16.67) at 7 days after treatment. The lowest population was observed in the treatment Malathion 50 EC 0.1% (7.33) which was on par with dasagavya 3% (7.67), fish jaggery extract 0.6% (8.00), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (8.00), cashew nut shell liquid 0.1% (8.67) and azadirachtin 0.003% (10.00).

At ten days after treatment, all the treatments except azadirachtin 0.003% (19.67) and chitin based Pseudomonas 2.5 kg $ha^{-1}$ (21.67) recorded significantly low population of rice bugs. The lowest population was recorded from dasagavya 3% (13.00) and was on par with fish jaggery extract 0.6% (14.67), Malathion 50 EC 0.1% (14.67) and cashew nut shell liquid 0.1% (16.33). Control recorded the highest population of 26.0.

***4.3.3.2. Green leaf hopper***

The population of green leaf hopper recorded from the field and represented in Table 20.

**4.3.3.2.1. Green leaf hopper (Treatment at 50 DAS)**

At five days after treatment there was no significant difference between all treatments and control. However dasagavya 3% and Malathion 50 EC 0.1% recorded the lowest population of 0.33. The other treatments *viz.*, chitin based Pseudomonas 2.5 kg $ha^{-1}$ and cashew nut shell liquid 0.1% recorded a population of 0.67. Azadirachtin 0.003% and fish jaggery extract 0.6% recorded a population of 1.00 and 1.33 respectively and control plot recorded the highest population of 3.33.

All the treatments recorded significantly low population of GLH over control at seven days after treatment. The treatments *viz.*, fish jaggery extract 0.6%, dasagavya 3%, azadirachtin 0.003% and cashew nut shell liquid 0.1% recorded a population of 0.67 hoppers and were on par with Malathion 50 EC 0.1% and chitin based Pseudomonas 2.5 kg $ha^{-1}$ with population of 1.00. The highest population was recorded in control (4.33).

At ten days after treatment, though no significant difference was observed between all the treatments and control (1.33), cent per cent reduction in population of GLH was recorded in the treatments azadirachtin 0.003% and dasagavya 3%.

Table 20. Population of green leaf hopper at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean population of green leaf hopper 10 sweeps$^{-1}$ | | | | | |
|---|---|---|---|---|---|---|
| | 50 DAS | | | 70 DAS | | |
| | 5DAT | 7DAT | 10 DAT | 5 DAT | 7DAT | 10 DAT |
| Azadirachtin 0.003% | 1.00 (1.18) | $0.67^{b}$ (1.05) | 0.0 (0.70) | $1.33^{b}$ (1.35) | 1.67 (1.47) | 0.33 (0.88) |
| Chitin based pseudomonas 2.5 kg ha$^{-1}$ | 0.67 (1.00) | $1.00^{b}$ (1.18) | 0.33 (0.88) | $2.00^{b}$ (1.47) | 2.33 (1.27) | 0.0 (0.70) |
| Cashew nut shell liquid 0.1% | 0.67 (1.05) | $0.67^{b}$ (1.05) | 1.33 (1.29) | $2.00^{b}$ (1.56) | 1.00 (1.56) | 0.33 (0.88) |
| Fish jaggery extract 0.6% | 1.33 (1.27) | $0.67^{b}$ (0.88) | 0.67 (1.0) | $1.00^{b}$ (1.18) | 1.00 (1.18) | 0.67 (1.00) |
| Dasagavya 3% | 0.33 (0.88) | $0.67^{b}$ (1.00) | 0.0 (0.70) | $0.67^{b}$ (1.00) | 0.67 (1.18) | 0.0 (0.70) |
| Malathion 0.1% | 0.33 (0.88) | $1.00^{b}$ (1.18) | 0.33 (0.88) | $2.00^{b}$ (1.58) | 0.67 (1.38) | 0.67 (1.00) |
| Control | 2.67 (1.76) | $4.33^{a}$ (2.2) | 1.33 (1.29) | $6.00^{a}$ (2.54) | 4.67 (1.94) | 1.33 (1.29) |
| CD (0.05) | NS | 0.652 | NS | 0.744 | NS | NS |

Figures in parenthesis are $\sqrt{x+1}$ transformed values, DAS: Days after sowing, DAT: Days after treatment, NS: Non significant

#### 4.3.3.2.1. Green leaf hopper (Treatment at 70 DAS)

All the treatments recoded significantly low population of GLH compared to control at 5 days after treatment. However, the least population of 0.67 was recorded in the treatment dasagavya 3% and was on par with fish jaggery extract 0.6%(1.00), azadirachtin 0.003% (1.33), chitin based Pseudomonas 2.5 kg $ha^{-1}$(2.00), cashew nut shell liquid 0.1%(2.00) and malathion 50 EC 0.1% (2.00). The control plot recorded the highest population (6.0)

At seven days after treatment, no significant difference was observed in population between treatments and control. However, the lowest population of 0.67 was recorded in dasagavya 3% and Malathion 50 EC 0.1%. The highest population was observed in control (4.67).

The same trend was observed at ten days after treatment also. Zero population was recorded from chitin based Pseudomonas 2.5 kg $ha^{-1}$and dasagavya 3%. The highest population of 1.33 was recorded in control. The remaining treatments *viz.,* azadirachtin 0.003%, cashew nut shell liquid 0.1%, fish jaggery extract 0.6% and Malathion 50 EC 0.1% recorded the mean population of 0.33, 0.33 0.67 and 0.67 respectively.

### *4.3.3.3. Effect of organic pesticides on population of natural enemies at different growth stages of the crop*

The population of natural enemies recorded from the field in ten sweeps is presented in Table 21, 22 and 23.

#### 4.3.3.3.1. Parasitoids

The population of parasitoids recorded from the field and presented in Table 21.

Table 21. Population of parasitoids at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean population of parasitoids 10 $sweeps^{-1}$ | | | | | |
|---|---|---|---|---|---|---|
| | 50 DAS | | | 70 DAS | | |
| | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10 DAT |
| Azadirachtin 0.003% | $17.67^{abc}$ (4.20) | $9.67^{b}$ (3.09) | $15.33^{bc}$ (3.83) | $17.67^{b}$ (4.2) | $16.00^{bc}$ (3.98) | $21.67^{ab}$ (4.66) |
| Chitin based pseudomonas 2.5 kg $ha^{-1}$ | $16.33^{abc}$ (4.04) | $17.00^{ab}$ (4.11) | $16.00^{bc}$ (4.00) | $16.67^{b}$ (4.04) | $12.33^{c}$ (3.50) | $22.00^{ab}$ (4.69) |
| Cashew nut shell liquid 0.1% | $16.67^{abc}$ (4.06) | $12.00^{b}$ (3.32) | $19.00^{ab}$ (4.33) | $14.00^{b}$ (3.72) | $21.00^{ab}$ (4.58) | $18.67^{bc}$ (4.31) |
| Fish jaggery extract 0.6% | $22.67^{ab}$ (4.77) | $17.33^{ab}$ (4.17) | $18.33^{ab}$ (4.27) | $16.33^{b}$ (4.0) | $19.00^{ab}$ (4.32) | $22.33^{ab}$ (4.69) |
| Dasagavya 3% | $23.67^{ab}$ (4.87) | $18.00^{ab}$ (4.21) | $21.67^{ab}$ (4.64) | $18.33^{b}$ (4.28) | $24.66^{a}$ (4.95) | $25.00^{a}$ (4.98) |
| Malathion 0.1% | $6.33^{c}$ (2.46) | $12.00^{b}$ (3.42) | $11.33^{c}$ (3.35) | $14.67^{b}$ (3.82) | $21.00^{ab}$ (4.59) | $15.00^{c}$ (3.86) |
| Control | $29.00^{a}$ (5.38) | $26.00^{a}$ (5.1) | $25.33^{a}$ (5.02) | $26.33^{a}$ (5.14) | $25.33^{a}$ (5.03) | $26.67^{a}$ (5.17) |
| CD(0.05) | 0.667 | 1.128 | 0.831 | 0.819 | 0.750 | 0.574 |

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

**4.3.3.3.1.1. Parasitoids (Treatment at 50 DAS)**

At five days after treatment there was significantly high population of parasitoids in control (29.0). This was on par with the treatments dasagavya 3% (23.67) and fish jaggery extract 0.6% (22.67). The treatments *viz.,* azadirachtin 0.003% (17.67), cashew nut shell liquid 0.1% (16.67) and chitin based Pseudomonas 2.5 kg $ha^{-1}$(16.33) were found to be on par. The lowest population was recorded from Malathion 50 EC 0.1% (6.33).

At seven days after treatment, significantly high population of parasitoids was recorded in control (26.00). This was on par with dasagavya 3%, fish jaggery extract 0.6% and chitin based Pseudomonas 2.5 kg $ha^{-1}$, with a population of 18.00, 17.33 and 17.00 respectively. The lowest population of 9.67 was reported from azadirachtin 0.003% and was on par with cashew nut shell liquid 0.1% and Malathion 50 EC 0.1% with a mean population of 12.0.

At ten days after treatment, the highest population was recorded in control (25.33) and was on par with dasagavya 3% (21.67), cashew nut shell liquid 0.1% (19.0), and fish jaggery extract 0.6% (18.33). The other treatments *viz.,* chitin based Pseudomonas 2.5 kg $ha^{-1}$(16.00), azadirachtin 0.003% (15.33) and Malathion 50 EC 0.1% (11.33) were on par

**4.3.3.3.1.2. Parasitoids (Treatment at 70 DAS)**

At five days after treatment, control recorded the highest population of parasitoids (26.33) which was significantly superior over all other treatments. The other treatments dasagavya 3% (18.33), azadirachtin 0.003% (17.67), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (16.67), fish jaggery extract 0.6% (16.33), Malathion 50 EC 0.1% (14.67) and cashew nut shell liquid 0.1%(14.00) were on par .

