EFFICACY OF SOME PROMISING CHEMICAL INSECTICIDES FOR CONTROLLING RICE STEM BORER, LEAF ROLLER AND BROWN PLANT HOPPER

A THESIS

BY

ANJUMAN SULTANA

MASTER OF SCIENCE
IN
ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

SHER-E-BANGLA NAGAR, DHAKA -1207, BANGLADESH

DECEMBER, 2013

EFFICACY OF SOME PROMISING CHEMICAL INSECTICIDES FOR CONTROLLING RICE STEM BORER, LEAF ROLLER AND BROWN PLANT HOPPER

ANJUMAN SULTANA
Registration No. 07-2246

A Thesis

submitted to
Department of Entomology
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
ENTOMOLOGY

SEMESTER: JULY-DECEMBER, 2013

APPROVED BY

………………………………	…………………………………………
Prof. Dr. Md. Razzab Ali	**Associate Prof. Dr. Tahmina Akter**
Supervisor	**Co-supervisor**

……………………………….
Dr. Tahmina Akter
Chairman
Examination Committee

Prof. Dr. Md. Razzab Ali
Department of Entomology
Sher-e-Bangla Agricultural University
Dhaka, Bangladesh

CERTIFICATE

*This is to certify that thesis entitled,"**EFFICACY OF SOME PROMISING CHEMICAL INSECTICIDES FOR CONTROLLING RICE STEM BORER, RICE LEAF ROLLER AND BROWN PLANT HOPPER**" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in ENTOMOLOGY,** embodies the result of a piece of bona fide research work carried out by **Anjuman Sultana, Registration No. 07-2246** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information, as has been availed of during the course of this investigation has duly been acknowledged.

Dated :December,2013
Dhaka, Bangladesh

Prof. Dr. Md. Razzab Ali
Supervisor

Dedicated to

My

Beloved Parents

ABBREVIATIONS AND ACRONYMS

AEZ	:	Agro-Ecological Zone
et al.	:	And others
BBS	:	Bangladesh Bureau of Statistics
cm	:	Centimeter
CV	:	Coefficient of variation
DAT	:	Days After Transplanting
^{o}C	:	Degree Celsius
d.f	:	Degrees of freedom
etc.	:	Et cetra
EC	:	Emulsifiable Concentrate
FAO	:	Food and Agriculture Organization
Fig.	:	Figure
g	:	Gram
ha	:	Hectare
p^H	:	Hydrogen ion conc.
J.	:	Journal
Kg	:	Kilogram
LSD	:	Least Significant Difference
L	:	Liter
m	:	Meter
MS	:	Mean sum of square
mm	:	Millimeter
MP	:	Murate of Potash
no.	:	Number
%	:	Percent
SAU	:	Sher-e-Bangla Agricultural University
m^2	:	Square meter
t	:	Ton
TSP	:	Triple Super Phosphate

ACKNOWLEDGEMENTS

All the praises, gratitude and thanks are due to the omniscient, omnipresent and omnipotent Allah who enabled her to complete this thesis work successfully for her MS degree.

She wishes to express her sincere appreciation and profound gratitude and best regards to her reverend supervisor, **Dr. Md. Razzab Ali,** Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207 for his scholastic guidance, innovative suggestion, constant supervision and inspiration, valuable advice and helpful criticism in carrying out the research work and preparation of this manuscript.

She deem it a proud privilege to acknowledge her gratefulness and best regards to her respectable co-supervisor and chairman of the examination committee, **Dr. Tahmina Akter,** Associate Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka-1207 for her valuable advice, constructive criticism and factual comments in upgrading the research work and preparation of this manuscript.

She wishes to express her cordial thanks to other respected teachers of the Department of Entomology, Departmental and field staffs for their active help during the experimental period.

She expresses her unfathomable tributes, sincere gratitude and heartfelt indebtedness from her core of heart to her parents, whose blessing, inspiration, sacrifice, and moral support opened the gate and paved the way of her higher study.She appreciates the sacrifices of her brothers and sisters.

She wants to say thanks to her classmates and friends for their encouragement and inspiration.

Dhaka, Bangladesh
December, 2013 **The Author**

EFFICACY OF SOME PROMISING CHEMICAL INSECTICIDES FOR CONTROLLING RICE STEM BORER, LEAF ROLLER AND BROWN PLANT HOPPER

BY

ANJUMAN SULTANA

ABSTRACT

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh, during the period from November 2012 to May 2013 (Boro season) to study the efficacy of some promising chemical insecticides for controlling rice stem borer, leaf roller and brown plant hopper. The experiment was laid out in a Randomized Complete Block Design with three replications with six treatments. Treatments were T_1= Untreated control, T_2= Virtako 40 WG (Thiamethoxam 20% in combination with Thiamethoxam Chlorantraniliprole 20%) @ 75 g/ha, T_3= Cartap hydrochloride @ 150 g/ha, T_4= Cartap hydrochloride @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g/ha, T_5= Cartap hydrochloride @ 100g/ha in combination with Thiamethoxam 25% @ 60 g /ha, T_6= Cartap hydrochloride @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha. Among the treatments, T_6 comprising Cartap hydrochloride @ 150 g/ha along with Thiamethoxam @ 60 g/ha was found most effective in reducing the stem borer infestation than sole Cartap hydrochloride (T_3) or any other treatments. On the other hand, T_4 comprising Cartap hydrochloride @ 75 g/ha in combination with Thiamethoxam @ 60 g/ha was found most effective in reducing the rice leaf roller infestation and brown plant hopper population in rice field. Though T_6 was the most effective against rice stem borer but its level of reduction was more or less similar to that of T_4 which was comprised of lower dose of Cartap hydrochloride along with Thiamethoxam and thus T_4 was better than T_6.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

CHAPTER I

INTRODUCTION

Rice, *Oryza sativa* is a cereal crop, belongs to the family Gramineae. It is the dominant food crop of Bangladesh, accounting for about 75 percent of agricultural land use. In 2004, more than 75 percent of the global rice harvested area, about 114 million out of 153 million hectare, come from the tropical region whose boundaries are formed by the tropic of cancer in the northern hemisphere and the tropic of Capricorn in the southern hemisphere. The world population projected to increase from 6.13 billion in 2001 to 7.21 billion in 2015 and 8.27 billion in 2030, indicating a corresponding increase in rice demand from 680 million tons in 2015 to 771 million tons in 2031 (FAO, 2004). Rice is more nutricious than any other cereal crops and is an ideal host for over 800 species of insect (Barr and smith, 1975). In tropical Asia, more than 100 species of insects infesting rice. Among them, only about 20 species are of major importance and regular occurrence (Grist and Lever 1969). In Bangladesh, about 175 insect pest species have been reported, which cause damage to the rice plants (Mustafi *et al.*, 2007). The estimated loss of rice in Bangladesh due to insect pests and diseases amounts to 1.5 to 2.0 million tons (Siddique, 1992).

Rice stem borer is a very common insect pest in the world. There are mainly three stem borer of rice. They are rice yellow stem borer, dark headed stem borer and pink headed stem borer. All of them are belong to the Lepidoptera order and Pyralidae family. At larval stage they attack the stem of rice. Only the caterpillar stage of these insects is very destructive in the rice field. Adult insects do not harm in crop field. Adult insects lay eggs on the leaf sheaths and a week after oviposition the emerged larvae become active and starts destructive activities. When larvae stay into the tunnel, they feed on the inner surface of the stem wall. This feeding starts from the base to the apical part of the plants. The central leaf whorl turns into brownish and dries off rapidly, if larvae attack at the vegetative stage of rice plants. But the leaves of the plant remain healthy. This symptom is called dead heart. Infested tillers fail to produce panicles and become dry. Sometimes panicles emerge but do not produce grains on the top of it. As the panicles are empty, they become whitish and remain straight. This symptom is very conspicuous in the rice field. This symptom is known as white head.

Rice leaf folder or roller is considered one of the major harmful insect pest of rice. It belongs to the family Pyralidae and order Lepidoptera. These insects do harm when they are at larval stage. They do harm by rolling leaf and reducing photosynthetic area.

The destructive stage of this insect is the larval stage. As they fold the leaves longitudinally before feeding. They feed the green mesophyll of leaf inside the fold. At first and second instar larvae feed within the slightly folded areas of leaf. At late second instar feed and roll up the maximum area of a leaf. After feeding one leaf, larva moves to another leaf. Feeding reduce the photosynthetic area of leaves. So it stop the vegetative growth and finally reduce the yield. Yield loss is maximum when flag leaf is damaged.

Two species of plant hopper infest rice. These are the brown plant hopper (BPH) and the white backed plant hopper (WBH). High population of plant hoppers cause leaves to initially turn orange-yellow before becoming brown and drying. This condition is called hopper burn which kills the plant. The feeding damage caused by plant hoppers results in the yellowing of the plants. At high population density, crop loss may be 100%. In the 1970s and 1980s, BPH was considered a threat to rice production in Asia. Brown plant hoppers also transmit ragged stunt and grassy stunt viruses. At a population density of 400−500 nymphs or 200 adults per plant, WBH can cause complete loss of rice plants. Outbreaks of WBH were reported in Pakistan in 1978, Malaysia in 1979, and India in 1982, 1984, and 1985.

The aim of this research work was to evaluate the right pesticide for suppressing rice stem borer, rice leaf folder & plant hopper for increasing rice production.

Objectives

Considering the above facts the present study was undertaken with the following objectives:

1. to assess the level of infestation caused by rice yellow stem borer, rice leaf roller and brown plant hopper on rice.
2. to find out the most effective insecticides applied against these insect pests and
3. to find out the effective combinations of promising insecticides used against these insect pests.

CHAPTER II

REVIEW OF LITERATURE

Rice suffers heavy losses every year due to attack of many insect pests, among those, yellow stem borer (YSB), leaf roller and brown plant hopper (BPH) are most important. They cause huge damage of grain, leaf, stem and ultimately yield. Sometimes its damage make them key pest. However, available literatures relevant to this research are reviewed below.

2.1 Rice yellow stem borer (YSB)

Scirpophaga incertulas, commonly known as the rice yellow stem borer. The rice stem borer is generally considered as the most serious pest of rice. They occur regularly and attack rice plants from seedling to mature stages. About 16 different stem borer species are found in rice fields.

Rahman *et al*. (2004) reported six species of rice stem borer cause damage to rice and among then the yellow stem borer, dark headed stripped borer and pink borer have major economic significance.

Kapur (1967) reported that in Bangladesh, the most destructive and widely distributed species is yellow stem borer (YSB).

2.1.1 Systematic Position of rice YSB

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Pyralidae

Genus: *Scirpophaga*

Species: *S. incertulas*

2.1.2 Life history of rice stem borer

Adult habits

Puttarudriah (1945) studied that the female moth is bigger than the male. The forewings are bright yellowish-brown with a clear single black spot in the center. Its wing venation is prominent; antennae filamentous and un-segmented; maxillary palpi well developed, erect and longer in the female than in the male; and its proboscis vestigial. The abdomen is wide; the tip is covered with tufts of yellowish hairs, forming a circle around a ventral opening. The male moth is pale yellow. Its abdomen is slender and the anal end has a thin, hairy covering dorsally. Spots on the forewing are not conspicuous. The axillary palpi are short and well developed. The moths are difficult to find during the day, even when a large population is present.

Puttarudriah (1945) observed that they are inactive during the day, but can be seen sitting on stems and leaves. They are active in the evening.

Kalshoven (1950) noted that at dusk, especially on still, warm, humid night after a rain, the moths fly and mate in the early evening. They have strong flight power.

Kawada *et al.* (1934) observed the mature larval stage are in the stubble of a winter crop. The larvae are found in their cocoons in the stubble, as far below as the root region. They and pupate before the onset of the hot season. The pupal stage lasts about three weeks.

Kawada *et al.* (1934) reported that the mature larvae pass the winter in rice stubble in a stage of diapauses, and as soon as warm weather begins in April-May, the larvae pupate. They further stated that the larvae are vulnerable to low temperature and high moisture; the percentage of mortality increase during a cold winter. Since the stem borer cannot survive in the cut straw, it goes down into the stubble to spend the period till harvests.

In Japan, where the stubble harbors fewer borers than in Formosa, where six inches of stubble is left on the ground (Shiraki, 1917).

Puttarudriah (1945) noted that the female moths lay eggs early at night in small masses covered with a felt like, buff-colored mass of hairs and scabs derived from the anal tuft of the female. The number of eggs in a cluster ranges from 15 to 80, with average being 25. The eggs are placed on the upper surface of growing leaves near the tip region.

Kalshoven (1950) recorded 100 to 150 eggs per cluster.The eggs are creamy white, flattened, oval and scale like. Before hatching, the eggs darken to a purplish tinge. The eggs hatched in 5 to 8 days during the monsoon months.

Puttarudriah (1945) described six instars of the larvae. The first instar larvae are 1.5 mm long and 0.5 mm wide. The body is pale white, the head and prothoracic shield dark brown and prominent. The first moult takes place within 5 to 6 days after hatching.

Larval habits

Puttarudriah (1945) pointed out that the newly hatched larvae move downward and wander about on the plant surface for one or two hours. They may hang down by a silken thread, get blown off to other plants, land on the water of the paddy field, swim freely in search of seeding, and get to the plants.

McNaughton (1917) observed that they are at home on water because they have an air layer next to their skin.Tender larvae do not survive long in water where no seedlings grow. During these wandering stages, high larval mortality is usually observed.

Shiraki (1917) recorded that only about 10 percent of the larvae developed after a few days when placed on rice plants.

Puttarudriah (1945) observed that they enter the leaf sheath wherever the space is open enough between the stem and the leaf sheath, even at the top of the seedling and feed upon the green tissues of the stem or the sheath for two or three days. They then bore into the stem or the sheath, if the latter is thick enough. Some are found to bore into the leaf sheath at the base from outside.

Often, the entrance site of the borer is node region. The caterpillars bore in at several places, searching for a suitable entrance. After attaching themselves to the stem they feed on the inner tissues and grow. At this stage the larvae distinctly tends to disperse; this explains why rarely more than one larva found in a stem. Frequently the larvae leave the stem after a week. They come out and move to other plants, often making for themselves cylindrical case from rolled-up leaf tips in which they drift on the irrigation water in search of a fresh host plant.

Puttarudriah (1945) observed that older larvae from the second instar onward usually to make leaf cases.

Shiraki (1917) claimed that the floating stage may last for one to three days, during which the larvae becomes darker. These cases, each of which takes an hour, on the average, to prepare and are made only at night. After reaching a new plant, the larvae bore in, leaving their cases sticking to the stem at right angle. The average time for boring is an hour and a half. During rearing, the larvae stay individually within paddy stem bits or cut portions of the stem, the cut cylindrical portion hanging from the mother stems, remaining attacked at one side or falling to the ground. This apparently is a safe means of migration.The larvae within these small bits look very much like those of the rice case worm. A large number of larvae exhibited this behavior under laboratory condition. The symptoms of ‘dead heart’ on young plants appear on the fourth day after boring. The tip of the central shoot fades and dries up in a day or two. The larvae then a bandon the damage plant and search for a new one. In order plants, the injury causes white, empty ear heads. In mature crops, the young larvae, which may be of first or second instar, have been observed to bore into the stalk at the top region, below the ear head; at this stage, a number of them are found in the same stalk.

Pupal habits

Puttarudriah (1945) recorded that the full-grown larvae make a thin silken case over themselves in the stem soon after the prepupal moult. Before pupation, they make an exit hole covered with thin webbing.

Pagden (1930) recorded that the white silken cocoon is closed at the upper end by an oerculum, the lower end being rounded and baglike. A silken tube leads to the hole in the stem which is closed by several membranes. Pupation always takes place in the stem, mostly in the lowest node of the plant or just above the water level in the early generation.

Puttarudriah (1945) found that in seedling they pupate in the root region only.

Isaac and Venkatraman (1941) observed that the pupae usually are 12.0 mm long and 3.0 mm wide, pale initially, then gradually turning dark brown; the abdominal regions, however, remain pale. The pupae are partly execrated, and the tips of their appendages are free. The pupal period is usually 6 to 10 days, but may be prolonged to a month, depending upon the climate. They also noted that the pupation starts sometime in March and the emergence of moths begin in April.The moths become active after dusk when they mate and lay eggs on rice plants.

Ahmed (1973) observed that larvae of yellow rice stem borer feed on green tissue of leaf sheath for 2 to 3 days. Bore into the stem at the nodal position and feed on inner tissue of plant – under severe conditions, it bores at the base and move upwards – central leaf whorl does not unfold, turns brown finally dries off. Lower leaves remain green. The young larvae after hatching bore and feed inside the stem. He also noted that two types of injury are caused dead hearts (D H)and white heads (W H). The act is in early stage the central shoot dries up resulting in the formation of D H. The attack is at a later or reproductive stage of rice crop preferred as W H and effected tillers do not produce normal grain. Investigation at the IRRI, Philippines have shown that early in the growing season, when the rice plant is an active vegetative stage, the plants having D.H. have the ability to produce new tillers to compensate for the early season damage.

Chaudary (1973) & Ghani (1966) observed that as the season progresses, new tillers are produced with a decreasing frequency, when the crop is heading, now new tillers are produced. It is, therefore clear that W.H. is a serious form of injury than D.H.

Kapur (1967), Rao and Israel (2004) observed that the rice stem borers are generally considered as the most serious pest of rice.They occur regularly and attack plants from seedling to maturity stages. About 16 different stem borer species are found in rice fields and among them the yellow stem borer, dark headed striped borer and pink borer are of major borer and have great economic significance.

2.1.3 Nature of damge

Ragini *et al.* (2005) conducted a survey to evaluate the seasonal occurrence and relative abundance of 3 rice stem borer species, i.e, the yellow stem borer (YSB, *Scirpophaga incertulas) and* the pink stem borer (PSB, *Sesamia inferens*) and the dark headed borer (DHB, *Chilo polychrysus*). YSB was the most predominant species in June- September (60.0%) and October -January (48.43%). PSB was as abundant as YSB in October - January (48.43%). DSB was least abundant during either season (4.29-7.18%). YSB infestation was predominant from early tillering to maximum tillering stage and decreased gradually with increasing PSB infestation from the flowering stage.

Srinavasa *et al.* (2000) monitored 3 insect pests of rice viz. *Nephotettix spp.*, *Nilaparvata lugens* and *Scirpophaga incertulas*. They reported spp. and *Nilaparvata lugens* were present throughout the year but showed peaks of abundance in November and May*: S. incertulas* was also present throughout the year with low incidence in March, and had peaks in November and June.

Rai *et al*. (1989) conducted a field survey to determine the relative abundance of stem borers infesting the deepwater rice and to study the population dynamics of these species. The stem borer species were *Scirpophaga incertulas*, *Chilo polychrysus* and *C. suppressalis*, and the Noctuid *Sesamia inferens*. The relative composition of the different species as a percentage of the total stem borer population during the growing and no growing seasons were 3-89,12-81,2-28 and 8 for the 4 species respectively in Bihar. Populations of *C.suppressalis* were highest during the first 2 weeks of November and remained high until July. *S incertulas* and *S. inferens* were predominant during the wet season.

Alam (1988) studied the relative abundance and species composition of 3 Lepidopterous stem borers in upland and irrigated rice in Nigeria and he found that the pyralid *Maliarpha separatella* was the predominant species in upland and irrigated rice, followed in upland rice by the Noctuid *Sesamia clamistis* and another pyralid, *Chilo zacconius,*and in irrigated rice by *C.zacconius* and *S. calamistis*. The proportion of *M.separatella* was higher in irrigated rice than in upland rice.

Saha and Saharia (1970) reported that stem borer moths preferred to oviposit on rice plants grown with high rates of nitrogenous fertilizers. The larvae also grown better on heavily fertilized plants.

The rice stem borers are generally considered as the most serious pest of rice. They occur regularly and attack plants from seedling to maturity stages. About 16 different stem borer species are found in rice fields and among them the yellow stem borer, dark headed striped borer and pink borer are of major and have great economic significance (Kapur 1967; Rao and Israel 2004)

Kamran and Raros (1967) worked on seasonal fluctuations in abundance of various rice borers in Philippines both during the wet and dry seasons. They also found that borer infestations were high during the wet season.

Scirpophaga incertulas could attack most of the growing stages of rice plant, begin with seedling through tillering and up to ear setting (Ranasinghe, 1992).

The caterpillars of *Scirpophaga incertulas* bore into the rice stem and hollow out the stem completely. The damage symptoms vary according to the stage of growth of the plant. During the very early stages of growth the larvae damage the growing point in the terminal shoot. This condition is known as ‘Dead heart’. The larvae also feed internally within the leaf sheath and damage the vascular tissue by feeding inside the stem; The damage to stem results in the entry holes around. If the borer attack at the flowering stage resulting the panicles white and empty, a condition known as the ‘white head’.Among the other symptoms of damage of this pest is the presence of egg massess on the leaves, presence of adult moth either flying around or floating on water and the curling of the young leaves (Pathak, 1970).

The larvae of *Scirpophaga incertulas* attack the young as well as the grown up stages of rice. The larvae enter into the stern and feed on the inner- tissues of the plant. Such feeding separates the apical parts of the plant from the base. When this occurs during the vegetative phase of the plant, the central leaf turns brownish and dries off. This condition is known dead heart and the affected tillers dry out without bearing panicles. After panicle initiation, growing plant parts from base dries the panicles, which may not emerge; panicles that have emerged do not produce grains. Being empty, they remain straight and are whitish. They are usually called white head.

2.1.4 Management of stem borer

Naqvi (1973) suggested that an integrated pest management programme for rice, including use of pest resistant/tolerant variety, minimum one application of granular insecticide in water in paddy fields at the vulnerable stage of the crop, non-application of pesticides during the period when parasittoids were active and use of cultural practices has been evolved and has been practiced under an operational research project. This has helped in considerably reducing cost on crop protectionand minimizing pesticide pollution.

MOA (2008) reported in biocontrol programme with collaboration of Andaman and Nicobar that the adoption of modern technology, comprising of introduction of high yielding varieties, use of chemical fertilizers and improved agronomic practices during late sixties and seventies has enabled the farmers in increasing the crop production two to three folds. Such intensive cropping system have also paved the way for emergence of pests, diseases and weed problems.

The relationship among yellow stem borer (YSB; *Scirpophaga Incertulas*) moth catch in a light trap, egg mass density, and parasitism (by *Telenomus digmus* and *rastichus schoenohil*) was determined by Manju *et al.* (2002) to correlate light trap data with levels of pest eggs in the field and to study whether parasitoids respond to increased egg density. A light trap was operated from January to December 1999 in a rice field in Tamil Nadu, India. Moth catch was positively correlated with the abundance of egg masses and parasitism levels in the field while egg population was positively correlated with parasitism. However the relationship was significant only between moth catch and parasitism.

2.1.5 Chemical control

Chen (1996), Chen and Yu (1998),Tu and Chang (1992) observed that dry seed or sprouted seed treatment with 0.02% carbofuran, carbosulfan, chlorpyriphos or isofenphos provided effective control of both stem borers and gall midge for 30 days. Triphenyltin hydroxide, an organotin compound was found to inhibit the feeding activity of first instar larva of yellow rice stem borer to the extent of 25-55% when used at 0.02 to 0.1% concentration over control

The efficacy of fipronil and other insecticides against rice stem borer (*Scirpophaga incertulas)* were studied by Saijoqi *et al.* (2002) in a field trial. The results showed that all insecticides gave significantly better control of rice stem borer than the untreated check. Padan 4G (cartap) at 22.23 kg/ha was found to be the most effective in reducing rice stem borer infestation, followed by Regent 300 EC (fipronil) at 197.6 mi/ha, Regent 300 EC mixed with fertilizer at 197.6 ml/ha and Furadan 3G (carbolliran) at 19.76 kg/ha, respectively. The highest yield (tonnes/ha)was obtained from Padan 4G treated plots, followed by Regent 300 EC; Regent 300 EC mixed with fertilizer and Furadan 3G compared to untreated plots.

The efficacy of carbosulfan (1000 g a.i./ha) against *S. incertulas* on rice cv. Red Triveni was studied by Karthikeyan and Purushothaman (2000) in Pattambi, Kerala, India, during 1996 (second cropping), 1997 (first and second cropping), and 1999 (first and second cropping). In all years. carbosulfan effectively controlled *S. incertulas*. The greatest reduction of dead hearts was observed in 1997 second cropping (1.50%) and 1999 second cropping (1.30%). White ear was reduced in 1996 second cropping (3.52%), 1999 first cropping (5.50%). and 1999 second cropping (4.10%). Carbosulfan gave a higher yield (3492 kg/ha) than the control insecticide 1000 g a.i. carbofuran/ha (3444 kg/ha) and the untreated control (2658 kg/ha).

Results of field experiments carried out by Korat *et al*. (1999) during kharif 1993-94 to 1996-97 at the Main Rice Research Station, Nawagam, Gujarat, revealed that among the treatments evaluated, the smallest (2.72 to 3.73 hoppers/hill) number of the white backed plant hopper *Sogatella furcifera* (Horv.) were observed following treatment with buprofizin 25 W1 (0.5 kg a. 1./ha) followed by acephate 75 sp. (0.75 kg a.i./ha). A relatively low (3.9 1%) incidence of the leaf folder, *Cnaphalocrocis medinalis* Guen, was Ibund in the plots treated with monocrotophos 36=WSC (0.75 kg a. i./ha), acepbate 75 sp (4.38%) and triazophos 40 EC (5.03%) compared with 9.30% in untreated check plots. The minimum incidence (120.67 white earheads/plot of 27.6 rn2) of the stem borer *Scirpophaga incertulas* (Walker) was recorded following triazophos 40 EC (0.50 kg a. i./ha) treatment. The greatest (2625 kg/ha) grain yield was obtained from the plots treated with buprofezin followed by acephate (2618 kg/ha), carbofuran 30 (2572 kg/ha) and monocrotophos (2499 kg/ha). The greatest cost benefit ratio was found after acephate treatment (1:7.73) followed by triazophos (1:4.99) and buprofezin (1:4.71).

A field trial for the integrated management of stem borer *(Scirpophaga Incertulas*) and neck blast *(Pyricularia grisea [Magnaporthe grisea*]) in scented rice (cv. Taraori basmati) was carried out by Dodan and Roshan (1999) during kharif in 1995 and 1996 in Kaul (Haryana, India). The following treatments were tested: burnt rice husk (BRH) incorporated pre-transpianting at 10 t/ha; Nimbecidine [a neem-based pesticide] at 20 ml/litre BRH+Nimbecidine + Trichogramma japonicum; carbendazim (Bavistin at 0.1%) + monocrotophos (Nuvacron at 0.25%); and an untreated control. In both years, all treatments reduced neck blast incidence and stem borer damage compared to the control. BRH alone and in combination with Nimbecidine and *T. japonicum* were as effective as the pesticide combination for neck blast control (28.1, 27.2 and 26.1% neck blast incidence, respectively). Under conditions of low stem borer infestation in 1996. BRH, Nimbecidine and BRH + Nimbecidine + T. japonicum provided superior stem borer control, compared to the pesticide combination (3.8, 3.6, 3.1 and 4.3% stem borer damage, respectively). Under high infestation, the pesticide combination was most effective. The mean yields were 29.7, 29.6, 31.4, 31.2 and 28.6 q/ha for BkH, Nimbecidine, BRH + Nimbecidine + 7: japonlcum, carbendazim + monocrotophos and the control, respectively.