At seven days after treatment, control recorded significantly high population of 25.33 parasitoids, which was on par with dasagavya 3% (24.67), cashew nut shell liquid 0.1% (21.00), Malathion 50 EC 0.1% (21.00) and fish jaggery extract 0.6% (19.00). The lowest population of 12.33 was recorded in chitin based Pseudomonas 2.5 kg $ha^{-1}$ followed by azadirachtin 0.003% (16.00).

At ten days after treatment significantly high population of parasitoids was observed in control(26.67) which was on par with the treatments dasagavya 3%, fish jaggery extract 0.6%, chitin based Pseudomonas 2.5 kg $ha^{-1}$ and azadirachtin 0.003% with a population of 25.00, 22.33, 22.00 and 21.67 respectively. Cashew nut shell liquid 0.1% (18.67) and Malathion 50 EC 0.1% (15.0) were on par.

**4.3.3.3.2. Predators**

The population of predators recorded from the field by sweeping is presented in Table 22.

**4.3.3.3.2.1. Predators (Treatment at 50 DAS)**

At five days after treatment, significantly high population of predators was recorded in control (14.33) which was on par with dasagavya 3% (17.00), fish jaggery extract 0.6%(13.67) and cashew nut shell liquid 0.1% (9.67). Chitin based Pseudomonas 2.5 kg $ha^{-1}$, Malathion 50 EC 0.1% and azadirachtin 0.003% were on par with a population of 7.67,6.67, and 6.33 respectively.

At seven days after treatment also control recorded significantly high population of predators (11.00). This was on par with the treatments dasagavya 3% (8.67) and fish jaggery extract 0.6% (8.00). The treatments chitin based Pseudomonas 2.5 kg $ha^{-1}$, cashew nut shell liquid 0.1%, Malathion 50 EC 0.1% and azadirachtin 0.003% were on par and recorded a population of 7.67, 6.33, 5.00 and 4.00 respectively.

Significantly high population of predators was recorded in the treatments dasagavya 3% and control with mean population of 14.33 at ten days after treatment.

Table 22. Population of predators at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean population of predators10 sweeps$^{-1}$ | | | | | |
|---|---|---|---|---|---|---|
| | 50 DAS | | | 70 DAS | | |
| | 5 DAT | 7 DAT | 10DAT | 5 DAT | 7 DAT | 10 DAT |
| Azadirachtin 0.03% | $6.33^{c}$ (2.46) | $4.00^{c}$ (1.94) | $6.67^{c}$ (2.55) | $9.33^{b}$ (3.05) | $9.00^{bc}$ (2.95) | $11.67^{c}$ (3.42) |
| Chitin based pseudomonas 2.5 kg ha$^{-1}$ | $7.67^{c}$ (2.72) | $7.67^{b}$ (2.77) | $8.67^{abc}$ (2.93) | $10.33^{b}$ (3.20) | $13.00^{abc}$ (3.6) | $15.33^{bc}$ (3.9) |
| Cashew nut shell liquid 0.1% | $9.67^{c}$ (3.046) | $6.33^{b}$ (2.51) | $13.67^{ab}$ (3.7) | $13.33^{ab}$ (3.58) | $15.33^{ab}$ (3.88) | $13.67^{c}$ (3.65) |
| Fish jaggery extract 0.6% | $13.67^{b}$ (3.66) | $8.0^{b}$ (2.83) | $11.67^{abc}$ (3.25) | $14.33^{ab}$ (3.76) | $13.00^{bc}$ (3.52) | $16.67^{c}$ (3.65) |
| Dasagavya 3% | $17.00^{a}$ (4.11) | $8.67^{b}$ (2.95) | $14.33^{a}$ (3.77) | $17.67^{a}$ (4.20) | $16.0^{ab}$ (3.99) | $20.67^{ab}$ (4.54) |
| Malathion 0.1% | $6.67^{c}$ (2.47) | $5.0^{c}$ (2.21) | $8.00^{bc}$ (2.83) | $9.00^{b}$ (3.0) | $7.00^{c}$ (2.64) | $11.33^{c}$ (3.36) |
| Control | $14.33^{b}$ (3.78) | $11.00^{a}$ (3.31) | $14.33^{a}$ (3.77) | $18.00^{a}$ (4.25) | $21.00^{a}$ (4.57) | $25.33^{a}$ (5.04) |
| CD (0.05) | 1.156 | 0.573 | 0.875 | 0.820 | 1.049 | 0.795 |

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

The treatments dasagavya 3% (14.33), cashew nut shell liquid 0.1% (13.67) and fish jaggery extract 0.6% (11.67) were on par with control. Chitin based Pseudomonas 2.5 kg $ha^{-1}$(8.67), Malathion 50 EC 0.1% (8.00) and azadirachtin 0.003% (6.67) were on par.

**4.3.3.3.2.2. Predators (Treatment at 70 DAS)**

At five days of treatment also the same trend was observed. Significantly high population of predators was observed in control with a population of 18.00 which was on par with dasagavya 3% (17.67), fish jaggery extract 0.6% (14.33) and cashew nut shell liquid 0.1% (13.33). The treatments *viz.*, chitin based Pseudomonas 2.5 kg $ha^{-1}$, azadirachtin 0.003% and Malathion 50 EC 0.1% were on par with predator count of 10.33, 9.33 and 9.00 respectively.

At seven days after treatment, untreated control recorded the highest predator population (21.0). This was on par with dasagavya 3% (16.0), cashew nut shell liquid 0.1% (15.33) and chitin based Pseudomonas 2.5 kg $ha^{-1}$(13.0). The treatments fish jaggery extract 0.6% (13.0), azadirachtin 0.003% (9.0) and Malathion 50 EC 0.1% (7.0) were on par

At ten days after treatment also significantly high population was observed in control (25.33) which was on par with dasagavya 3% with population of 20.67. the treatments *viz.,* fish jaggery extract 0.6%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, cashew nut shell liquid 0.1%, azadirachtin 0.003% and Malathion 50 EC 0.1% were on par with population of 16.67 15.33, 13.67, 11.67 and 11.33 respectively.

**4.3.3.3.3. Spiders**

The population of spiders recorded from the field by sweeping is presented in Table 23.

Table 23. Population of spiders at intervals after treatment with organic pesticides under upland rice

| Treatment | Mean population of spiders 10 $sweeps^{-1}$ | | | | | |
|---|---|---|---|---|---|---|
| | 50 DAS | | | 70 DAS | | |
| | 5 DAT | 7 DAT | 10 DAT | 5 DAT | 7 DAT | 10 DAT |
| Azadirachtin 0.003% | 0.33 (0.88) | 0.33 (0.88) | 0.33 (0.88) | 0.67 (1.00) | $0.33^{b}$ (1.05) | 0.67 (1.05) |
| Chitin based pseudomonas 2.5 kg $ha^{-1}$ | 0.33 (0.88) | 0.33 (0.88) | 1.00 (1.09) | 0.67 (1.00) | $0.33^{b}$ (1.18) | 0.67 (1.00) |
| Cashew nut shell liquid 0.1% | 0.67 (1.00) | 0.33 (0.88) | 1.00 (1.23) | 2.00 (1.56) | $2.00^{a}$ (0.88) | 1.67 (1.45) |
| Fish jaggery extract 0.6% | 0.33 (0.88) | 0.67 (1.00) | 0.67 (1.00) | 0.67 (1.0) | $0.67^{b}$ (0.88) | 1.33 (1.35) |
| Dasagavya 3% | 1.00 (1.18) | 1.00 (1.18) | 1.33 (1.35) | 2.00 (1.58) | $2.00^{b}$ (0.88) | 1.67 (1.46) |
| Malathion 0.1% | 0.33 (0.88) | 0.33 (0.88) | 0.0 (0.70) | 0.67 (1.0) | $0.33^{b}$ (1.46) | 1.00 (1.09) |
| Control | 1.00 (1.18) | 1.33 (1.35) | 2.33 (1.68) | 2.33 (1.68) | $3.33^{a}$ (2.04) | 2.00 (1.56) |
| CD (0.05) | NS | NS | NS | NS | 0.532 | NS |

Figures in parenthesis are $\sqrt{x+1}$ transformed values, DAS: Days after sowing, DAT: Days after treatment, NS: Non significant

#### 4.3.3.3.3.1. Spiders (Treatment at 50 DAS)

At five days after treatment, no significant difference was observed among all the treatments including control. However, control and dasagavya 3% recorded the highest population of 1.00. This was followed by cashew nut shell liquid 0.1% (0.67), azadirachtin 0.003%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, fish jaggery extract 0.6% and Malathion 50 EC 0.1% which recorded a population of 0.33.

All the treatments including control recorded no significant difference in population of spiders at seven days after treatment also. The control recorded the highest population of 1.33 spiders. This was followed by dasagavya 3% (1.00) and fish jaggery extract 0.6% (0.67). All the remaining treatments *viz.,* azadirachtin 0.003%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, cashew nut shell liquid 0.1%, and Malathion 50 EC 0.1% recorded a population of 0.33.

At ten days after treatment, also there was no significant difference among the treatments including control. The untreated control recorded a population of 2.33 spiders followed by dasagavya 3% (1.33). Chitin based Pseudomonas 2.5 kg $ha^{-1}$ (1.09), cashew nut shell liquid 0.1% (1.00), fish jaggery extract 0.6%(0.67) and azadirachtin 0.003% (0.33) were the other treatments. Malathion 50 EC 0.1% recorded zero population of spiders.

#### 4.3.3.3.3.2. Spiders (Treatment at 70 DAS)

At five days after treatment no significant difference was observed between treatments including control. However, control recorded the highest population of spiders (2.33) followed by dasagavya 3% and cashew nut shell liquid 0.1% with 2.00 spiders. The treatments *viz.,* azadirachtin 0.003%, chitin based Pseudomonas 2.5 kg $ha^{-1}$, fish jaggery extract 0.6% and Malathion 50 EC 0.1% recorded a population of 0.67.

At seven days after treatment, control recorded significantly high population of spiders (2.038) over all the treatments. Among the treatments dasagavya 3% and cashew nut shell liquid 0.1% recorded the highest population of 2.0 spiders.

Ten days after treatment, there was no significant difference in population of spiders between treatments including control. However control recorded the highest population of 2.00 followed by dasagavya 3% (1.67)

**4.3.4. Effect of organic pesticides on yield**

The results on effect of organic pesticides on yield of upland rice was presented in the Table 24.

The grain yield varied from 1.88 t $ha^{-1}$ to 3.27 t $ha^{-1}$. The highest grain yield of 3.27 t $ha^{-1}$ was recorded in the treatment cashew nut shell liquid 0.1 % .This was on par with dasagavya 3% (2.98 t $ha^{-1}$), fish jaggery extract 0.6% (2.85 t $ha^{-1}$),) and malathion 50 EC 0.1% (2.81t $ha^{-1}$). The treatments azadirachtin 0.003%, chitin based Pseudomonas 2.5 kg $ha^{-1}$ and control were on par with yield of 2.46, 2.38, and 1.88 t $ha^{-1}$ respectively. The highest marginal B: C ratio of 2.8 was worked out for cashew nut shell liquid 0.1 %. This was followed by dasagavya 3% (2.6) and Malathion (2.5).

The highest straw yield of 3.36 t $ha^{-1}$ was recorded in the treatment cashew nut shell liquid 0.1% and was on par with dasagavya 3% (3.30t $ha^{-1}$), fish jaggery extract 0.6% (2.73 t $ha^{-1}$), chitin based Pseudomonas 2.5 kg $ha^{-1}$ (2.55 t $ha^{-1}$) and azadirachtin 0.003% (2.54 t $ha^{-1}$). The control plot recorded the lowest yield of 1.35 t $ha^{-1}$.

Table 24. Grain and straw yield in upland rice treated with organic pesticides at different intervals

| Treatment | Grain yield ($t\ ha^{-1}$) | Straw yield ($t\ ha^{-1}$) | Marginal B:C ratio |
|---|---|---|---|
| 1% Azadirachtin 0.003% | 2.46 | 2.54 | 2.1 |
| Chitin based Pseudomonas 2.5 Kg $ha^{-1}$ | 2.38 | 2.55 | 2.4 |
| Cashew nut shell liquid 0.1% | 3.27 | 3.36 | 2.8 |
| Fish jaggery extract 0.6% | 2.85 | 2.73 | 1.8 |
| Dasagavya 3% | 2.98 | 3.30 | 2.6 |
| Malathion 50EC 0.1% | 2.81 | 2.28 | 2.5 |
| Untreated control | 1.88 | 1.35 | - |
| CD (0.05) | 0.781 | 0.909 | - |

# DISCUSSION

# 5. DISCUSSION

Rice being the staple food crop in India, it is grown in all most all the states under different agro climatic situations. For achieving self-reliance in paddy production, upland rice cultivation is being promoted and popularized throughout the state of Kerala by motivating and providing assistance to farmers cultivating upland paddy. Recently, with the aim of attaining self-sufficiency, the government has decided to take up upland paddy farming in around 2,500 hectares during 2016-17. The rice crop suffers from serious setback in yield due to attack a number of insect pests. Among the different insect pests attacking the crop, stem borer, leaf roller, blue beetle, green leafhopper and ear head bug were considered as the most important pests in upland rainfed situation during kharif season. The incidence of insect pests in endemic areas reaches very high on susceptible rice cultivars. In order to tackle this pest problem it is necessary to understand their population status during the season in related rice crop ecology. Ecofriendly management of major pests of upland rice ecosystem is of prime importance. The bio-efficacy evaluation using botanical pesticides is the need of the hour to replace conventional pesticides thereby reducing the adverse effects of synthetic pesticides. The present study is a pioneer one in the concept of pest management under upland rice ecosystem of the state. The problem has been addressed well covering documentation of major insect pests and natural enemies under the upland rice ecosystem in six different locations of Alapuzha District representing the Onattukara rice belt of Kerala. Ecofriendly management of major pests using botanical / biopesticides and studying their effect on the natural enemy fauna associated with the upland rice ecosystem have been discussed with available earlier reports below.

## 5.1. SURVEY AND DOCUMENTATION OF PESTS AND NATURAL ENEMIES OF UPLAND RICE IN ALAPUZHA DISTRICT.

Rice field is having stable ecosystem with rich complex of pests and general and specific natural enemies including predators, parasitoid and spiders (Premila, 2003). In order to know the diversity and occurrence of pest and natural enemies at different growth stages under upland rice ecosystem, a detailed survey has been undertaken in six selected locations of Alapuzha District representing the Onattukara rice belt of Kerala.

### 5.1.1. Insect pests recorded from upland rice ecosystem in Alapuzha district

Bhagya and Jyothi are the short duration varieties which are commonly cultivated by farmers in upland condition in the region. Among the insect pests, Lepidopterans are usually more damaging in the rice crop followed by Coleopterans and Hemipterans. Various pests are found at different stages of crop causing enormous crop loss. In the present study the incidence of leaf roller (*C. medinalis)*, stem borer (*S. incertulas),* hispa (*D. armigera)*, and blue beetles (*L. pygmaea)* are recorded all the six locations of Alapuzha district (Fig. 1). Among these, stem borer and leaf roller were found throughout the cropping period though caused damage in low intensities. The kind of micro ecology prevailed in the aerobic rice may be conducive for the insect. The results of present study on the incidence of leaf roller are in agreement with the findings of Kuligod (2009) who observed the leaf folder population from beginning of season. During the reproductive stage of the crop low and medium infestation of rice bug were seen in 50 and 33 per cent of the fields respectively. The incidence of leptispa beetle was low at both the crop stages and hispa population was completely nil during reproductive stage of the crop. The kind of micro ecology prevailed in the aerobic rice may not be conducive for the insect. Further, comparatively poor crop canopy growth and number of tillers under upland rice ecosystem might have created less favorable condition for the pests to buildup.

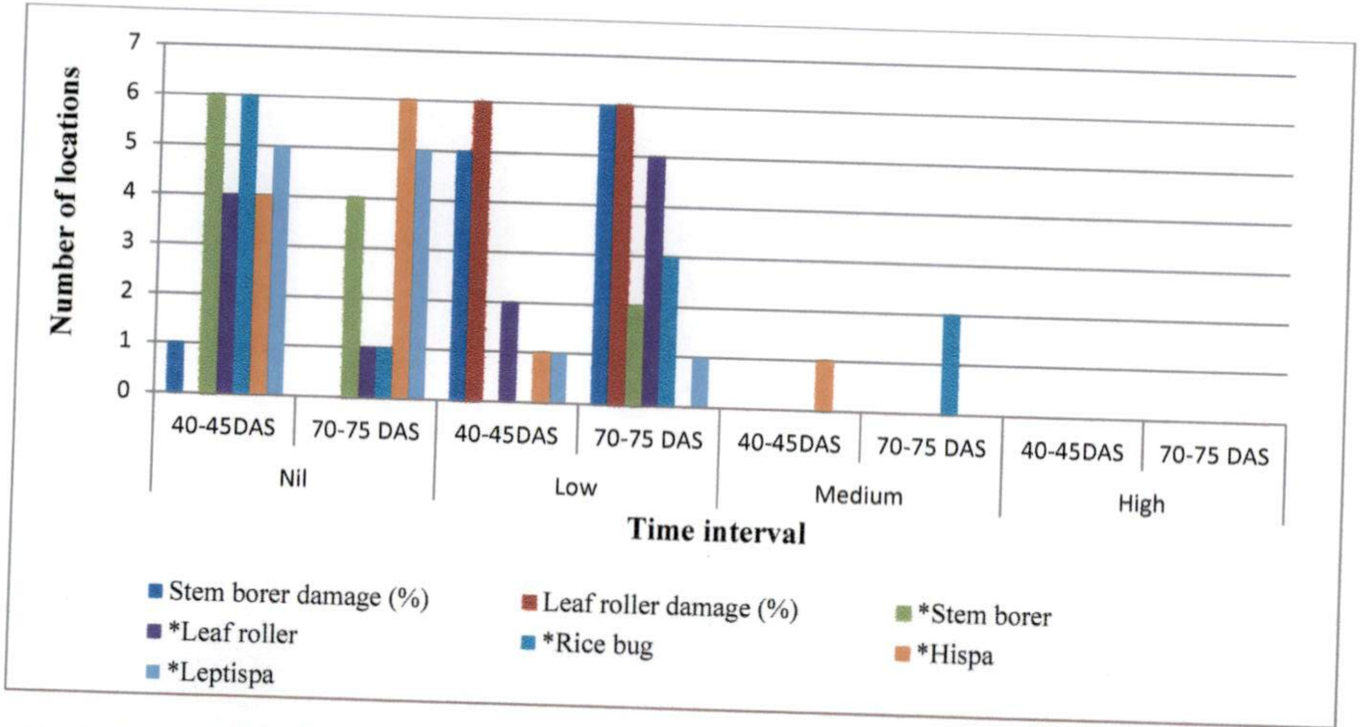



**Fig 1. Occurrence of insect pests in the locations surveyed under upland rice in Alapuzha district**

* adults 10 sweeps$^{-1}$

Percentage Stem borer and leaf roller incidence: Nil: 0, Low: 0.1-25%, Medium: 26-50% and High: >50%