A field experiment was conducted by Hugar *et al*. (2009) at Shimoga, Karnataka, India, during the kharif season of 2006 to evaluate the efficacy of monocrotophos 36 SL (500 g a.i./ha), imidacloprid 17.8 SL (20 g a.i./ha), lambda -cyhalothrin 2.5 EC (12.5 g a.i./ha), beta -cylluthrin 25 LC (12.5 g a.i./ha), imidacloprid 70 WS (5 ml/kg of seeds), flubendiamide 500 SC (24 g a.i./ha), indoxacarb 14.5 SC (30 g a.i./ha),carbofuran 3G (750g a.i./ha control), carbosulfan 60 (1000 g a.i/ha), cartap hydrochloride 4 0 (1000g a.i./ha) and fipronil 0.3 G (7.5 g a.i/ha) against *S. Incertulas* on rice (cv. Rasi). At 50 and 75 days after sowing (DAS), fipronil 0.3 0 resulted in the lowest percentages of dead heart (DH) damage (3.40 and 2.43%, respectively). This treatment also resulted in the lowest white ear head incidence (2.59%), and highest grain (42.97 kg/ha) and fodder (61.25 kg/ha) yields, net return (14 729 rupees/ha) and cost: benefit ratio (1:7.86).

A study was conducted by Sherawat *et al.* (2007) in Sheikhupura, Pakistan, during 2001-03 to determine the economic threshold level (ETL) for the chemical control of rice stem borers, *Scirpophaga incertulas* and *S. innotata*. Infestation levels of 0.0, 2.5, 5.0, 7.5, 10.0, 12.5 and 15.0% were induced artificially by clipping off tillers at 55 days after transplanting. The cost of application of Padan (cartap 4G) below 7.5% infestation level was higher compared to the value of reduced grain yield due to borer infestation. At 7.5% infestation level, the cost of chemical control was equal to or less than the cost of yield reduction; thus, this level can be considered as the ETL for rice stem borers.

Rice stem borers, *Scirpophaga incertulas, Scirpophaga innotata and Sesamia inferens* pose a serious threat to scented rice in Haryana, India reported by Roshan (2006). Trials were conducted on the novel use of cartap hydrochloride 40 against stem borers at CCS Haryana Agricultural University, Rice Research Station, Kaul for two consecutive kharif seasons during 2001 and 2002. Cartap hydrochloride 40 at 1.0 and 0.75 kg a.i./ha were applied at 30, 50; 30, 70; 50, 70 and 30, 50 and 70 days after transplanting (DAT) and were compared with monocrotophos 36 WSC at 0.45 kg a.i/ha applied at 30, 50 and 70 L)AT. Cartap hydrochloride at 1.0 and 0.75 kg a.i./ha applied at 30, 50 and 70 DAT proved most effective in managing the incidence of stem borers and realizing higher rice grain yield. Application of cartap hydrochloride initiated at 50 and 70 DAT could not suppress the incidence of stem borers. Two applications of cartap hydrochloride at 30, 50 and 30, 70 DAT were equally effective to three applications of monocrotophos in managing the incidence of stem borers and realizing higher yield. The effect of cartap hydrochloride was observed more than 30 days when applied at 30 DAT and observation recorded up to 70 days. All the treatments increased yield over the control. The cost:beneltt ratio was the highest in monocrotophos (1:8.68), followed by cartap hydrochloride at 0.75 kg a.i./ha broadcasted at 30 and 50 DAT (1:7.64), but the lowest in cartap hydrochloride at 1.0 and 0.75 kg a.i./ha applied at 50 and 70 DAT (1:2.80).

Harish (1995) conducted the studies in the Philippines in April-October 1992, the flight activity of the yellow stem borer *Scirpophaga incertulas* (Lepidoptera:Pyralidae) peaked in the months of April-May, May-June, August-September and October. The number of egg masses and the number of adults attracted to light sources were used as indicators of *S. incertulas* flight activity. The rice varieties TKM6, 1R22, 1R60, 1R66 and 1R74 were infested at 7, 10, 12 and 16 weeks after the addition of 5, 10, 20 and 40 neonates of *S. incertulas*. All varieties except 1R66 were susceptible to dead heart damage by *S incertulas*. When the rice varieties TKM6, BPLRi2, BPJRi4, 1R22, 1R36, 1R60, 1R66 and 1R74 were treated with carbofuran insecticide at the time of peak oviposition by *S. incertulas* in the field, the dead heart damage on all the varieties was significantly reduced in comparison to the untreated plots. Indiscriminate routine insecticidal treatments (fixed schedule) can be replaced by schedule based on the dynamics of *S. incertulas.*

Control of *Scirpophaga incertulas* in rice was attempted by mating disruption using the natural ratio of pheromone components, a 1:3 blend of (Z)-9- and (Z)-11-hexadecenal, in replicated trials by Cork *et al*. (1998) at three locations in Andhra Pradesh, India, during 1994 and 1995 dry seasons. The pheromone was formulated in Selibate and applied by hand at a rate of 40 g a.i./ha. In Medehal and Nellore, pheromone-mediated communication was reduced by at least 94% for the first 50 and 64 days after application, respectively, as measured by pheromone trap catch suppression. Compared with adjacent farmers' practice plots, subsequent dead heart and white head damage were reduced by 74 and 63% and 83nd 40% in Medchal and Nellore, respectively. In Medehal, average rice yields were increased compared to the farmers' practice plots, 4108 and 3835 kg/ha respectively, but in Nellore, they were the same as those obtained in the farmers' practice piots, 6400 and 6733 kg/ha. In Warangal the level ol communication disruption over the first 70 nights after pheromone application was less than obtained in either Medchal or Nellore and averaged between 50 and 87%. The maximum dead heart and white head damage recorded in the pheromone-treated plots in Warangal was 2.8 and 15.7%, respectively, compared to 7.0 and 20.9% in the farmers' practice plots. Differences in *S. incertulas* larval damage estimates obtained from the pheromone-treated and farmers' practice plots in Warangal were reflected in grain yields, 4036 and 3715 kg/ha, respectively. Surveys of insecticide use indicated that 92% of smaliholders in Medchal applied insecticide at least once per season while in Warangal over 60% applied insecticide on two or more occasions. The data show that season-long control of S. incertulas comparable to that obtained with conventional insecticides can be achieved by mating disruption in smaliholder rice fields in India

Mishra *et al* (2007) conducted a field experiment in Uttar Pradesh, India during kharif seasons of 2002 and 2003 to evaluate the effect of certain granular insecticides against leaf roller (*Cnaphalocrocis medinalis*) and stem borer (*Scirpophaga incertulas).*

2.1.6 Cultural control

Ploughing down or burning of stubbles just after harvest of the crop was found to destroy substantial stem borer larval population. Keeping the fields and bunds clean and destruction of weeds such as *Echinochloa colonum* reduced gundhibug population. *Mnesethialaevis*, *E. crusgalli* and *Panicum* species were identified as alternate hosts for gall midge. Insect juvenile hormone, ZR-777 was found to inhibit metamorphosis of green leafhopper (Agrios, 1987).

2.2 RICE LEAF ROLLER

The rice leaf folder, *Cnaphalocrocis medinalis* Guenée (Lepidoptera: Pyralidae) is a predominant foliage feeder in all the rice ecosystems.

2.2.1 Systematic position:

Phylum: Arthropoda

Class: Insecta

Order: Lepidoptera

Family: Pyralidae

Genus: *Cnaphalocrocis*

Species: *C. medinalis*

2.2.2 Distribution of leaf roller

Das(1998), Biswas *et al.*, (2001),Biswas(2008) observed that the leaf roller *Cnaphalocrocis medinalis* Guenée has appeared as the most damaging pest in recent years.

Sachan and Gangwar (1980) observed that the insect is found in India, Thailand, the Philippines and other countries of Asia.

Khan *et al*;(1988) Shanmugam *et al*. (2006), Kaushik(2010) observed that the rice leaf folder, *Cnaphalocrocis medinalis* Guenée (Lepidoptera: Pyralidae), is the most widely distributed and commonly found foliage feeder in all the rice growing tracts of Southeast Asia. An increase in *C. medinalis* population could be attributed to the large scale cultivation of high yielding varieties, application of fertilizers, and continuous use of insecticides leading to outbreak of this pest in several countries, including India.

Sato *et al*. (1978) observed that adult female moth is golden yellow with brown margins on both the wings. While resting, the body shape is like that of an equal-sided triangle. It has three bands traversing entire forewing. Middle band was short, comma like and curved outside. Male moths are smaller than female moths and have a prominent patch of dark brown andraconial scales along the mid costa of forewing. Adults usually emerge in the evening and mating occurs atnight.Pre- oviposition period of 3 days and oviposition period of 4 days.

Tobin *et al*. (2003) observed that eggs are jelly-like, transparent, and ovoid with irregular upper surfaces. It is ventrally flattened. Eggs are laid singly or in groups of 3 to 8 along the mid rib of young leaves. A female lays about 135 to 175 eggs. Hatching occurs in about 5 days .

Godase and Dumbre (1982) observed that larva turns pinkish white just before pupation.*C. medinalis* completes its larval development in 14 to 18 days after passing through five instars. Biswas and Islam (2012) observed that morphologically the full-grown larvae of leaf roller are light green in colour and 10-15 mm in length and 3-4 mm in breadth. Usually one larva can be found in none folded leaf. But sometimes 2-3 larvae are also observed within the same folded leaf. Leaf roller has six larval instars and the entire larval period of 12-15 days and the pupal period are spent within the folded leaves.

Chang and Wu (1988) observed that pupation occurs mostly at the base of the plant and a single leaf was folded for pupation. Pupal period range from 6 to 9 days .

2.2.3 Nature of damage

The destructive stage of this insect is the larval stage. At this stage they fold the leaves longitudinally before feeding. They tie the leaf margins with the threadlike silk. They feed the green mesophyll of leaf inside the folded leaf. They feed by scraping. At first and second instar larvae feed within the slightly folded areas of leaf. At late second instar feed and roll up the maximum area of a leaf . There is one larva in one leaf. After feeding one leaf, larva moves to another leaf. In this way one larva can damage a number of leaves. Feeding reduce the photosynthesis area of leaves. So vegetative growth and finally yield is hampered. Yield loss is maximum when flag leaf is damaged.

Biswas *et al*. (2001) observed that the adult moth is creamy yellow to light brown with oblique wavy black lines on both pairs of wings. Females lay about 400 eggs in batches of 10-20 on the young leaves. Hatching out from the eggs in a week, the young larvae feed on the epidermal layer of the leaves. The larvae roll the leaves from tip downwards and then feed inside the young leaves and buds. Damaged leaves have a silvery-brown papery look and are noticeable from a distance.

Fraenkel *et al*. (1981) observed that *C. medinalis* damages the rice plant throughout the crop growth period. The larvae fold the leaves longitudinally by stitching the leaf margins and feed by scraping the green mesophyll tissue from within the folded leaves. This feeding causes linear, pale white stripes that result in membranous patches.

Campbell *et al*. (1974) observed that among the climatic factors, temperature is the most important, as it has profound. Influence on the development and survival of insects. The rate of insect development is affected by the temperature to which insects are exposed.

Gordan (1999) observed that insects require a certain amount of heat units (degreedays) to develop from one life stage to the other.

Murugesan and Chelliah (1987) observed that quantification of the relationship between insect development and temperature is useful to predict the seasonal occurrence and population dynamics of the insects. The ability of an insect to develop at different temperatures is an important adaptation to survive under various climatic conditions (tropical, subtropical, and temperate).So far, there is no published report from India on the effect of constant temperatures on *C. medinalis*.This pest has been reported to attain the major pest status in important paddy growing areas.

Bhanu and Reddy (2008) reported that the leaf folder affected the crop adversely under favourable conditions causing 60% loss in India. The synthetic chemical pesticides have been the widely used approach to reduce the estimated 45% gross crop uninhibited use of them has necessitated for alternatives mainly for environmental concerns. Therefore, an eco-friendly alternative is the need of the hour. Biopesticides or biological pesticides based on pathogenic microorganisms specific to a target pest offer an ecologically sound and effective solution to pest problems. They pose less threat tothe environment and to human health.

Philip Srihar (1988) and Hariprasad (1999) reported that the peak population of leaf folder was recorded at higher RH. It was evident that a range of 85-95 per cent RH would be conducive in this coastal region for the rapid buildup of leaf folder population. With this background, present study was conducted to correlate the percentage of infection with the weather parameters. Wada (1979) has reported that leaf folder larvae developed rapidly within a temperature range of 17 to 30°C which is comparable with the present results.

2.2.4 Chemical control

Dependence of the farmers of Noakhali region solely on the use of chemical insecticides for controlling the pests has posed a number of potential problems that include resistance of the pest, destruction of beneficial organisms and environmental pollution (McIntyre *et al*. 1989).

Saxena *et al*.(19981), Haque and Islam (1988) observed that botanicals are less toxic, naturally available materials, less expensive, and also safe for beneficial organisms. Neem products containing azadirachtin, salanin and meliontriol have been found to be effective for controlling different insect pests.

(Sarode *et al*. (1995) observed that the neem products also act as repellent to the insect and thus reduce insect infestation.

2.2.5 Integrated management

Timely planting and wider spacing reduces the leaf folder incidence. Avoid excessive use of nitrogenous fertilizers. Keep the bunds clear by trimming them and remove the grassy weeds as they serve as alternate hosts. Avoid using chemicals like carbofuran, phorate that cause resurgence of leaf folder. Setting up of light traps at 4/ha to attract and kill adult moths.Release *Trichogramma chilonis*, 5- 6 times @ 1,00,000 adults/ ha starting from 15 days after transplanting. When the damage exceeds ETL, spray cartaphydrochloride 50WP @ 600 g a.i/ ha or monocrotophos 36 WSC @ 850 ml/ha or chlorpyriphos 20 EC @ 1500 ml/ ha. The heavy use of fertilizer encourages rapid multiplication of the leaf folder. High humidity and shady areas of the field favour their development. The presence of grassy weeds in rice fields and surrounding borders support continuous development of the pest. Expanded rice areas with irrigation systems, multiple rice cropping and insecticide induced resurgences are important factors in the leaf folder’s abundance. The adults are nocturnal and during the day, they stay under shade to escape predation. They are active year-round and moths fly short distances when disturbed.