No. of adults per 10 sweeps (Stem borer, Leaf roller, Rice bug, Hispa , Leptispa); Nil: 0,
Low: 0.1-2.5, Medium: 2.6-5.0, High: >5.0

DAS: Days after sowing

The common stem borer species *S. incertulas* was documented in upland rice from Alapuzha district. Abraham (1972) made an observation that climatic factors are more crucial for pest occurrence in rice and found a negative correlation of rain, low temperature and relative humidity with the incidence of *S. incertulas*. No adult stem borer was recorded from sweeps in vegetative stage but at low intensities in reproductive stage of upland rice from all the locations. This was in agreement with the observation made by Girish (2011) who reported that, under upland cultivation, the population of stem borer is common and abundant in reproductive stage. Stem borer damage (dead heart or white ear head) is common during both the stages of the crop. However, more damage was noticed at reproductive stage. The cropping pattern and climate play an important role in stem borer population and its damage incidence. Shanker (2011) documented many species of stem borers which are distributed throughout India and among them *S. incertulas* was the predominant and most destructive one. Though white borer *Scirpophaga innotata* is predominant in south Kerala, it was not reported during the present study. Saini *et al*. (2017) noticed the three species of stem borers *viz., S. incertulas*, *S. virginia* and *S. fasciflua*. Among this *S. incertulas* population was found to be prevalent from Tamil Nadu.

The common species of leaf roller documented in upland rice in Alapuzha district is *C. medinalis*. This species was recorded to be common in all the locations both in vegetative and reproductive stages. However, population gradually increased from vegetative to reproductive stage. Though observations are braced up with findings of Nadarajan and Skaria (1988) who reported *C. medinalis, Marasmia patnalis* and *Brachmia atrotarea* as predominant species from Pattambi. *Cnaphalocrocis medinalis* and *M. patnalis* were predominant in Thiruvananthapuram district (Lekha, 2003). Damage caused by leaf roller was only in low intensities from all the six locations at both tillering and flowering stages in upland rice. Since upland rice is usually cultivated with the use of pesticides only in very low quantities, pesticides induced resurgence is very less in this crop which is comparatively a non congenial poor host for rice leaf roller. This was supported by the findings of Gangwar (2015) who opined that, the main reason for abundance of leaf roller in irrigated rice is pesticide induced resurgence. Saini *et al.* (2017) documented six species from Tamil Nadu, of which *C. patnalis*, *C. medinalis* and*C. ruralis* were more prevalent. He also documented the species *Cnaphalocrosis poeyalis* (Boisduval) for first time from Tamil Nadu.

Rice hispa, *D. armigera* was recorded from Alapuzha district in low and medium intensities in vegetative stage and was completely absent in reproductive stage of the crop. This shows that, hispa commonly prefer early stage of the crop for survival and it is of minor importance in upland rice. Hispa was reported to be more damaging and severe during drought periods (Nair, 1978). But in recent years, the incidence of hispa is increasing particularly in wet land and is emerging as major pest (Pasalu, 2011). The low incidence of hispa population observed in the present study may be attributed to the well distributed rainfall received during crop season.

The rice blue beetle *L. pygmaea* reported in tillering and flowering stages in low intensities in only one location indicates its minor importance in upland rice cultivation. *L. pygmaea* was documented as a minor pests of wetland rice earlier. But recently in Kerala, it is appearing as an important defoliator in which most of the varieties are vulnerable to attack under wetland condition. It is attaining the status of major pest of rice crop in Palakkad, Kannur and Kasargod district (CPSS, Govt of Kerala). Nadarajan (1996) reported that *L. pygmaea* is more severe in nurseries both in Kharif and Rabi season in Pattambi region of Kerala. It is also emerging as a major pest in Uttar Kannada district of Karnataka in rainfed condition (Japur, 2012). From these studies, it can be inferred that blue beetles are becoming a threat to wet land direct sown crop.

Rice bug, *Leptocorisa acuta* is the major pest observed during reproductive stage of the crop in which more than 70 per cent of fields recorded the incidence. In the present study low and medium incidence of rice bugs were recorded in three and two out of six locations respectively in the upland rice cultivated fields. However, It has got economic importance since the attack is at the milky stage of crop and reduce the yield by 30 per cent. (KAU, 2016). It is considered as serious pest of upland rice in Kerala as reported by Pathak and Khan, (2011) and Mohan (2014).

### 5.1.2. Natural enemies recorded from upland rice ecosystem in Alapuzha district

Whenever, the population of insect pests increases, defensive mechanism of nature act on them and reduce their further multiplication and protect the crop from injury. Rice field create a better niche for many living creatures. From the survey conducted in upland rice ecosystem in Alapuzha district revealed the presence of predators *viz.,* dragonfly, damselfly, *O. nigrofasciata, Paederus* sp.,, *Micraspis* sp., gryllids and spiders *viz., Tetragnatha maxillosa* and *Argiope* sp. The parasitoids documented during survey were *Goniozus nephantidis* and *Cotesia* sp. These natural enemies had been reported from different rice ecosystem in Kerala by Reghunathan *et al.* (1990) and Premila and Nalinakumari (2002). This arthropod community is dominated with insects followed by spiders (Jayanthi *et al.,* 2006).

Results of the study (4.1.3) showed the distribution of different parasitoids in rice ecosystem from Alapuzha district (Fig 2). The highest population of parasitoids was recorded during reproductive stage of crop which coincides with high incidence of leaf roller and stem borer. This shows the increase in parasitoid population simultaneously with population increase of these pests. Ranjith *et al.,* (2015) reported that *Cotesia* sp. was the most abundant parasitoid population recorded in rice fields of Kerala.

The predators included dragonflies and damselflies are recorded low population under upland rice. Most of the predators were observed throughout the

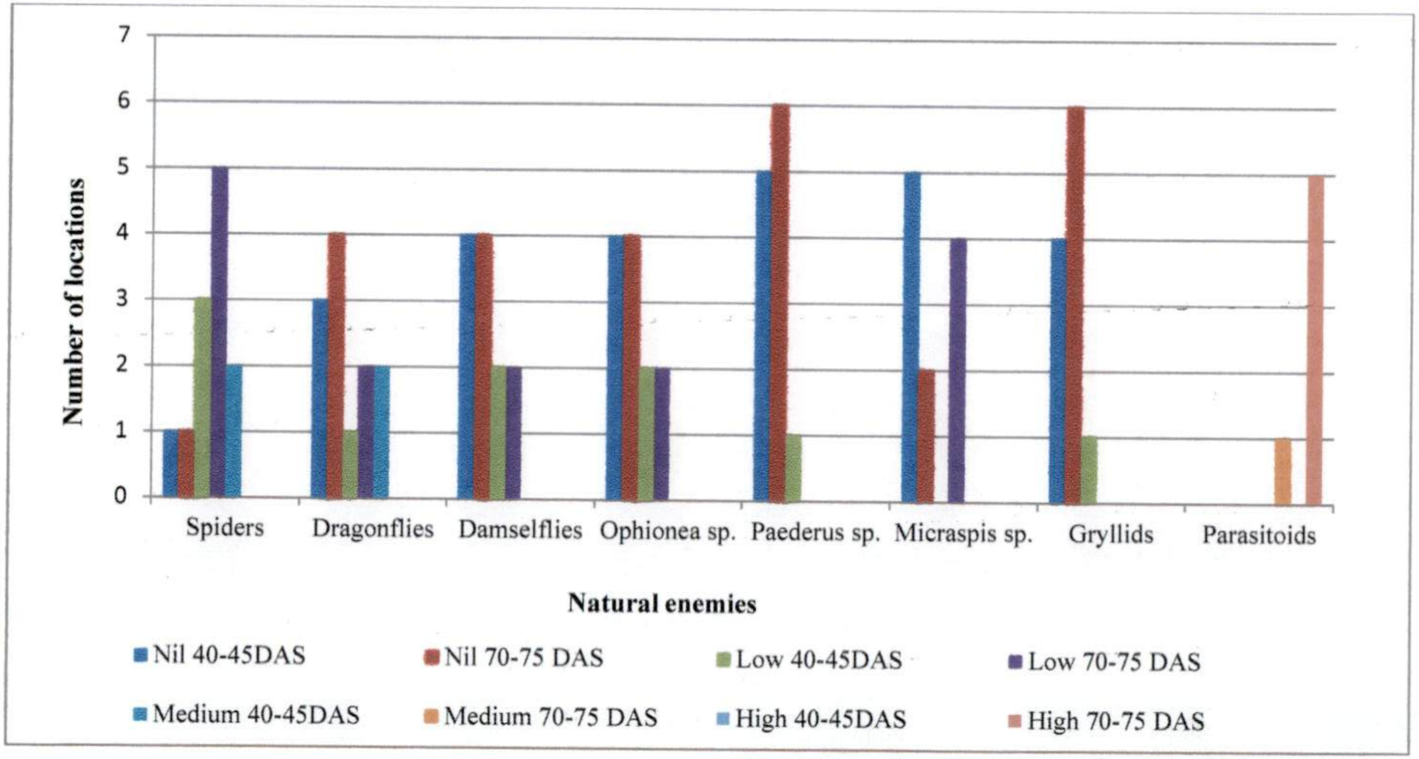



**Fig 2. Occurrence of natural enemies in the locations surveyed under upland rice in Alapuzha district**

Predators / Parasitoids (Adults 10 sweeps$^{-1}$); Nil: 0, Low: 0.1-2.5, Medium: 2.6-5.0, High: >5.0
DAS: Days after sowing

cropping period and it increased gradually when crop reached reproductive stage with high pest incidence. Some are stage specific *viz., P. fuscipes* and gryllids found only at vegetative stage and *M. discolor,* at reproductive stage. William settle (1994) ascertained that predators are abundant during vegetative stage as they depend on sap feeders in rice crop. However, studies made by Premila, (2003) revealed that different predators are distributed continuously throughout cropping period and increased gradually from early to later stage of the crop.

Spiders were found throughout the cropping period, recorded low and medium population at vegetative stage and low at reproductive stage. *Agriocnemis* sp. and *T. maxillosa* are abundant in rice ecosystem of Thiruvananthapuram and population of *C. flavipes* and *Tetrastichus schoenobii* Ferriere population vary depending on the growth stages of the crop (Ajaykumar, 2000). Lekha (2003) consolidated different natural enemies *viz., Agriocnemis* sp, *M. crocera, P. fuscipes, O. nigrofasciata,* and *T. maxillosa* from Thiruvananthapuram district. *G. triangulifer, X. flavolineata* and *Cotesia* sp. were found in rice ecosystem of Thiruvananthapuram and their population gradually increased from vegetative to reproductive stage. These spiders have seen commonly in kuttanad rice ecosystem (Premila, 2003). Spiders *viz., Tetragnatha* sp. and *Argiope* sp. were present in all growth stages of rice as reported by Joseph, 2010 from Kalliyor panchayath of Thiruvananthapuram district. Spiders are omnipresent and have the role of natural enemies in rice pest management. These are given prime importance in developed countries *viz.,* China, Japan, Philippines etc., and treated as major biocontrol agents. Singh and Singh, 2012 opined that spiders are less studied arthropods in rice ecosystem in India and less explored in Kerala. Seventeen different species of documented spiders played a key role in pest regulation from rice ecosystem of Kerala (Anis and Premila, 2016).

Most species of natural enemies which were recorded from wet land rice cultivation are commonly found in upland also indicating their suitability under upland rice ecosystem.

## 5.2. MANAGEMENT OF STEM BORER, LEAF ROLLER AND GALL MIDGE IN UPLAND RICE

Rice is a crop which is infested by pests at all stages from seed to seed. After intensification of agriculture, many chemical pesticides were introduced to get rid of these pests in rice. However, this disturbed the ecosystem by affecting the beneficial fauna. Hence protecting rice ecosystem is having a crucial role by adopting ecofriendly tactics.

Basically upland rice is a poor habitat for most of the pests. However, the results obtained from all the treatment are highly variable. Congenial climate make the organic pesticides more effective in managing the pests and are found to be safer to natural enemies. Various bio pesticides were tested along with a safe chemical which is recommended (KAU, 2016) against stem borer and leaf feeders of rice.

An investigation on the efficacy of organic pesticides with check synthetic pesticide chlorantraniliprole was undertaken. The results of the experiment on management of stem borer and leaf roller are represented in 4.2. The dead heart incidence was significantly reduced in all the treatments, the lowest being observed in the treatment of cashew nut shell liquid 0.1% throughout the period of observation. However, significant reduction in damage compared to control occurred at 50 and 70 DAS by cashew nut shell liquid 0.1% (Fig. 3). Cashew nut shell liquid 5-25 % concentration caused cent per cent mortality of coconut root grub *L. coneophora* (John *et al.,* 2008). The cashew nut shell liquid 1% showed the deformed larva and delayed larval and pupal development in *H. armigera* and *S. obliqua* studied by Mahapatro (2011). Chitin based Pseudomonas 2.5 kg ha$^{-1}$was found to be effective at 10 days after treatment at 30 and 50DAS. The damage of dead hearts observed in plots treated with synthetic pesticide chlorantraniliprole 18.5 SC 0.005% was also significantly lower. This was supported from study of Omprakash *et al.* (2017). Of all the treatments significantly reduced the damage over control.

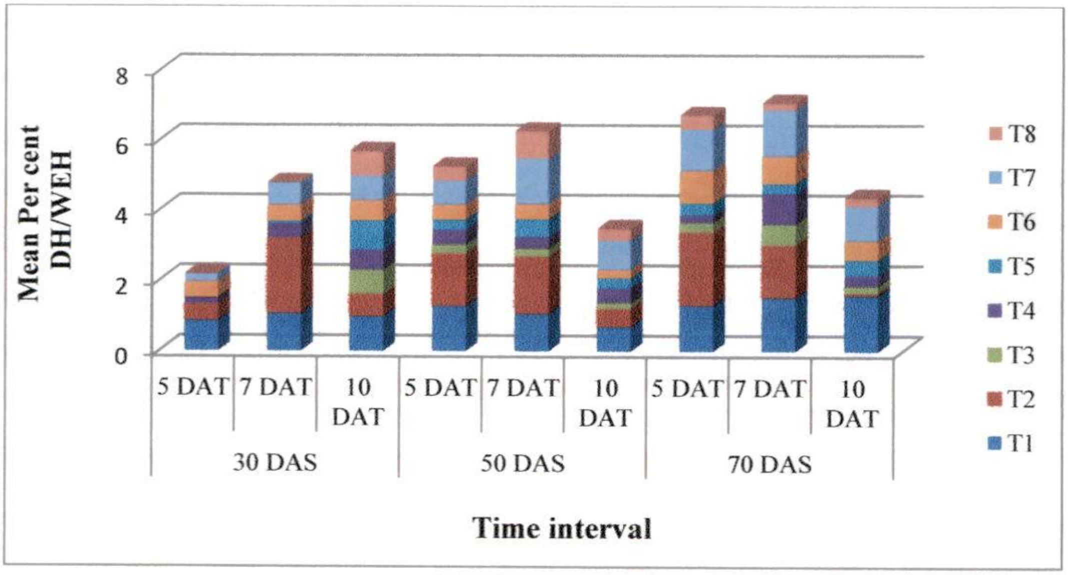



**Fig. 3 Effect of organic pesticides on per cent dead heart/white ear head at different growth stages of the crop**

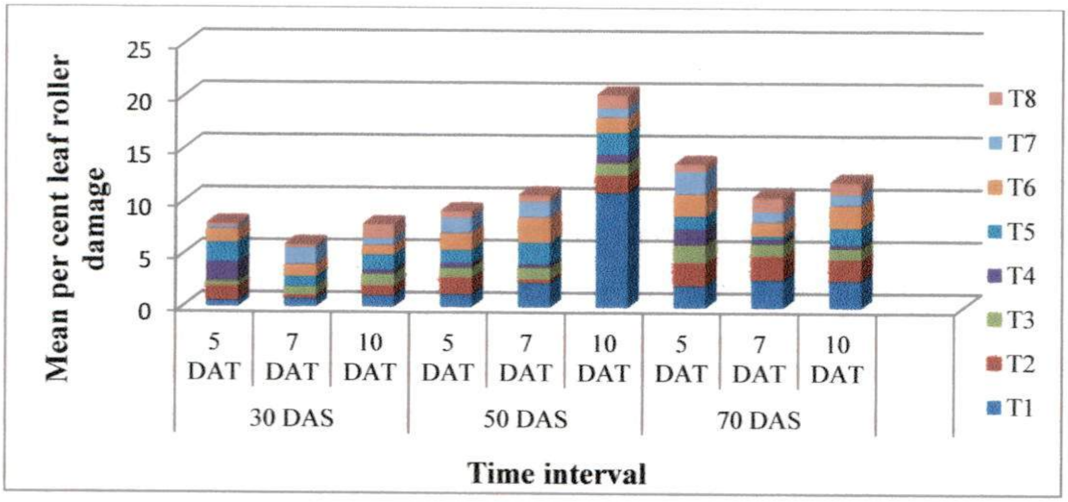



**Fig. 4 Effect of organic pesticides on per cent damage caused by leaf roller at different growth stages of the crop**

**Treatments:** $T_1$-Talc formulated *B.bassiana* ITCC 6063 -2%, $T_2$-1% Azadirachtin 0.003%, $T_3$-Cashewnut shell liquid 0.1%, $T_4$-Fish jaggery extract 0.6%, $T_5$-Dasagavya 3%, $T_6$-Chitin based Pseudomonas 2.5 kg ha$^{-1}$, $T_7$-*B. thuringiensis* 0.04%, $T_8$-Chlorantraniliprole 18.5 SC 0.005% (POP of KAU), $T_9$-Untreated control

DAS: Days after sowing, DAT: Days after treatment

Though all the treatments recorded significant reduction in damage by leaf roller compared to control the lowest damage was recorded in the treatment fish jaggery extract 0.6% throughout the period of observation except at five days after treatment at 30 DAS. At five days after treatment at 30 DAS, the treatments *B. thuringiensis* 0.04% and chlorantraniliprole 18.5 SC 0.005% recorded the lowest damage (Fig. 4). The other organic pesticides *viz.*, dasagavya 3%, cashew nut shell liquid 0.1% and azadirachtin 0.003% also have some effect in reducing the damage by leaf roller in upland rice. Khater, 2012 reported that botanicals can greatly reduce the use of toxic pesticides thereby delaying resistance development

Regarding the effect of organic pesticides on population of adult stem borer, all the treatments except *B. thuringiensis* 0.04% recorded significant reduction in adult population compared to control at five days after treatment at 30DAS. However, the lowest population of adult stem borer was observed in the treatment cashew nut shell liquid 0.1% throughout the period of observation.