2.3 Brown plant hopper

The brown plant hopper (BPH) *Nilaparvata lugens* has been one of the most important pests of rice in Japan since ancient times (Hirao 1979).

The pest, BPH belongs to the plant sucking group of insects called Homoptera. It has been a serious pest of rice in Japan for many years and in Taiwan since 1960.

Until 1970, the insect was only a minor pest in the tropics, but now the BPH has greatly increased in abundance and caused heavy yield losses in many countries.

Considenng the unpredictable nature of infestations and the severe damage caused, the BPH is regarded as the most serious pest of rice in today's South, South-East Asia and the Fareast (Alam *et al*. 1978).

2.3.1 Systematic position of brown plant hopper

Phylum: Arthropoda
Class: Insecta
Order: Homoptera
Family: Delphacidae
Genus: *Nilaparvata*
Species: *Nitaparvata lugens*

2.3.2 Distribution of brown plant hopper

The BPH is widely distributed in South, South East and East Asia in the South Pacific Islands and Australia. Earlier reports listed specific countries of incidence. But presently, the insect is distributed in Bangladesh, India, Pakistan, Sri Lanka, Nepal, Cambodia, Vietnam, Thailand,China, Taiwan, Malaysia, Singapore, Indonesia, Philippines, Korea, Hong Kong, Japan, Australia and on many Islands of South East Asia, Micronesia and Melanesia like Caroline and Mariana Islands, Fiji, Papua New Guinea and Solomon Islands (Nasu 1967 Misra and Israel, 1970. Varea and Feuer, 1976 and Alam *et al*. 1978).

Alam *et al.* (1978) observed that the insect is found mainly on rice throughout the year, except in Japan and Korea where it migrates in the summer.

BPH cannot survive the winter in Japan and migrate to Japan each year from the Chinese mainland. Plant hoppers must have the ability to fly continuously for at least 30 and up to 48 hours. The migrations of BPH from the Asian mainland to Japan entail over-water flights of at least 750km, or if the migrants originate in south-east China, over 1200 km (Holt *et al.* 1996).

The mass immigration of plant hoppers occurs every year during late June to middle July because this timing is the rainy season in Japan and plant hoppers can fly to Japan on the lower jet stream that is formed in a seasonal rain front from main land China to Japan.

2.3.3 Nature of damage

Raddy *et al*.**(**1993) observed that among the insect pests of rice, BPH is one to the most important. It remains at the base of the plant and sucks the phloem sap from the growing plant. Both the nymph and adult infest the rice crop at all stages of plant growth. They insert their stylets into the plant tissue and suck sap from the phloem cells. Apart from the direct damage, BPH also acts as vector of virus diseases in several rice growing countries. As a result of their feeding, the lower leaves start drying from the tips.

Misra (1980) observed that yellowing starts uniformly up to the mid half from the tip of the leaf and the other half remains yellowish green. Then the whole leaf dries upIn addition, the BPH blocks the ascent of nutrition by laying numerous egg masses in the midribs of leaf sheath and leaf blade.

Heinrichs *et al.*(1985) reported that at early infestation stage of feeding by BPH caused round yellow patches in the field, which soon turned brownish due to the drying up of the plants Thus condition is called "Hopper burn' which may spread out and cover the entire field.

Reissig *et al*. (1985) observed that the BPH removes more plant sap than it can digest. The excess plant sap, which is high in sugar is expelled from the body as honeydew. The honey dew drops fall on the base of plants and in time turn black from infection by a sooty mold fungus.

BPH suck sap from rice plants, reducing their yield potential. If BPH density is high, plants die and a condition known as “hopper burn” results. Plants dry and take on the brownish appearance of plants that have been damaged by fire. The BPH usually goes through three generations in a paddy field, multiplying abundantly as the generations advance until harvest. The rice plant is most vulnerable to damage by *N. lugens* during the active tillering and booting stages. As a result, the earlier the incidence of hopper burn, the greater the loss in yield. When the rice suffers hopper burn within 30, 40, and 50 days after heading, yield losses are estimated at about 80-90, 50, and 10%, respectively (Kiritani, 1979).

Different species of leaf and plant hoppers infest rice in the Indian subomment. Of these, the green leafhopper. zigzag leafhopper, the white backed plant hopper and the brown plant hopper are considered economically important (Misra and Israel 1970). The several areas, they frequently occur in large number enough to cause hopper burn.

Nath and Bhagabati (2005) reported that the leafhopper population was first appeared in the rice secdbed during June- July, reaching the peak in October - November in the main rice field and disappeared from field from December to May. They also reported that the population of *N. virescens*, the most efficient vector of rice tungro virus disease was low compared *to N. nigropictus,* but more than *Recilia dorsalis*.

Tsueda *et al*. (2002) studied on the occurrence of rice bugs, a total of 22 species, in rice fields. They also observed that *Stenotus rubrovittatus* was the important species and the peak occurrence of it coincided with the date of heading of early -ripening rice. They further reported the populations of bugs and rate of damaged rice was related to the area of heading rice.

Mallick and Chowdhury (2000) observed the population dynamics of zigzag leafhopper in rice ecosystems. They found that one peak appearance of this insect was from April to May and the second one from October to November. They also reported that *R. dorsalis* was the less eflicient vectors of rice tungro virus than *N. virescens* and *N. nigropictus* to some extent; its presence in seed beds was expected to play a vital role on the carryover of the virus.

Reddy *et al*. (1995) stated that both nymphs and adults infest the rice crop at all stages of plant growth. They insett their stylets into plant tissue and suck sap from the phloem cells. Apart from the direct damage, brown plant hopper (BPH) acts as a vector of virus disease in several rice growing countries.

Chakraborty *et al*. (1990) studied that the abundance of rice pests at 2 sites in Bihar and Orissa, India. Patterns of relative pest abundance were similar in most years of the study. ‘Ibey also flund that *Nilapurvata lugens* was the most abundant pest at the Orissa site. While *Nephotettix sp*. were the most abundant at the Bihar site. The most abundant natural enemies of rice pests at both sites were *Cyrtorhinus lividipennls* and spiders of the families Lycosidae and Tetragnathidae.

Cook and Perfect (1989) investigated the population dynamics of 3 vectors of rice tungro bacillifrom and spherical viruses, *N. virescens*, *N. nigropictus and Recilia* d*orsalis* in farmers' fields. They also reported that *R. dorsalis* was the most abundant vector species on the rice seed beds.

Gupta *et al*. (1989) reported that the pentatomids Nezara viridula and Eusarcoirs yen/ru/is cmised 6.9%-14.8% grain damage during the dry season and 2.3%- 8.1% grain damage during the wet season.

Reduced settling on the resistant varieties was attributed to chemical cues, mainly the hydrocarbon and carbonyl containing fractions of the surface wax (Woodhead and Padgham, 1988).

Velusamy (1988) reported that significantly more individual of *N. lugens* were settled on susceptible TNI rice plants than resistant ones.

Sharivastava *et al.* (2000) found that the major period of activity of both species was September to November with the highest in October. The frequency of peaks in the catches indicated the possibility of the completion of 4 to 5 generations during the kharif season (July to December)

Kim *et al*. (1986) observed the low population growth of *N. malayanus* and *N. virescens* on resistant rice cultivar.

The green leaf hoppers, *Nephotettix spp*. (Homoptera: Cicadellidae) are most devastating pests of rice throughout the rice growing areas of Asia (Razzaque *et al*, 1985). These have been reported from Bangladesh, Bhutan India, Indonesia, Kampuchca, Malaysia, Nepal, Phillippiness, Sri Lanka, Thailand, and Vietnam (Alam 1983. Alam and Catling 1976. Heinrichs *et al*. 1984. Reissing *et al*. 1985). They don't do only cause direct damage by sucking plant sap and by ovipositing on the leaf sheath but also act as efficient vector of rice tungro virus, one of the most menacing diseases of rice.

As a result of feeding both the nymphs and adults at the base of tillers, plants turn yellow and dry up rapidly. At early infestation, round yellow patches appear which soon turn brownish due to the drying up of the plants. This condition is called hopper burn. The patches of infestation then may spread out and cover the entire field (Heinrichs *et al*. 1984).

Misra *et al.* (1985) reported that the seasonal changes in population density of *Nephotettix virescens, N. nigropictus, Nilaparvata lugens, Sogatella furcfera, Recilia dorsalis,* and *Nisia airovenosa,* which are important pests of rice in India during the kharif season.

Zhang *et al.* (1984) reported that population number of *N. lugens* on the new rice lines viz. Hong-Yuan and Tainuo-Xuan were less than the susceptible variety TN1.

Alam *et al.* (1983) reported that the brown plant hopper has become a serious pest of high yielding variety of rice. The leaf hoppers feed on the leaves and supper parts of the rice plant whereas the plant hopper confines themselves to the basal parts. In the warm and humid tropics, different species of leaf hoppers and plant hoppers remain active year round and their population fluctuates according to the availability of food plants, natural enemies end environmental conditions.

2.3.4 Management and chemical control

Holt *et al.* (1996) observed that insecticide applications are the main control method against BPH in Japan. Crop breeders have made many attempts to develop resistant varieties. However, resistant-breaker strains of plant hoppers have easily appeared. In Japan, the planthopper’s natural enemies decline to very low densities during the winter. When BPH populations start to grow rapidly, the numbers of predators are insufficient to prevent the increase.

Watanabe *et al.* (2009) observed that more than 60% of the rice fields in Japan are planted following the application of persistent systemic insecticides to seeds in nursery box applications. This treatment provides effective control of the first immigrants.

Hirao (1979) observed that the need for foliar applications of insecticides is determined throughout Japan based on an elaborate monitoring and modeling system that forecasts where and when outbreaks of BPH will occur.

The International Rice Research Institute, P.O. Box 933, Manila, Philippines. IR26 and other rice cultivars with the same gene for resistance to the BPH were infested and reported hopper burned in two widely separated small areas in the Philippines (Anonymous 1975).

Stapley (1975) observed that in the Solomon Islands all resistant selections, including IR26, “broke down”.

New BPH biotypes capable of attacking IR26 have been identified (IRRI 1975).

Different scientists conducted research on varietal performances of different rice varieties to different insect pest infestation. Koral *et al.* (1998) evaluated rice cultivars for resistance to insect pests. Mo-1 Co-29 and lET- 10750 were resistant to major insect pests (white backed plant hopper, leaf folder and stem borer) of rice. These cultivars yielded 17.54-17.94% higher grain yields over presently recommended high yielding varieties like Masuri and Narmada Breeders can utilize these promising cultures as donor for developing high yielding and pest resistant variety of rice.

Emmanuel *et al*. (2003) evaluated 65 rice genotypes for their resistance against the white backed plant hopper (*S. furcifera*). The overall assessment in the present study indicated that resistance in rice to WBPH was shown by the combined influence of non-preference, antibiosis and tolerance.

Misra *et al.* (2001) evaluated 27 cultivars for growth performance and pest and disease resistance. Brown plant hopper, *Nilaparvata lugnes* and green leaf hopper, *Nephotettix virescens* were below moderate levels on all cultivars except Suryu- 52, IRRI- 137, MTU- 1001 and Nagarjuna. Yellow stem borer (*Scirpophaga incertulas*) incidence was low to moderate in Pusa-basmati, IRRI- 123. Basmati and Nagarjuna, hut was trace to low in all other cultivars. The occurrence of biological control agents and natural enemies in these cultivars was also recorded.

White -backed plant hopper, *Sogatella furcfera* which was previously only a minor pest of rice in the Kuttanad region of Kerala, India reached the status of a major pest during the rabi season of 1997-98. The population packed during .January 1998 (Ambikadevi *at al*. 1998).

Quing *et al*. (2000) also rcporcd that white- backed plant hopper (*Sogatetta fwqfera*) is becoming a major pest in the rice- cultivating area around Luzhou, Sichuan, China, with the extension of hybrid rice growing in recent years.

2.3.5 Cultural Control

Kulshreshtha *et al,* (1974), Nishida (1975) and Fernando (1975) observed that indiscriminate and faulty application of insecticides kills effective biological control agents of the pest.

IRRI (1970), Fernando (1975) and Muriya (1976) reported that development of resistance to various insecticides. Ripper (1956), Akesson and Yates (1964), Newsom (1967), Cope (1971), Pimentel *et al.*(1971) and Georghiou (1972) reported that other methods that will help keep down the insect population while reducing the frequency of pesticide applications that may have unwanted side effects should be explored.

Cultural control is perhaps as old as agriculture itself. It may be defined as the modification of certain farm operations to make the environment unfavorable for the development and multiplication of insect pests but favorable for crop production. Certain techniques, such as modification of planting, growing, cultivating, or harvesting, aim at preventing insect damage rather than at destroying existing insects (National Academy of Sciences 1971).

Walker and Coot (1925) observed that other methods of cultural control, such as flooding the fields or plowing the stubble after harvest, aim at destroying certain pest populations. They can reduce the number of larvae and pupae of the rice stem borer *Tryporyza innotata*.

Orita (1935) lshikura and Nakatsuka (1955) observed that digging of rice stubble to control *T. incertulas* was done in Japan from 1880 until around 1940.

On the other hand, keeping plots flooded or saturated favors build up of the BPH Dyck (1973) .

Thus, through knowledge of the eco-biology of the BPH, other pests, and the crop plant is needed before cultural control techniques are introduced. The techniques should be compatible with other control methods and with the needs of the crop. They must be economical to be readily adopted by farmers. Unlike insecticidal control, cultural control may not give spectacular and immediate results; however, it is the first line of defense against pest attack,and its methods are dependable, economical, ecologically sound, and nonpolluting (NAS 1971, Clark *et al*. 1970).

Kuno (1973) and Kisimoto (1976) observed that the potential of some cultural control methods already used to combat certain pest complexes should be fully exploited,especially against typical epidemic-type insect pests, such as the BPH,that have high rates of population growth, high tolerance for crowding, high degrees of aggregation, and high dispersal ability. One reason might be that the insect was generally a minor pest of rice until recently. In Japan cultural control of the BPH is not practiced (pers. comm. with R. Kisimoto, Central Agricultural Experiment Station, Konosu, Saitama 365, Japan).

Kisimoto (1971) observed that epidemics of the insect, which are mainly caused by long-distance migration from mainland China, are effectively prevented by applying insecticides in late July and August.

CHAPTER III

MATERIALS AND METHODS

This chapter describes the materials used and methods followed in the experiment. It includes a brief description of experimental site, soil, crop, climate, treatments, experimental design, land preparation, transplanting of seedling, intercultural operations, harvesting, data recording, collection and preparation of soil and plant samples and the methods for the chemical and statistical analysis.

3.1 Experimental site

The plants of rice seedlings were grown at the Agronomy Farm, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh. The experiment was carried out during Boro season (November 2012 to May 2013). The location of the experimental site was at 23.75^0 N latitude and 90.34^0 E longitude with an elevation of 8.45 meter from sea level.

3.2 Climate

The experimental area was situated in the sub-tropical climatic zone, which was characterized by heavy rainfall during the month of April to September and scanty rainfall during the rest period of the year. Details of weather data in respect of temperature (^{0}C), rainfall (cm) and relative humidity (%) for the study period were collected from the Meteorological Department of Bangladesh, Agargoan, Dhaka.

3.3 Soil

Soil of the study site was silty clay loam in texture belonging to series. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ No. 28) with pH 5.8-6.5, ECE-25.28. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resource Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka.

3.4 Plant materials used in the experiment

The rice variety BRRI Dhan 28 was used in the experiment. The seeds of the rice variety was developed by Bangladesh Rice Research Institute and seeds were collected from Supreem Seed Company, Dhaka-1216.

3.5 Seedbed preparation

Seedbed was prepared on 7 November 2012 for raising seedlings and the size of the seedbed was 3 m×1 m. For making seedbed, the soil was well ploughed. Weeds, stubbles and dead roots were removed from the seedbed. The soil was treated by Seven 50WP @ 5 kg/ha to protect the young plants from the attack of mole crickets, ants and cutworm.

3.6 Seed treatment

Seeds were treated by Provax 200WP @ 3g/1kg seeds to protect some seed borne diseases such as leaf spot, blight, anthracnose, etc.

3.7 Seed sowing

Seeds were sown on 11 November 2012 in the seedbed. Seeds were sown at a depth of 2 cm and covered with a fine layer of soil followed by light irrigation by water can.

3.8 Raising of seedlings

Light watering and weeding were done several times. No chemical fertilizers were applied for raising seedlings. Seedlings were not attacked by any kind of insect or disease. Healthy and 21 days old seedlings were transplanted in the experimental field on 20 December 2012.

3.9 Layout and design

The field experiment was conducted following Randomized Complete Block Design (RCBD) with three replications. The experimental plot was first divided into three blocks. Each block consisted of 6 plots. Thus, the total numbers of plots were 18.

Different treatments were assigned to each plot as per design of the experiment. The size of a unit plot was 3 m × 6 m. Distance of 0.5 m between the plots and 1.0 m between the blocks was maintained. Thus the total area of the experiment was 20.5 m × 20 m.

3.10 Treatments of the Experiment

T_1= Untreated control

T_2=Virtako 40 WG (Thiamethoxam 20% in combination with Thiamethoxam Chlorantraniliprole 20%) @ 75 g/ha

T_3= Cartap hydrochloride @ 150 g /ha

T_4= Cartap hydrochloride @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g /ha

T_5= Cartap hydrochloride @ 100 g/ha in combination with Thiamethoxam 25%@ 60 g /ha

T_6= Cartap hydrochloride @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha

3.11 Cultivation procedure

3.11.1 Land preparation

The experimental area was first opened on 15 December 2012 with a disc plough to exposed to direct sunshine for killing soil born pathogens and soil inhabitant insects. It was prepared by several ploughing and cross ploughing with a power tiller followed by laddering to bring about a good tilth. The land was leveled, corners were shaped and the clods were broken into pieces. The weeds, crop residues and stables were removed from the field. The doses of manure were applied and finally leveled. The soil of the plot was treated by Seven 50wp @ 5kg/ha to protect the young plants from the attack of mole cricket, ants and cutworm.

3.11.2 Recommended fertilizer dose

The following doses of manure and fertilizers were used in the field where Cowdung @ 15 ton / ha, Urea @ 100 kg /ha, TSP @ 125 kg /ha, MP @ 150 kg /ha were applied.

3.11.3 Transplanting

The seedbed was watered before uprooting the seedlings to minimize the damage of roots. At the time of uprooting, care was taken so that root damage became minimum and some soil remained with the roots. Twenty one days old healthy seedlings were transplanted at a spacing of 3m × 6m in the experimental plots on 20th December 2012. Thus, 2 plants/hill, 450 hills were accommodated in each 18 sqm unit plot. Planting was done in the afternoon.

3.11.4 Intercultural operations

3.11.4.1 Gap filling

Very few seedlings were damaged after transplanting and gap filling was carried out with new seedlings from the same stock.

3.11.4.2 Weeding

The plants were kept under careful observation. Three times weeding were done during cropping period for proper growth and development.

3.11.4.3 Irrigation

Irrigation was given by observing the soil moisture condition for proper growth and development of plants.

3.11.4.4 Insects and Pests control

Rice plants were damaged by stem borar brown plant hopper and rice leaf roller after the seedlings were transplanted in the experimental plots. Diazinon 60 EC @ 1.7L/ha was applied to controlled stem borer. Some of the plants were infected by brown plant hopper. Furadan 3G @ 16.8 kg/ha was sprayed to control brown plant hopper.some plants were infected by leaf roller.Sumethion 50 EC @ 1.00L/ha was applied to control Leaf roller. Bird pests were seen visiting the rice field very frequently. The birds were found to puncture the soft leaves and damage grain and were controlled by striking of a metallic container.

Plate.1: The experimental plots of the present study at SAU, Dhaka

3.11.4.5 Harvesting

Harvesting was started on 11 May 2013 and was completed on 13 May 2013.

3.12 Data collection

3.12.1 Filled grain: Randomly selected ten (10) panicles per plot were selected separately and threshed after drying and the numbers of grains were counted to obtain the wt. of grain per 10 panicles and weight of grains per plot.

3.12.2 Unfilled grain: From 10 randomly selected panicles, the numbers of unfilled grains were counted to obtain the weight of unfilled grain per 10 panicles and unfilled grain wt per plot. The significant variations among different treatments have been observed in respect of the reduction of unfilled grains by number over control.

3.12.3 1000 grain weight: After drying the randomly selected 1000 grain wt. was counted from each plot.

3.12.4 Yield on 25 hills/plot: The weight of grains of 25 tagged hills per plot was recorded.

3.12.5 Yield per plot

The yield per unit plot was calculated by adding the yields of all plants of each unit plot and expressed in kilogram (kg)

3.12.6 Yield per hectare

The yield per hectare was calculated out from the per plot yield data.

3.13 Statistical analysis

The recorded data on different parameters were statistically analyzed with the help of MSTAT program. The treatment means were separated by Duncan’s Multiple Range Test (DMRT) (Gomez and Gomez, 1983) at 5% level of significance for interpretation of the results.

CHAPTER IV

RESULT AND DISCUSSION

The present experiment was conducted to determine the comparative efficacy of some promising chemical insecticides against yellow stem borer, leaf roller and brown plant hopper pests of rice that caused damage of rice plant which affect the yield. The results of the study have been presented, discussed and possible interpretations also given below with the following sub-heading:

4.1 Infestation of rice yellow stem borer

The number of affected rice plants showing dead heart symptoms(dead shoots) and white head symptoms(dead panicles) caused by rice stem borer were recorded from randomly selected 25 hills per plot for each treatment and replication. The percent dead and white head symptoms by number out of total number of plants per 25 tagged hills per plot as well as percent reduction of dead heart and white head symptoms over control have been calculated for each plot and replication. The data were recorded at 7 107 DAT. The findings of the evaluation study on the basis of efficacy of tested chemicals have been presented below:

4.1.1 Dead heart

At vegetative stage very fewer number of dead heart symptom have been observed and recorded in the rice field. The variations of the efficiency of different treatments as compared with untreated control on dead heart symptoms by number are given below:

Considering the different insecticidal treatments, the percent dead heart symptom is ranged from 0.0 to 1.05%, and the percent reduction of dead heart symptom by number over control is ranged from 66.7% to 100.0%, where the highest reduction (100.0%) has been achieved by T_3, T_5 and T_6treatment on second observation (92 DAT), where lowest reduction achieved by T_2 (79.16%) followed by T_4treatment (92.90%) as well as 100.0% reductions have also been achieved by T_3, T_4, T_5 and T_6treatment on third observation (99 DAT).

Based on the amount of chemicals (dose) applied, more or similar rate of reduction have been recorded for most of the treatments. Here, if we consider the performance of single chemical instead of any combination, the T_3 treatment comprised with Cartap hydrochloride g/ha was most effective for safety of rice against stem borer in terms of dead heart symptom as compared with lower or same dose of Cartap hydrochloride along with Thiamethoxam.

Table1.Effect of different insecticidal treatments on the rice yellow stem borer (dead heart) infestation throughout the growing period at the vegetative stage of rice

Treatment	Rice yellow stem borer infestation by number at different DAT							
	1st observation (86 DAT)		2nd observation (92 DAT)		3rd observation (99 DAT)		4th observation (107 DAT)	
	%dead heart	%reduction over control	%dead heart	%reductionover control	%dead heart	%reduction over control	%dead heart	%reduction over control
T_1	0.0	-	1.05a	-	0.58a	-	0.24a	-
T_2	0.0	-	0.17b	79.16	0.00b	100	0.00a	66.67
T_3	0.0	-	0.00b	100.00	0.00b	100	0.00a	66.67
T_4	0.0	-	0.08b	92.90	0.00b	100	0.00a	66.67
T_5	0.0	-	0.00b	100.00	0.00b	100	0.00a	66.67
T_6	0.0	-	0.00b	100.00	0.00b	100	0.00a	66.67
LSD(0.01)	-	-	0.4482	-	0.2004	-	0.26	-
CV(%)	-	-	79.66	-	80.46	-	243.24	-

DAT =Days after transplanting

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per represents 0.01 level of probability and numeric data represents the mean value of 3 replications.

[T_1= Untreated control,T_2= VIRTAKO 40 WG @ 75 g/ha (Thiamethoxam 20% + Chlorantraniliprole 20%), T_3=Cartap hydrochloride (SCA-1201) @ 150 g /ha, T_4= Cartap hydrochloride (SCA-1201) @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g /ha , T_5= Cartap hydrochloride (SCA-1201) @ 100 g/ha in combination with Thiamethoxam 25%@ 60 g /ha ,T_6= Cartap hydrochloride (SCA-1201) @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha.

Considering the observation period, no dead heart symptom have been found and recorded on first observation (86 DAT). But with the increase of the observation time the rate of dead heart symptom (Plate 2) have been decreased up to third observation (99 DAT) except untreated control, where the rate have been increased and finally on fourth observation period (107 DAT), the rate the dead heart symptom have been declined and reached up to 66.7% and this declining of dead heart symptom might be the result of reaching the plants at full panicle stage (Table 1)

4.1.2 White head

At reproductive stage comparatively higher number of white head symptom (Plate 3) have been observed and recorded in the rice field during study period. The variations of the efficiency of different treatments as compared with untreated control on average white head symptom by number are given below:

Considering the different treatments, the percent white head symptom is ranged from 0.08 to 2.92%, and percent reduction of white head symptom by number over control is ranged from54.73% to 94.97%. On average reduction of white head symptom, the highest reduction over control has been achieved by T_6 followed by T_5, and T_4treatments respectively, whereas the lowest reduction has been achieved by T_2 treatment followed by T_3treatment.

Table2. Effect of different insecticidal treatments on the rice yellow stem borer (white head)infestation at the reproductive stage of rice plant

Treatment	Rice yellow stem borer infestation by number at different DAT							
	1st observation (86 DAT)		2nd observation (92 DAT)		3rd observation (99 DAT)		4th observation (107 DAT)	
	%white head	%reduction over control	%white head	%reduction over control	%white head	%reduction over control	%white head	%reduction over control
T_1	1.66a	-	2.0a	-	2.36a	-	2.92a	-
T_2	0.75b	54.73	0.49b	79.69	0.66b	67.26	0.59b	76.68
T_3	0.69b	58.00	0.35b	85.58	0.43b	82.03	0.18	93.79
T_4	0.68b	57.31	0.34b	85.69	0.17b	89.72	0.25b	93.39
T_5	0.33bc	79.40	0.16b	93.28	0.24b	88.89	0.33b	88.94

T_6	0.8c	94.97	0.24b	90.14	0.48b	76.51	0.16b	94.94
LSD(0.01)	0.5610	-	0.6124	-	0.9578	-	1.101	-
CV(%)	31.19	-	35.84	-	51.10	-	57.65	-

In a column means having similar letter(s) are statistically identical and those havingdissimilar letter(s) differ significantly as per represents 0.01 level of probability andNumeric data represents the mean value of 3 replications

[T_1= Untreatedcontrol,T_2= VIRTAKO 40 WG @ 75 g/ha (Thiamethoxam 20% + Chlorantraniliprole 20%), T_3=Cartap hydrochloride (SCA-1201) @ 150 g /ha, T_4= Cartap hydrochloride (SCA-1201) @ 75 g/ha in combination withThiamethoxam 25% @ 60 g /ha , T_5= Cartap hydrochloride (SCA-1201) @ 100 g/ha in combinationwithThiamethoxam 25%@ 60 g /ha ,T_6= Cartap hydrochloride (SCA-1201) @ 150 g /ha in combination withThiamethoxam 25% @ 60 g /ha]

Based on the amount (dose) and combination of chemicals applied, the T_6 comprised with cartap (SCA-1201)@ 150 g/ha along with Thiamethoxamwas most effective for safety of rice against stem borer in terms of white head symptom than sole cartap (SCA-1201) (T_3), T_2 and or any other combinations (Table 2).