All the treatments recorded significantly lower population of adult leaf roller. The treatment fish jaggery extract 0.6% recorded the lowest population among organic pesticides throughout the period of observation. But at five and seven days after treatment at 50 DAS the treatment dasagavya 3% recorded cent per cent reduction in population of adult leaf roller

The other pests recorded in sweeps were grass hopper, hispa, leptispa and rice bug. Though all the treatments recorded significantly low population of grass hopper, among the organic pesticides, fish jaggery extract 0.6% recorded the lowest population at five and seven days after treatment at 30 and 50 DAS. But at 70 DAS, cashew nut shell liquid 0.1% recorded the lowest population throughout the crop period.

In the case of hispa though all the treatments recorded significantly low population, cashew nut shell liquid 0.1% and fish jaggery extract 0.6% recorded the lowest population throughout the period of observation. But at 7days after treatment at 50 DAS, azadirachtin 0.003% recorded the lowest population of hispa.

Like grass hopper and hispa, leptispa population was reduced significantly in the treatment fish jaggery extract 0.6% at five days after treatment at 30 DAS. But cent per cent reduction in population was observed in the treatment chitin based Pseudomonas 2.5 kg $ha^{-1}$ at seven days after treatment at 50 DAS. The other treatments *viz.,* cashew nut shell liquid 0.1% and chitin based Pseudomonas 2.5 kg $ha^{-1}$ also recorded reduction in population of blue beetle at 50 and 70 DAS.

No incidence of gall midge was recorded in uplands which is still considered as a major pest in low land rice. Early stage of the crop in wet season is not suitable for gall midge incidence under rainfed condition (Williams *et al.,* 2007). Ukwungwu and Joshi, 2008 reported that commonly gall midge prefer wet season and low land rice is best niche for gall midge and also climatic conditions affect the pest incidence.

All the organic pesticides were found to be safer to natural enemies represented in 4.2.5. Highest population of natural enemies was recorded at all the crop stages in control which harboured more pests and hence conserved more natural enemies. Control plot had created a good habitat for conserving maximum population of predators throughout the crop period. The treatments cashew nut shell liquid 0.1% and fish jaggery extract 0.6% recorded highest population on par with control throughout the cropping period. Parasitoids and spider population was also the highest in control plots followed by the organic pesticides *viz.,* cashew nut shell liquid 0.1%, fish jaggery extract 0.6% and Dasagavya 3%. Among the organic pesticides, cashew nut shell liquid 0.1%, fish jaggery extract 0.6% and dasagavya 3% were recorded to be safer to natural enemies. The maximum population of predators was recorded during later stage of the crop (70 DAS). Parasitoids population was declining from 30DAS to 50 DAS, and later increased at 70 DAS.

Results presented in 4.2.6 showed that when compared to control significantly higher yield of grain was obtained from the treatments cashew nut shell liquid 0.1 %, fish jaggery extract 0.6% and chlorantraniliprole 18.5 SC 0.005% (Fig. 5). Palis *et al* (1988) reported that rice yield was heavily reduced with high incidence of leaf roller. The highest marginal benefit cost ratio of 2.6 was worked out to be the highest for the treatment cashew nut shell liquid 0.1% followed by 2.5 for chlorantraniliprole 18.5 SC 0.005% and 2.1 for fish jaggery extract 0.6%.

Overall results showed that, organic pesticides have immense capacity in management of insect pests and also involved in enhancing the population of natural enemies. However, though the population of pests and its damage recorded in the treatment check chlorantraniliprole 0.005% was on par with organic pesticides, the natural enemy population was relatively low.

## 5.3. MANAGEMENT OF BROWN PLANT HOPPER (BPH) AND RICE BUG IN UPLAND RICE

BPH was considered as minor pest earlier. Parasappa *et al.* (2007) opined that the reduction in population could be attributed to fluctuation in climatic condition and cropping pattern. He also proved that BPH prefer direct sown irrigated wet land having stagnant water and completes their life stages at the base of the crop near water level. Chaudhary *et al.* (2014) reported that BPH incidence was directly proportional to temperature and humidity and inversely proportional to rain. Due to intensification and heavy application of chemicals it was emerged as major under low land cultivation (Dharavath and Chandrer, 2017) and cause direct and indirect damage by virus transmission. In upland rice ecosystem, the incidence was completely nil. This may be due to the dry condition in upland cropping system.

From the results 4.3.1, it is seen that rice bug population was effectively controlled by dasagavya 3% at 50 and 70 DAS and was also effective in reducing the grain damage (Fig 6 and 7). Secondary metabolites and minerals and organic acids

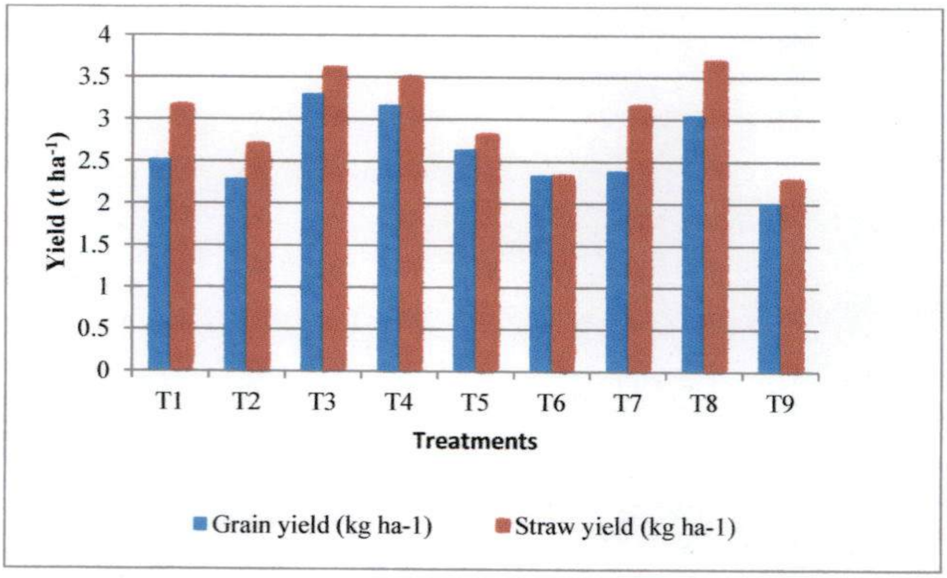



**Fig 5. Effect of organic pesticides on yield of upland rice (Exp. 2)**

**Treatments:** $T_1$-Talc formulated *B.bassiana* ITCC 6063 -2%, $T_2$-1% Azadirachtin 0.003%, $T_3$-Cashewnut shell liquid 0.1%, $T_4$-Fish jaggery extract 0.6%, $T_5$-Dasagavya 3%, $T_6$-Chitin based Pseudomonas 2.5 kg $ha^{-1}$, $T_7$-*B. thuringiensis* 0.04%, $T_8$-Chlorantraniliprole 18.5 SC 0.005% (POP of KAU), $T_9$-Untreated control