Considering the above findings it was revealed that the T_3 treatment comprising sole cartap hydrochloride (SCA-1201) @150 g/ha was the most effective in reducing dead heart symptom than other treatments, whereas the T_6 treatment comprising cartaphydrochloride (SCA-1201)@ 150 g/ha along with Thiamethoxam @ 60 g/ha was the most effective in reducing the white head symptom than sole cartap (SCA-1201) (T_3) or any other treatments. But in terms of level of infestation, higher incidence was observed for white head than dead heart, and the better performance was achieved by T_6 for the reduction of white head symptom than T_3 for dead heart reduction. Therefore, T_6 treatment comprising cartap(SCA-1201) @ 150 g/ha along with Thiamethoxam @ 60 g/ha may be recommended for effective control of rice stem borer.

Plate 2. The rice plants showing dead heart symptom in the experimental field

Plate 3. The rice plants showing white head symptom in the experimental field

4.2 Leaf roller infestation on rice plant

At vegetative stage the variations of the efficiency among different treatments as compared with untreated control in reducing rolled leaf of rice by number have been given below:

Considering the different treatments, the percent rolled leaf caused by rice leaf roller was ranged from 0.13 to 2.26%, and the percent reduction of rolled leaf infestation (plate 4) by number over control was ranged from 76.07% to 93.68%. Considering the pooled data, among different treatments, the highest reduction of rolled leaf over control was achieved by T_4 followed by T_3,and T_5 treatment whereas the lowest reduction was achieved by T_2 followed by T_6treatment. This trend of results was more or less similar for almost all observation period (Table 3).

Table3. Effect of different insecticidal treatments on the Leaf roller infestation of rice at vegetative stage of rice plant

Treatment	Leaf roller infestation by number at different DAT			
	1st observation (86 DAT)		2nd observation (92 DAT)	
	% rolled leaf	%reduction over control	% rolled leaf	%reduction over control
T_1	1.75a	-	2.26a	-
T_2	0.40b	80.98	0.53b	76.07
T_3	0.13b	93.72	0.18b	91.80
T_4	0.14b	93.18	0.17b	92.30
T_5	0.18b	91.23	0.31b	86.71
T_6	0.27b	86.19	0.36b	84.42
LSD(0.01)	0.7087	-	0.6286b	-
CV(%)	56.61	-	38.22	-
SE	0.1581	-	0.1402	-

DAT =Days after transplanting

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ

significantly as per represents0.01 level of probability and numeric data represents the mean value of 3 replications.

[T_1= Untreated control,T_2= VIRTAKO 40 WG @ 75 g/ha (Thiamethoxam 20% + Chlorantraniliprole 20%), T_3=Cartap hydrochloride (SCA-1201) @ 150 g /ha, T_4= Cartap hydrochloride (SCA-1201) @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g /ha , T_5= Cartap hydrochloride (SCA-1201) @ 100 g/ha in combination with Thiamethoxam 25%@ 60 g /ha ,T_6= Cartap hydrochloride (SCA-1201) @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha]

At reproductive stage the variations of the efficiency among different treatments as compared with untreated control in reducing rolled leaf of rice by number have been given below:

Considering the different treatments, the percent rolled leaf caused by rice leaf roller was ranged from 0.17 to 2.89%, and the percent reduction of rolled leaf infestation by number overcontrol was ranged from 73.89 to 93.62%. Considering the pooled data, among different treatments, the highest reduction of rolled leaf over control was achieved by T_4 followed by T_3, and T_5 treatments respectively whereas the lowest reduction was found by T_2 followed by T_6 treatment. This trend of results more or less similar for almost all observation period (Table 4).

Table 4. Effect of different insecticidal treatments on the Leaf roller infestationof rice at reproductive stage of the rice plant

Treatment	Leaf roller infestation by number at different DAT			
	3rd observation (99 DAT)		4th observation (107 DAT)	
	% rolled leaf	%reduction over control	% rolled leaf	%reduction over control
T_1	2.67a	-	2.89a	-
T_2	0.63b	76.36	0.73b	73.89
T_3	0.26b	90.21	0.29b	89.66
T_4	0.17b	93.62	0.26b	90.80
T_5	0.33b	87.74	0.33b	88.51
T_6	0.43b	83.91	0.43b	85.08
LSD(0.01)	0.5303	-	0.7087	-
CV(%)	-	-	27.24	-

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per represents 0.01 level of probability and numeric data represents the mean value of 3 replications.

[T_1= Untreated control,T_2= VIRTAKO 40 WG @ 75 g/ha (Thiamethoxam 20% + Chlorantraniliprole 20%), T_3=Cartap hydrochloride (SCA-1201) @ 150 g /ha, T_4= Cartap hydrochloride (SCA-1201) @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g /ha , T_5= Cartap hydrochloride (SCA-1201) @ 100 g/ha in combination with Thiamethoxam 25%@ 60 g /ha ,T_6= Cartap hydrochloride (SCA-1201) @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha]

Based on the amount (dose) and combination of chemicals applied, the T_4 treatments comprised with cartap @ 75 g/ha) in combination with Thiamethoxam @ 60 g/ha was the most effective for safety of rice against leaf roller infestation than sole cartap (T_3) treatment or any other combinations of cartap and Thiamethoxam or T_2 treatment.

Considering the above findings it was revealed that the T_4 comprising cartap (SCA-1201)@ 75 g/ha in combination with Thiamethoxam @ 60 g/ha may be recommended for effective control of rice leaf roller.

Plate 4. Leaf roller infested rice plants showing rolled leaf symptom in the experimental field

4.3. Brown plant hopper infestation on rice plant

At vegetative stage the variations of the efficiency of different treatments as compared with untreated control in reducing the incidence of brown plant hopper by number were given below:

Considering the different treatments, the incidence of brown plant hopper (BPH) by number was ranged from 0 to 9.33 BPH adult and nymph per two sweeps per plot from 1st observation to 2nd observation and the percent reduction of BPH incidence over control was ranged from 71.83 to 90.48.% (Table 5).

Table5. Effect of different insecticidal treatments on the brown plant hopper(BPH)
Infestation of rice plant at the vegetative stage

Treatment	Incidence of BPH by number at different DAT			
	1st observation (86 DAT)		2nd observation (92 DAT)	
	BPH(no./2sweeps)	%reduction over control	BPH(no./2sweeps)	%reduction over control
T_1	0.0	-	9.33a	-
T_2	0.0	-	0.67b	90.48
T_3	0.0	-	1.33b	82.01
T_4	0.0	-	0.67b	90.48
T_5	0.0	-	2.33b	71.83
T_6	0.0	-	0.67b	90.48
LSD(0.01)	-	-	4.009	-
CV(%)	-	-	61.97	-

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per represents 0.01 level of probability and numeric data represents the mean value of 3 replications.

[T_1= Untreated control,T_2= VIRTAKO 40 WG @ 75 g/ha (Thiamethoxam 20% + Chlorantraniliprole 20%), T_3=Cartap hydrochloride (SCA-1201) @ 150 g /ha, T_4= Cartap hydrochloride (SCA-1201) @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g /ha , T_5= Cartap hydrochloride (SCA-

1201) @ 100 g/ha in combination with Thiamethoxam 25%@ 60 g /ha ,T_6= Cartap hydrochloride (SCA-1201) @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha]

The incidence of BPH have been recorded nil at 86 DAT just before the first application of treatments and the incidences were decreased with the increase of observation period except untreated control, where the incidence of BPH was increased in the following observations. Considering the pooled data, among different treatments, the highest reduction of the incidence of BPH over control was achieved by T_4 followed by T_2, and T_3 whereas the lowest reduction was achieved by T_5 followed by T_6treatment. This trend of results was more or less similar during the observation period (Table 5).

At reproductive stage the variations of the efficiency of different treatments as compared with untreated control in reducing the incidence of brown plant hopper by number were given below:

Considering the different treatments, the incidence of brown plant hopper (BPH) by number was ranged from 0 to 16.0 BPH adult and nymph per two sweeps per plot from 3rd observation to 4th observation and the percent reduction of BPH incidence over control is ranged from 91.56 to 100.0%. The incidence of BPH were recorded nil at 86 DAT just before the first application of treatments and the incidences was decreased with the increase of observation period except untreated control, where the incidence of BPH was increased in the following observations. Considering the pooled data, among different treatments, the highest reduction of the incidence of BPH over control has been achieved by T_4 followed by T_2, and T_3 treatment whereas the lowest reduction has been achieved by T_5 followed by T_6treatment. This trend of results was more or less similar during the entire observation period (Table 6).

Table6. Effect of different insecticidal treatments on the brown plant hopper(BPH) infestation of rice at reproductive stage

Treatment	Incidence of BPH by number at different DAT			
	3rd observation (99 DAT)		4th observation (107 DAT)	
	BPH(no./2sweeps)	%reduction over control	BPH(no./2 sweeps)	%reduction over control
T_1	16.0a	-	14.0a	-

T_2	0.67b	94.71	0.33b	98.04
T_3	0.33b	98.04	0.00b	100.00
T_4	0.33b	96.67	0.00b	100.00
T_5	0.67b	96.45	0.00b	100.00
T_6	1.00b	92.75	1.00b	91.56
LSD(0.01)	6.214	-	3.525	-
CV(%)	75.83	-	53.30	-
SE	1.386	-	0.7866	-

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per represents 0.01 level of probability and numeric data represents the mean value of 3 replications.

[T_1= Untreated control,T_2= VIRTAKO 40 WG @ 75 g/ha (Thiamethoxam 20% + Chlorantraniliprole 20%), T_3=Cartap hydrochloride (SCA-1201) @ 150 g /ha, T_4= Cartap hydrochloride (SCA-1201) @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g /ha , T_5= Cartap hydrochloride (SCA-1201) @ 100 g/ha in combination with Thiamethoxam 25%@ 60 g /ha ,T_6= Cartap hydrochloride (SCA-1201) @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha]

Based on the amount (dose) and combination of chemicals applied, the T_4 comprised of cartap @ 75/ha in combination with Thiamethoxam @ 60 g/ha was most effective for safety of rice against brown plant hopper infestation than sole cartap (T_3), or any other combinations of cartap and Thiamethoxam or T_2. Considering the above findings it was revealed that the T_4comprisngcartap (SCA-1201)@ 75 g/ha in combination with Thiamethoxam @ 60 g/ha may be recommended for effective control of brown plant hopper in rice field.

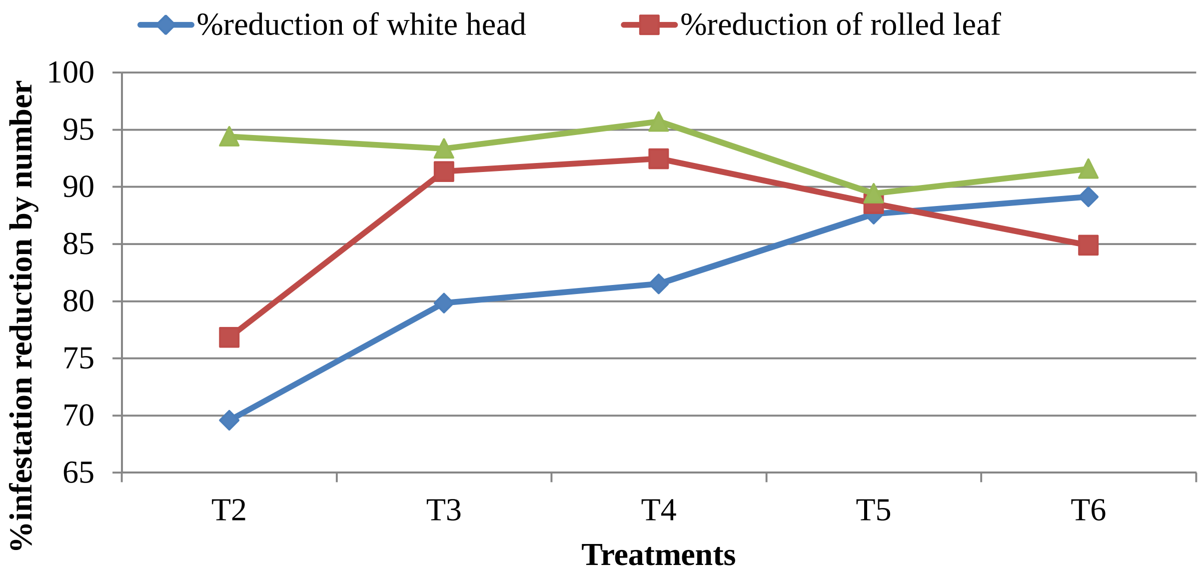

Figure 1. Comparative efficiency of different chemicals in reducing the infestation of rice stem borer, rice leaf roller and BPH infestation over control

[T_1= Untreated control,T_2= VIRTAKO 40 WG @ 75 g/ha (Thiamethoxam 20% + Chlorantraniliprole 20%), T_3=Cartap hydrochloride (SCA-1201) @ 150 g /ha, T_4= Cartap hydrochloride (SCA-1201) @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g /ha , T_5= Cartap hydrochloride (SCA-1201) @ 100 g/ha in combination with Thiamethoxam 25%@ 60 g /ha ,T_6= Cartap hydrochloride (SCA-1201) @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha]

From the (Figure1) it was shown that in case of white head, the percent white head symptom was ranged from 0.08 to 2.92%, and percent reduction of white head symptom by number over control was ranged from 54.73% to 94.97%. On average reduction of white head symptom the highest reduction over control was achieved by T_6 treatment followed by T_5, and T_4, whereas the lowest reduction was achieved by T_2 treatment followed by T_3 treatment.

in case of leaf roller at vegetative stage, the percent rolled leaf caused by rice leaf roller was ranged from 0.13 to 2.26%, and the percent reduction of rolled leaf infestation by number over control was ranged from 76.07% to 93.68%. Considering the pooled data, among different treatments, the highest reduction of rolled leaf over control was achieved by T_4 followed by $T_{3,}$ and T_5 treatment whereas the lowest reduction was achieved by T_2 followed by T_6 treatment.