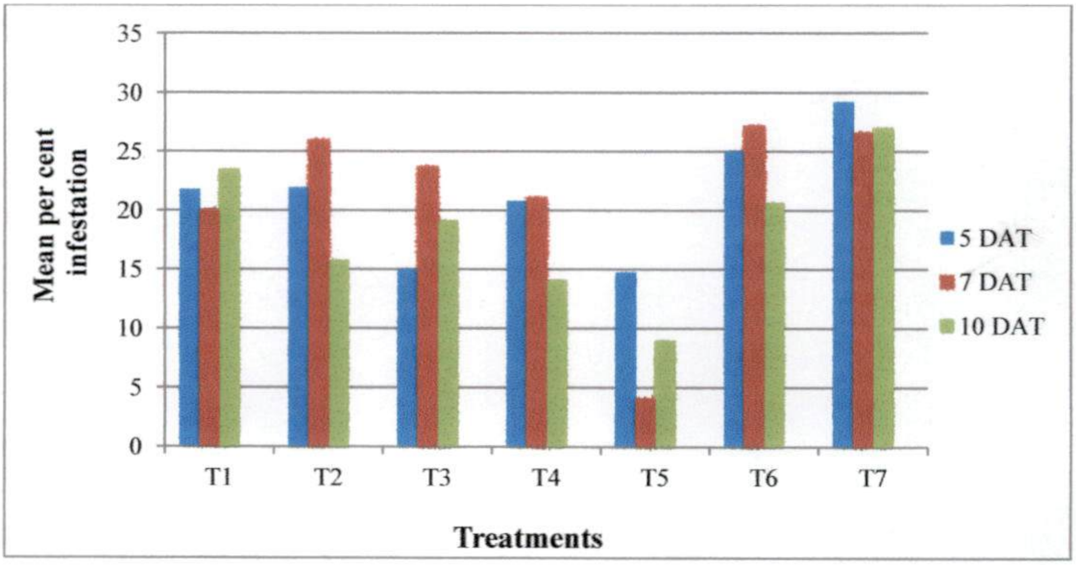



**Fig. 6 Effect of organic pesticides on infestation of grains by rice bug at 70 DAS**

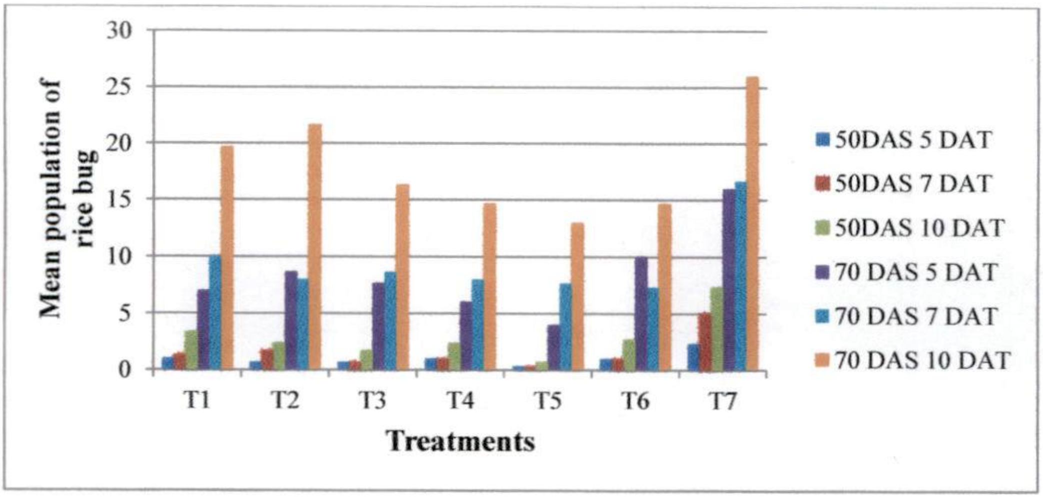



**Fig. 7 Effect of organic pesticides on population of rice bug at different growth stages of crop**

**Treatments:** $T_1$-1% Azadirachtin 0.003%, $T_2$-Chitin based Pseudomonas 2.5 kg ha$^{-1}$, $T_3$-Cashewnut shell liquid 0.1%, $T_4$-Fish jaggery extract 0.6%, $T_5$-Dasagavya 3%, $T_6$-Malathion 50 EC 0.1%, $T_7$-Untreated control

DAS: Days after sowing, DAT: Days after treatment

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found in plant extracts used in dasagavya imparts them insecticidal property (Das *et al.,* 2004). The other organic pesticides *viz.,* cashew nut shell liquid 0.1% and fish jaggery extract 0.6% and chitin based Pseudomonas 2.5 kg $ha^{-1}$ were also recorded to be effective. This finding is supported by Zhou *et al.* (2013) who reported the same effect of entomopathogens in pest control. Being a major pest, rice bug caused 30% annihilation of the crop at milky or soft dough stage to harvesting under upland rice cultivation (Tiwari *et al.,* 2014). Gupta and Kumar (2017) reported the effectiveness of the check insecticide Malathion 50EC 0.1% in controlling rice bug attack.

The other pests recorded were stem borer, leaf roller, hispa and grass hopper and green leaf hopper. The green leaf hopper was effectively controlled with Dasagavya 3% at 50 and 70 DAS. The other treatments *viz*., Fish jaggery extract 0.6% and Malathion 50 EC 0.1% were also effective in controlling green leaf hopper.

Significantly high population of parasitoids was observed in control and the treatments fish jaggery extract 0.6% and dasagavya 3% at 50 DAS. But at 70 DAS significantly high population was observed in the treatments cashew nut shell liquid 0.1%, chitin based Pseudomonas 2.5 kg $ha^{-1}$ and azadirachtin 0.003% also.

The highest population of predators were recorded by control throughout the period of observation followed by the treatment dasagavya 3%. The population of predators in the treatments fish jaggery extract 0.6% and cashew nut shell liquid 0.1% were as high as in control and dasagavya 3%. In the case of spiders also, though not significant control recorded the highest population throughout the period of observation. Among the treatments dasagavya 3% with the highest population can be considered safer to spiders. Overall population of predators and parasitoids was found to be maximum during later crop stage. Spider population was increasing gradually and reached maximum at 70 DAS.

Results of 4.3.4 represent the yield of rice. The highest yield was recorded in the treatment cashew nut shell liquid 0.1% which was on par with the yield recorded

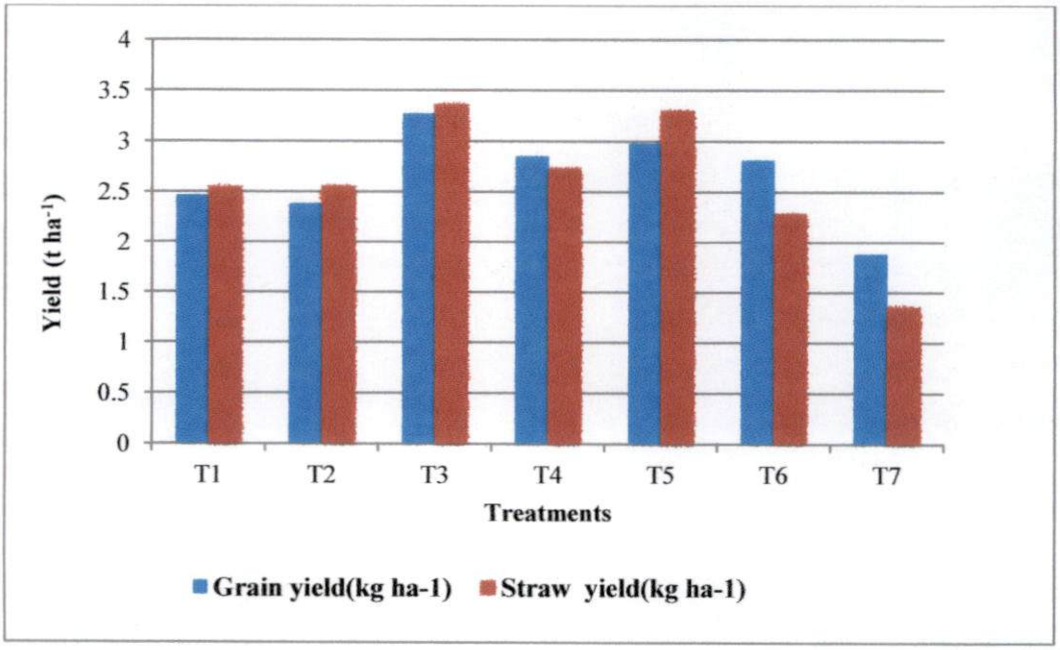


**Fig. 8 Effect of organic pesticides on yield of upland rice (Exp.3)**

**Treatments:** $T_1$-1% Azadirachtin 0.003%, $T_2$-Chitin based Pseudomonas 2.5 kg $ha^{-1}$, $T_3$-Cashewnut shell liquid 0.1%, $T_4$-Fish jaggery extract 0.6%, $T_5$-Dasagavya 3%, $T_6$-Malathion 50 EC 0.1%, $T_7$-Untreated control

DAS: Days after sowing, DAT: Days after treatment

from dasagavya 3% and Malathion 50 EC 0.1% (Fig. 8). Regarding straw yield, highest yield was recorded in the treatment cashew nut shell liquid 0.1% followed by dasagavya 3%. The highest marginal benefit cost ratio of 2.8 was obtained from treatment cashew nut shell liquid 0.1% followed by 2.6 from dasagavya 3%

From the present study it was found that yellow stem borer, leaf roller and rice bug are the major insect pests in the upland rice ecosystem. Stem borer and leaf roller was present throughout the cropping period and rice bug during reproductive stage of the crop. The natural enemies recorded throughout the crop and population increases from earlier to later stages based on pest population.

Nalinakumari *et al.*, 1996 observed that up to certain stage, rice can resist the pest incidence with residence of defenders in moderate population without use of insecticides. Hence, the conservation of carnivorous arthropods in situ for suppressing pest population seems to be best. High diversity of parasitoids in rice ecosystem is beneficial for sustainable natural control (Buchori *et al.*, 2008). The results of this investigation showed that the organic pesticides *viz.*, cashew nut shell liquid 0.1%, fish jaggery extract 0.6% and dasagavya 3% were more effective than microbial insecticides *viz.*, Chitin based Pseudomonas 2.5 Kg $ha^{-1}$ and *B. bassiana* . Gangwar*et al.*, (2015) who opined that biological control should be preferable over chemical as biocontrol contributes 60% mortality of rice pests. Microbials prefer microclimate with high humidity and favours water logged fields for effective control (Nilamudeen, 2015). This may be reason for reduced effect of microbial pesticides on the pests infesting upland rice. With regard to natural enemies, botanicals are safer and less toxic. Though the chemicals insecticides *viz.*, chlorantraniliprole 18.5 SC 0.005% and Malathion 50 EC 0.1% were effective on pest suppression, they will affect the natural enemies of the rice ecosystem. Bio pesticides have a great role in safety and conservation of natural enemies in order to manage rich biodiversity by balancing pests and natural enemies.

Biopesticides dedicate ample scope for pest control by keeping away dangerous pesticides and conserving natural enemies under upland cultivation. Under normal state, the best technique is to conserve the existing natural enemies by using safer pesticides and tolerant varieties to manage the rice pests (Gopan, 2004).

As a future line of work, study on the biodiversity of insect pests and natural enemy complex in association with environmental correlation studies on the organic pesticides like cashew nut shell liquid, dasagavya and chitin based Pseudomonas on management of key pests in major rice tracts of the state may be under taken up.