At reproductive stage, the percent rolled leaf caused by rice leaf roller was ranged from 0.17 to 2.89%, and the percent reduction of rolled leaf infestation by number over control is ranged from 73.89 to 93.62%. Considering the pooled data, among different treatments, the highest reduction of rolled leaf over control was achieved by T_4 followed by T_3, and T_5 treatments whereas the lowest reduction was achieved by T_2 followed by T_6treatment.

in case of brown plant hopper at vegetative stage, the incidence of brown plant hopper (BPH) by number was ranged from 0 to 9.33 BPH adult and nymph per two sweeps per plot from 1st observation to 2nd observation and the percent reduction of BPH incidence over control was ranged from 71.83 to 90.48.%. The incidence of BPH were recorded nil at 86 DAT just before the first application of treatments and the incidences have been decreased with the increase of observation period except untreated control, where the incidence of BPH have been increased in the following observations. Considering the pooled data, among different treatments, the highest reduction of the incidence of BPH over control was achieved by T_4 followed by T_2, and T_3 whereas the lowest reduction was achieved by T_5 followed by T_6 treatment.

at reproductive stage, the incidence of brown plant hopper (BPH) by number was ranged from 0 to 16.0 BPH adult and nymph per two sweeps per plot from 3rd observation to 4th observation and the percent reduction of BPH incidence over control was ranged from 91.56 to 100.0%. The incidence of BPH have been recorded nil at 86 DAT just before the first application of treatments and the incidences were decreased with the increase of observation period except untreated control, where the incidence of BPH was increased in the following observations. Considering the pooled data, among different treatments, the highest reduction of the incidence of BPH over control was achieved by T_4 followed by T_2, and T_3 treatment whereas the lowest reduction was achieved by T_5 followed by T_6treatment.

From the Figure 2 it was shown that the percent unfilled grains by number was ranged from(4.453 to 19.31% and the percent reduction of unfilled grains by number is ranged from 54.99 to 76.93, where the height reduction (76.93%) was achieved by T_4 treatment followed byT_6 (72.15) treatment. and lowest reduction (54.99) was achieved by T_2treatment followed by T_3 (62.10) and T_5(62.66)treatments.

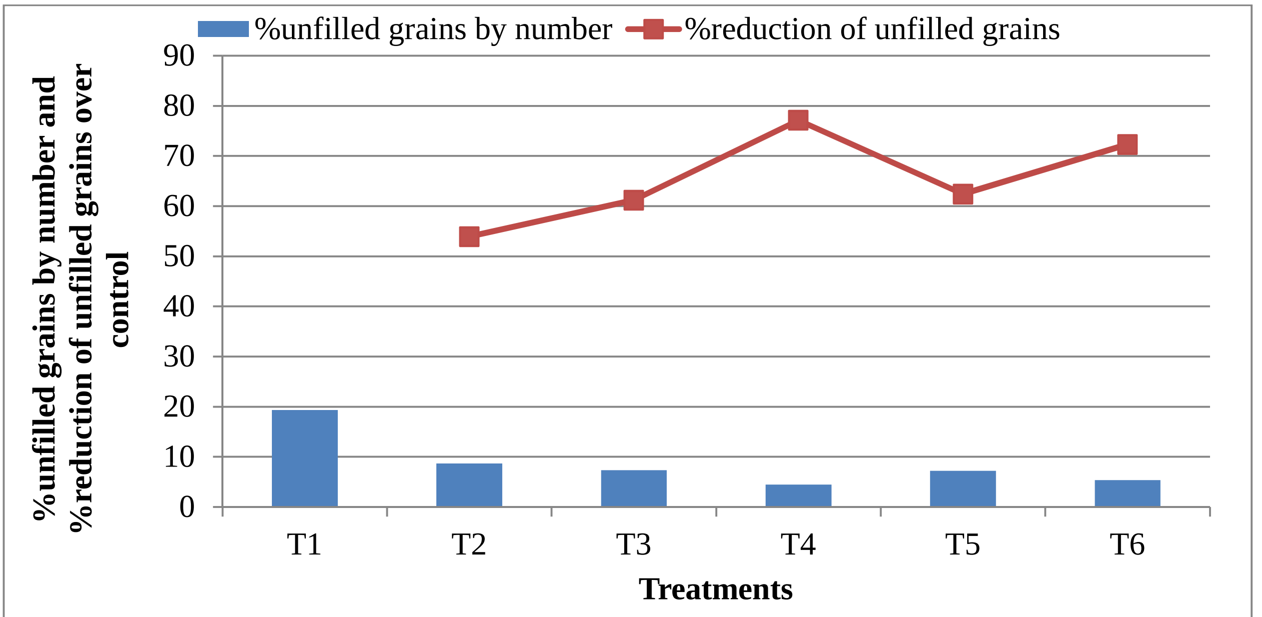

Figure 2. Comparative performance of different insecticides in reducing the unfilled grains of rice

[T_1= Untreated control,T_2= VIRTAKO 40 WG @ 75 g/ha (Thiamethoxam 20% + Chlorantraniliprole 20%), T_3=Cartap hydrochloride (SCA-1201) @ 150 g /ha, T_4= Cartap hydrochloride (SCA-1201) @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g /ha , T_5= Cartap hydrochloride (SCA-1201) @ 100 g/ha in combination with Thiamethoxam 25%@ 60 g /ha ,T_6= Cartap hydrochloride (SCA-1201) @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha]

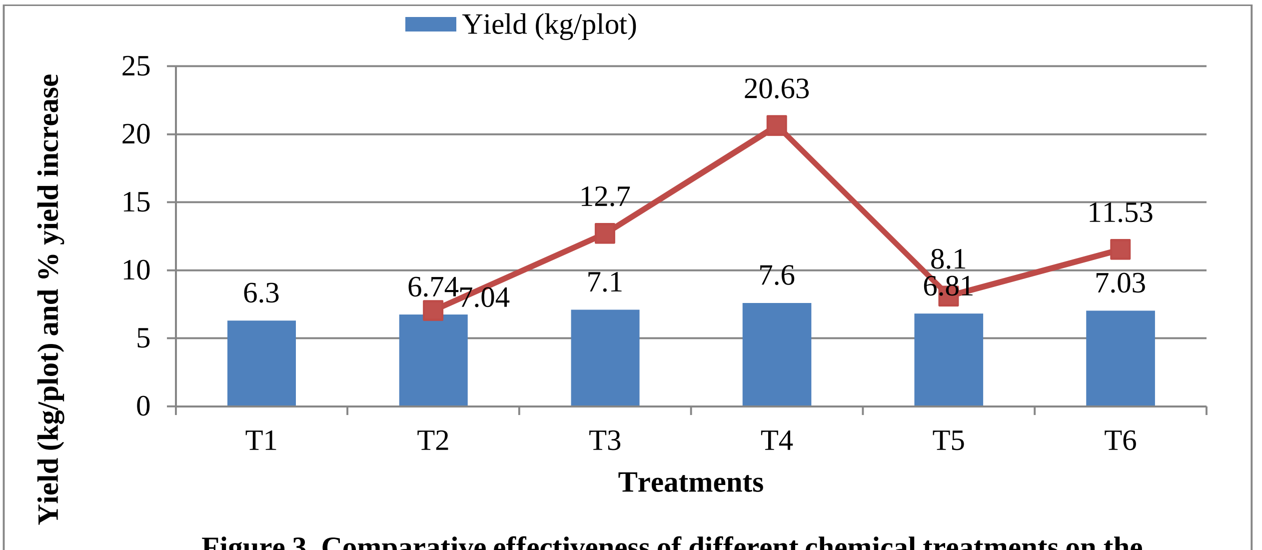

Figure 3. Comparative effectiveness of different chemical treatments on the yield performace of rice

[T_1= Untreated control,T_2= VIRTAKO 40 WG @ 75 g/ha (Thiamethoxam 20% + Chlorantraniliprole 20%), T_3=Cartap hydrochloride @ 150 g /ha, T_4= Cartap hydrochloride @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g /ha , T_5= Cartap hydrochloride @ 100 g/ha in combination with Thiamethoxam 25%@ 60 g /ha ,T_6= Cartap hydrochloride @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha]

Figure 3 showed the result on effect of different treatments and percent increase of yield was 20.63 in T_4treated plot followed by T_3 (12.7%) and T_6 (11.53%) treatments. The percent decrease of yield was recovered in T_1 (6.3%) followed by T_2 (6.74%) treated plots.

Table 7. Effect of different insecticidal treatments on the number of grain of rice

Treatment	Number of grain			
	No. of filled grain per 10 panicles	No. of unfilled grain per 10 panicles	% unfilled grains by number	% reduction unfilled grains by number
T_1	595.0a	142.3 a	19.31 a	-
T_2	719.3 a	69.33 b	8.690 b	54.99
T_3	735.7 a	58.00 b	7.317 b	62.10
T_4	686.0 a	32.00 b	4.453 b	76.93
T_5	666.7 a	51.00 b	7.210 b	62.66
T_6	656.0 a	37.33 b	5.377 b	72.15
LSD (0.01)	151.4	36.30	4.274	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per represents 0.01 level of probability and numeric data represents the mean value of 3 replications.

[T_1= Untreated control,T_2= Virtako 40 WG @ 75 g/ha (Thiamethoxam 20% + Chlorantraniliprole 20%), T_3=Cartap hydrochloride (SCA-1201) @ 150 g /ha, T_4= Cartap hydrochloride (SCA-1201) @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g /ha , T_5= Cartap hydrochloride (SCA-1201) @ 100 g/ha in combination with Thiamethoxam 25%@ 60 g /ha ,T_6= Cartap hydrochloride (SCA-1201) @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha]

The result on effect of different treatments on indicated theheighest number of filled grain was in by T_3(735.7)treated plot and the lowest number of filled grain was recorded in T_1(595.0) treatment plot.Theheighest number of unfilled grain was obtained in T_1(595.0) treated plot and the lowest number was found in T_4(32.00) treated plot.The percent unfilled grains by number was ranged from 4.453 to 19.31% and the percent reduction of unfilled grains by number was ranged from 54.99 to 76.93,where the heighest reduction (76.93%) was achieved in T_4 treated plot followed by T_6(72.15)treated and lowest reduction (54.99) was recorded in by T_2 treatment followed by T_3(62.10) and T_5(62.66) treatments(Table 7).

Table 8. Effect of different insecticidal treatments on the weight of grain of rice

Treatment	Weight of grain			
	Weight of filled grain (10 panicles)	Weight of unfilled grain (10 panicles)	% unfilled grains by weight	% reduction unfilled grains by weight
T_1	13.30 b	0.5667 a	4.137 a	-
T_2	13.70 b	0.3667ab	2.617 b	36.74
T_3	17.70 a	0.3333 b	1.807 bc	56.32
T_4	16.83 ab	0.1333 b	0.7967 c	80.74
T_5	14.70 ab	0.2000 b	1.373 bc	66.81
T_6	15.37 ab	0.1667 b	1.073 c	74.06
LSD (0.01)	3.498	0.2165	1.398	
CV (%)	8.85%	28.86%	27.45%	

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per represents 0.01 level of probability and numeric data represents the mean value of 3 replications.

[T_1= Untreated control,T_2= VIRTAKO 40 WG @ 75 g/ha (Thiamethoxam 20% + Chlorantraniliprole 20%), T_3=Cartap hydrochloride (SCA-1201) @ 150 g /ha, T_4= Cartap hydrochloride (SCA-1201) @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g /ha , T_5= Cartap hydrochloride (SCA-1201) @ 100 g/ha in combination with Thiamethoxam 25%@ 60 g /ha ,T_6= Cartap hydrochloride (SCA-1201) @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha]

The result on the effect of different treatments on the weight of filled grain indicate that the heighest weight of filled grain was recorded in $T_{3\ \text{treated plot}}$ (17.70) and the lowest number of filled grain was obtained in T_1(13.30) treatment and highest weight of unfilled grain was recorded from T_1(0.5667) treatment and the lowest weight was obtained from T_4(0.1333) treatment. The percent unfilled grains by weight was ranged from 1.073 to 4.137% and the percent reduction of unfilled grains by number was ranged from 36.74 to 80.74 where the highest reduction (80.74%) was obtained in T_4 treatment followed by T_6 (72.15) treatment. The lowest reduction (36.74) was measured in T_2 treatment followed by T_3 (56.32) and T_5 (66.81) treatments (Table 8).

Table 9. Effect of different insecticidal treatments on the yield of rice

Treatment	Yield		
	1000 grain weight/plot (g)	Yield on 25 hills/plot (g)	Yield/plot (kg)
T_1	20.10 d	336.7 d	6.300 c
T_2	21.27 c	370.3 cd	6.743 bc
T_3	21.53bc	393.7 bc	7.100 ab
T_4	23.00 a	450.3 a	7.600 a
T_5	22.40ab	403.6 abc	6.810 bc
T_6	21.33 c	440.2ab	7.027 ab
LSD (0.01)	0.9437	52.43	0.6546
CV (%)	1.69%	5.08%	3.66%

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per represents 0.01 level of probability and numeric data represents the mean value of 3 replications.