# SUMMARY

# 6. SUMMARY

Rice is a diverse ecosystem, home for many pests and natural enemies. Information regarding occurrence, distribution and type of damage caused by the pests are important to adopt ecofriendly management strategy. This was studied through survey conducted in six different locations from Alapuzha district. The detailed information regarding population, damaging percentage and associated natural enemies in upland rice ecosystem were documented at vegetative and reproductive stages of the crop. The efficiency of four botanicals *viz.,* azadirachtin 0.003%, cashew nut shell liquid 0.1%, fish jaggery extract 0.6% and dasagavya 3%, three microbials *viz.,* talc formulated *B.bassiana* ITCC 6063 -2%, chitin based Pseudomonas 2.5 kg $ha^{-1}$and *Bacillus thuringiensis* 0.04% and two synthetic chemicals *viz.*, chlorantraniliprole 18.5 SC 0.005% and Malathion 50 EC 0.1% were tested against borers, leaf feeders and sucking pests of upland rice. These were also evaluated against the population of natural enemies under field condition.

The major findings of the study are summarized below.

The results of the survey revealed that all the six locations of Alapuzha district recorded the incidence of leaf roller (*Cnaphalocrocis medinalis* Guenee), stem borer (*Scirpophaga incertulas* Walker), hispa (*Dicladispa armigera* Oliver), and blue beetles (*Leptispa pygmaea* Baly.). Among these, stem borer and leaf roller were found throughout the cropping period causing damage in low intensities. The damage by stem borer was high in reproductive stages. Stem borer population was zero in vegetative and low in reproductive stage of the crop. The leaf roller population increased gradually from vegetative to reproductive stage.

During reproductive stage, 50% and 33% of fields showed low and medium infestation by rice bug. The incidence of blue beetle population was low at both the crop stages and hispa was completely nil during reproductive stage of the crop.

Natural enemies documented during the survey were parasitoids (*Goniozus nephantidis* Muesebeck, *Cotesia* sp.), spiders (*Tetragnatha maxillosa* Thorell, *Argiope* sp.), and predators (dragonflies, damselflies, gryllids, *Ophionea nigrofasciata* Schmidt-Goebel, *Paederus* sp. and *Micraspis* sp.) Parasitoids were predominant in reproductive stage. *Paedarus* sp. and gryllids were specific at vegetative stage and *Micraspis sp.* at reproductive stage of the crop.

Among organic and synthetic pesticides tried, organic pesticides were found to be as effective as chemical check in controlling stem borer and leaf roller. Among organic pesticides tested against stem borer and leaf roller, cashew nut shell liquid 0.1% was found to be effective and superior to other treatments against stem borer. Leaf roller damage was reduced significantly with fish jaggery extract 0.6%. The treatments *B. thuringiensis* 0.04%, dasagavya 3% , cashew nut shell liquid 0.1% and azadirachtin 0.003% also had some effect in reducing the damage by leaf roller in upland rice.

The lowest population of adult stem borer was observed in the treatment cashew nut shell liquid 0.1% throughout the period of observation. The treatment fish jaggery extract 0.6% recorded the lowest population of leaf roller among organic pesticides throughout the period of observation. But at five and seven days after treatment at 50 DAS, the treatment dasagavya 3% recorded cent per cent reduction in population of adult leaf roller.

Significantly low population of hispa and grasshopper was recorded in cashew nut shell liquid 0.1% and fish jaggery extract 0.6%. The treatments cashew nut shell liquid 0.1% and fish jaggery extract 0.6% recorded the lowest population of rice hispa throughout the period of observation. But at 7 days after treatment at 50 DAS azadirachtin 0.003% recorded the lowest population of hispa. Among the organic pesticides, fish jaggery extract 0.6% recorded the lowest population of grass hoppers at five and seven days after treatment at 30 and 50 DAS. But at 70 DAS, cashew nut shell liquid 0.1% recorded the lowest population. Blue beetle population was reduced significantly in the treatment fish jaggery extract 0.6% at five days after treatment at 30 DAS. But cent per cent reduction in population was observed in the treatment chitin based Pseudomonas 2.5 kg $ha^{-1}$ at seven days after treatment at 50 DAS.

Gall midge incidence was nil in upland rice due to undesirable climatic condition and cropping pattern.

Among the organic pesticides, cashew nut shell liquid 0.1%, fish jaggery extract 0.6% and dasagavya 3% were recorded to be safer to natural enemies. Highest population of natural enemies were recorded at all the crop stages in control which harboured more pests and hence conserved more natural enemies. The treatments cashew nut shell liquid 0.1% and fish jaggery extract 0.6% recorded a predator population on par with control throughout the cropping period. The maximum population of predators were recorded during later stage of the crop (70 DAS). Parasitoids population was declining from 30DAS to 50 DAS, and later increased at 70 DAS.

Significantly higher grain yield was recorded in the treatments cashew nut shell liquid 0.1 %, fish jaggery extract 0.6% and chlorantraniliprole 18.5 SC 0.005%. The highest marginal benefit cost ratio of 2.6 was worked out for the treatment cashew nut shell liquid 0.1% followed by 2.5 for chlorantraniliprole 18.5 SC 0.005% and 2.1 for fish jaggery extract 0.6%. The highest straw yield was obtained from the treatment cashew nut shell liquid 0.1 % followed by fish jaggery extract 0.6%.

From the experiment on management of BPH and rice bug, it was observed that rice bug population was effectively controlled by dasagavya 3% at 50 and 70 DAS and was also effective in reducing the grain damage. Cashew nut shell liquid 0.1%, fish jaggery extract 0.6% and chitin based Pseudomonas 2.5 kg $ha^{-1}$ were also recorded to be effective against rice bug .

The population of green leaf hopper was effectively controlled with dasagavya 3% at 50 and 70 DAS. The treatment fish jaggery extract 0.6% was also effective in controlling green leaf hopper.

BPH incidence was nil in upland rice due to undesirable climatic condition and cropping pattern.

Significantly high population of parasitoids was observed in control and the treatments fish jaggery extract 0.6% and dasagavya 3% at 50 DAS. But at 70 DAS significantly high population was observed in the treatments cashew nut shell liquid 0.1%, chitin based Pseudomonas 2.5 kg $ha^{-1}$ and azadirachtin 0.003% also. The overall population of predators and parasitoids was maximum during later crop stage. Spider population was increasing gradually and reached maximum at 70 DAS.

Significantly higher grain yield was recorded by the treatments cashew nut shell liquid 0.1%, dasagavya 3% and Malathion 50 EC 0.1% compared to control with a marginal B: C ratio of 2.8, 2.6 and 2.5 respectively. The highest straw yield was recorded in the treatment cashew nut shell liquid 0.1% followed by dasagavya 3%.

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# ECO-FRIENDLY MANAGEMENT OF MAJOR PESTS OF UPLAND RICE ECOSYSTEM

*by*

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# ABSTRACT

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The research on "Eco-friendly management of major pests of upland rice ecosystem" was carried out at Onattukara Regional Agricultural Research Station, Kayamkulam to document the insect pests and natural enemies of upland rice and to develop an ecofriendly management strategy against major pests.

A survey was conducted in six selected locations of Alapuzha district during first crop season of 2017 having an area not less than 0.5 acre of rice under upland cultivation. The survey revealed that farmers commonly depend on short duration varieties for upland rice cultivation like Bhagya and Jyothi. Stem borer and leaf roller were found throughout the cropping period causing damage in low intensities. The damage by stem borer was high in reproductive stages and leaf roller population increased gradually from vegetative to reproductive stage. During reproductive stage, rice bugs were present in low and medium intensities and blue beetle and hispa were the minor pests observed.

Natural enemies documented during the survey were parasitoids (*Goniozus nephantidis, Cotesia* sp. and *Tetrastichus* sp.), spiders (*Tetragnatha maxillosa, Argiope* sp.), and predators (dragonflies, damselflies, gryllids, *Ophionea nigrofasciata, Paederus* sp. and *Micraspis* sp.) Parasitoids were predominant in reproductive stage. *Paedarus* sp. and gryllids were specific at vegetative stage and *Micraspis sp.* at reproductive stage of the crop.

Results from field experiment on management of stem borer, leaf roller and gall midge revealed that, among organic pesticides cashew nut shell liquid 0.1% was found to be effective and superior to other treatments in reducing the damage and adult population of stem borer. Leaf roller damage ant its population was reduced significantly with fish jaggery extract 0.6%. Fish jaggery extract was found to be reducing the population of grass hoppers, hispa and blue beetles also.

Among the organic pesticides, cashew nut shell liquid 0.1%, fish jaggery extract 0.6% and dasagavya 3% were recorded to be safer to natural enemies. Significantly higher grain yield was recorded in the treatments cashew nut shell liquid 0.1 %, fish jaggery extract 0.6% and chlorantraniliprole 18.5 SC 0.005% with a high marginal benefit cost ratio of 2.6, 2.1 and 2.5 respectively. The highest straw yield was obtained from the treatment cashew nut shell liquid 0.1 % followed by fish jaggery extract 0.6%.

Results of the experiment on management of BPH and rice bug revealed that rice bug population and grain damage was effectively controlled by dasagavya 3%. Cashew nut shell liquid 0.1%, fish jaggery extract 0.6% and chitin based Pseudomonas 2.5 kg $ha^{-1}$ were also recorded to be effective against rice bug .The population of green leaf hopper was reduced with dasagavya 3% followed by fish jaggery extract 0.6%. Significantly high population of parasitoids was observed in control and the treatments fish jaggery extract 0.6% and dasagavya 3%.

Significantly higher grain yield was recorded by the treatments cashew nut shell liquid 0.1%, dasagavya 3% and Malathion 50 EC 0.1% with a marginal B: C ratio of 2.8, 2.6 and 2.5 respectively. The highest straw yield was recorded in the treatment cashew nut shell liquid 0.1% followed by dasagavya 3%

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