[T_1= Untreated control,T_2= Virtako 40 WG @ 75 g/ha (Thiamethoxam 20% + Chlorantraniliprole 20%), T_3=Cartap hydrochloride (SCA-1201) @ 150 g /ha, T_4= Cartap hydrochloride (SCA-1201) @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g /ha , T_5= Cartap hydrochloride (SCA-1201) @ 100 g/ha in combination with Thiamethoxam 25%@ 60 g /ha ,T_6= Cartap hydrochloride (SCA-1201) @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha]

The result on effect of different treatments on the number 1000 grain weight per plot was presented in Table 9.The maximum number of 1000 grain weight was found in by T_4(23.00g) treatment and minimum number was recorded in T_1(20.10g) treatment.

The maximum yield of 25 hills per plot was obtained inT_4 (450.3g) treatment and minimum yield was obtained in T_1 (336.7g) treatment. The maximum yield per plot was found in T_4 (7.600g) treatment and The minimum yield per plot was recorded in T_1 (6.300g) treatment (Table 9).

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was conducted at the Agronomy Farm, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh, during the period (Boro season) from November 2012 to May 2013 to study the effectiveness of some promising chemical insecticides for controlling rice stem borer, leaf roller and brown plant hopper. The treatments were comprised with some promising synthetic chemical insecticides and one untreated control and these were T_1= Untreated control, T_2= Virtako 40 WG (Thiamethoxam 20% in combination with Thiamethoxam Chlorantraniliprole 20%) @ 75 g/ha, T_3= Cartap hydrochloride (SCA-1201) @ 150 g/ha, T_4= Cartap hydrochloride (SCA-1201) @ 75 g/ha in combination with Thiamethoxam 25% @ 60 g /ha, T_5= Cartap hydrochloride (SCA-1201) @ 100g/ha in combination with Thiamethoxam 25%@ 60 g /ha, T_6= Cartap hydrochloride (SCA-1201) @ 150 g /ha in combination with Thiamethoxam 25% @ 60 g /ha. The experiment was laid out in single factor Randomized Complete Block Design (RCBD) with three replications.

SUMMARY

Considering the different treatments, the percent white head and the percent dead heart symptom was ranged from 0.08 to 2.92% and 0.0 to 1.05%, respectively, and percent reduction of white head and dead heart symptom by number over control was ranged from 54.73% to 94.97% and 66.7% to 100.0% respectively. On average reduction of white head symptom, the highest reduction over control was calculate in $T_{6\ \text{treatment}}$ followed by T_5, and T_4 treatments. The lowest reduction was obtained in T_2 treatment followed by T_3 treatment. Incase of dead heart, highest reduction (100.0%) was achieved in T_3, T_5 and T_6 treatment, where lowest reduction was observed in T_2 (79.16%) followed by T_4 treatment (92.90%).

Considering the different treatments, the percent rolled leaf caused by rice leaf roller was ranged from 0.13 to 2.26% and 0.17 to 2.89% and the percent reduction of rolled leaf by number over control is ranged from 76.07% to 93.68% and 73.89 to 93.62% at the vegetative stage and reproductive stage of rice respectively. Among different treatments, the highest reduction of rolled leaf over control was seen in by T_4 followed by $T_{3,}$ and T_5 treated plot, whereas the lowest reduction has been achieved by T_2 followed by T_6 treatment.

Result revealed that the incidence of brown plant hopper (BPH) by numberwas ranged from 0 to 9.33 BPH adult and nymph per two sweeps per plot and the percent reduction of BPH incidence over control was ranged from 71.83 to 90.48.%. Among different treatments, the highest reduction of the incidence of BPH over control was achieved by T_4 followed by T_2, and $T_{3\ \text{treated plots}}$ whereas the lowest reduction was obtained from T_5 treated plot T_6 treated ones. The more or less similar trend was observed at all reproductive stage. The variations of the efficiency of different treatments as compared with untreated control reduced the incidence of brown plant hopper by number.

The result on effect of different treatments on the weight of filled grain was obtained height and weight of filled grain was obtained T_3 (17.70) treatment and lowest number of filled grain was found in T_1 (13.30) treatment and height weight of unfilled grain was measured in T_1 (0.5667) treatment and the lowest weight obtained in T_4 (0.1333) treatment. The percent reduction of unfilled grains was ranged from 54.99 to 76.93,where the highest reduction (76.93%) was reported in T_4 treatment followed by T_6(72.15) treatment and lowest reduction (54.99) was found in T_2 treatment followed by T_3(62.10) and T_5(62.66) treatments.

The result on effect of different treatments on the 1000 grain weight per plot was presented and found that T_4 (23.00g) treatment gave the maximum weight while the minimum was obtained in T_1 (20.10g) treatment. The maximum yield of 25 hills per plot was found in T_4 (450.3g) treatment and minimum yield was found in T_1 (336.7g) treatment and maximum yield per plot has been achieved by T_4(7.600g) treatment and minimum yield per plot was found in T_1 (6.300g) treatment.

Among the different treatments, T_6 comprising SCA-1201 @ 150 g/ha along with Thiamethoxam @ 60 g/ha was found most effective in reducing the stem borer infestation than sole SCA-1201 (T_3) or any other treatments. In terms of safety protection against rice leaf roller, T_4 comprising SCA-1201 @ 75 g/ha in combination with Thiamethoxam @ 60 g/ha was obtained most effective in reducing the rice leaf roller infestation. Similarly, in case of safety protection against brown plant hopper, T_4 comprising SCA-1201 @ 75 g/ha in combination with Thiamethoxam @ 60 g/ha was also been found most effective in reducing brown plant hopper population in rice field.

CONCLUTION

Five insecticidal treatments along with one untreated control have been evaluated to test their against rice stem borer, rice leaf roller and brown plant hopper under field condition Among the treatments, T_6 comprising SCA-1201 @ 150 g/ha along with Thiamethoxam @ 60 g/ha was found most effective in reducing the stem borer infestation than sole SCA-1201 (T_3) or any other treatments. On the other hand, T_4 comprising SCA-1201 @ 75 g/ha in combination with Thiamethoxam @ 60 g/ha was found most effective in reducing the rice leaf roller infestation and brown plant hopper population in rice field.

Considering the comparative effectiveness of the treatments applied against rice stem borer, rice leaf roller and brown plant hopper, T_6, comprising SCA-1201 @ 75 g/ha in combination with Thiamethoxam @ 60 g/ha can be recommended for profitable rice production. Though T_6 is most effective against rice stem borer but its level of pest reduction was more or less similar to T_4 comprising lower dose of SCA-1201 along with Thiamethoxam, thus T_4 was better than T_6.

CHAPTER VI

REFFERENCES

Agrios, G. N. (1987). Plant Pathology, 3rd ed. Academic Press. New York. 703 p.

Alam, S. and Catling, H. D. (1976). Preliminary observation of deep water rice pest in Bangladesh. In Proc. Deep water rice workshop. IRRI, Philippines 239p.

Alam, S. and Karim, A. N. M. R. (1978). Brown plant hopper (*Nilaparvata legens*) a probable threat to rice cultivation in Bangladesh. A paper presented at second Annual Bangladesh Science Conference. January, 1977. BAU, Mymensing.

Alam,S.and Catting , l-l.D. (1978). Preliminary observation of deep water rice pest in Bangladesh. In Proc. Deep water rice workshop. IRRI, Philippines Z39p.

Alam, S. (1983). Current application methods o insecticides in rice farmers fields in Bangladesh. FAO/IRRI workshop on judicious and efficient use of pesticides on rice. IRRI. The Phillipines. l9p.

Alam, S, Karim, A. N. M. R., Alam, M.S. and Nurullah, C.M. (1983). Important rice insect pest control transferable to farmer's fields. In: Proc. Workshop on Modern Rice Cultivation in Bangladesh, BRRI, Gazipur. pp.106-116.

Alam, M.S. (1988).Seasonal abundance of rice stem borer species in upland and irrigated rice in Nigeria. *Insect* Sci. *Appl.* **9**(2): 191-195.

Ambikadevi, I. S. Valencia, S. L. and Chelliah, C. (1998). Incidence of White backed plant hopper *Sogatella furcfera* Guen. On paddy in Haryana. *Indian, J. Entol.* **49**(4):465-467.

Anonymous. (1975). International Rice Research 25 Years of Partnership. Los Banos. Philippines.

Barr, B. A. S and Smith, R. F. (1975). Crop loss to insects, diseases and other pests. USID , pest management and related environmental protection project. University of California, Berkley. 64p.

Bhanu and Reddy (2008). The lepidopterious Stalk borers of rice and their life cycles in the Tropics. The Major insect prsts of rice plant. Proceeding of a symposium at the International Rice Research Institute, Philippine, Pp103 - 123

Biswas, G. C. M. M., Hossain and Majumder U. K. (2001). Screening of some soybean entries against leaf roller *(Lamprosema indicata* F.). *Bangladesh J. Agril. Res.* **26**(2): 295-300.

Biswas, G. C. (2001). Screening of some soybean entries for resistance to stem flies and their *incidence. J. Asiat. Soc. Bangladesh Sci*. **27** (1): 93-100.

Biswas, G. C. (2008). Insect pests and their management of soybean crop in Bangladesh. Proceedings of the Workshop on Prospects and Performance of Soybean in Bangladesh (M. A. Bakred). ORC, BARI, Gazipur. pp. 67..

Campbell, A., Frazer, BD., Gilbert, N., Gutierrez, AP. and Mackauer, M. (1974). Temperature requirements of some aphids and their parasites. *J. of Appl. Eco.* **11**: 431–438.

Chakraborty, D. P., Sirvastava, P. C., Ghose, G.C., Maslen, N. R., Holt, J. and Flower, S.V. (1990). Rice pest abundance in Bihar and Orissa States, *India Int.Rice Res. Newsl.* **15**(4): 26-27.

Chang. C.H. and Wu, J.G. (1988). Population dynamics abd forecasting of rice leaf fidder. *Cnaphalocrocis medinais* Guenee in Taiwan. Plant Protect Bull. **41**(3): 199-213.

Chaudary, G. Q. (1973) Strategies in the control of rice pests. Seminar held on rice research and production at Rice Research Station, Dokri (Larkana) on 14th - 15th March, under the Auspicious of Agriculture Research Council, Pp 248.

Chen, B. H. (1996). Breeding horticultural crops resistant to insect pests. Taiwan Agricultural Research Institute, Special Publication Series No. **57**: 47-55. (In Chinese with English abstract)

Chen, B. H. and Yu, J. Z. (1998).Biological control of major insect pests in cruciferous vegetables. In Proceeding of Development of Industry of cruciferous vegetables. Taiwan Taoyuan District Agricultural Improvement Station, Special Publication Series No.7:129-137. (In Chinese)

Clark, S. S. and Wu, S. C. (1970). A comparative study on geographical populations of the rice leaf roller, *Cnaphalocrocis medinalis* Guenee. Act a Entomologica Sinica **31**: 259–267.

Cook, A. G. and Perfect, T. J. (1989). Population dynamics of three leaf hopper vectors of rice tungro viruses, *Nephotettix virescens* (Distant*), N. nigropictus* (Stal) and *Recilia dorsalis* (Motschulsky) (Hemiptera : Cicadellinae). in farmers fields in the philippines, *Bull. Entoimol*. Res. **79**(3): 437-451.

Cope, (1971). Plant breeding for disease resistance. *In:* Proceedings of Symposium on Techniques of Non-chemical Measures in Control of Plant Pests. Pp.233-250.

Cork, A., Souza, K. D., Krishnaiah, K., Reddy, A. A. and Zainulabuddin, S. (1998). Season-long control of yellow stem borer, *Scirpophaga incertulas* (Lepidoptera:Pyralidae) by mating disruption with the natural ratio of pheromone components. Bull. Of Entomol. Res., **88**(2). 109-116.

Das, G. P. (1998). Major Insect and Mite Pests of Important Crops and Stored Products of Bangladesh. Bangladesh Agricultural Research Institute, Joydebpur, Gazipur-1701.pp. 102.

De kraker, J., Van Huis, A., Heong, K. L., Van Lenteren, J. C. and Rabbinge, I. (1999). Population dynamics of rice folders (Lepidoptera: pyralidae) and their nature in the irrigated rice in the Philippines. Bull. *Entomol. Res*. **89**(5):411-421.

Dodan, D. S. and Roshan, L. (1999). Integrated management of neck blast and stem borer in scented rice. Haryana Agril. Uni. J. Res., **29**(1/2): 47-49.

Dyck, V. A. (1973). The role of ecology in insect pest control. Paper presented at a Saturday seminar, 26 May, 1973. International Rice Research Institute, Los Banos, Philippines. 11.

.Emmanuel, M., Alam, S., and Karim, Ahmed, M. S. (2003). Varietal response of rice against White bucked plant hopper. *Indian J. Entomol* . **61**(3): 169-178.

FAO(Food and Agriculture Organization). (2004). FAO year book production Food and Agricultural Organization of the United Nations, Rome, Italy. 57: 115.

Fariduddin Ahmed, (1973). Rice Stem Borers and their control. Seminar held on rice research and production at Rice Research Stattion, Dokri (Larkana) on 14th– 15th March under Auspipicess of Agriculture Research Council, Pp 278.

Fernando, H. E.(1975).The brown plant hopper problem in srilanka. *Rice Entomol. Newsl*. **2**: 3436.

Fraenkel G, Fallil F, Kumarasinghe (1981). The feeding behavior of rice leaf folder, *Cnaphalocrocis medinals. Entomologia* Experimentaliset Applicata **29** : 147-161.

Ghani, M. A. (1966). Final Technical Report on the natural enemies of insect pests of rice. *Inst. Bio.Control*. Pakistan Station, Rawalpindi, Pp 48.

Godase, S. K. and Dumbre R. B.(1982). Laboratory studies on bionomics of rice leaf roller, *Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae). *Pestology*. **6**: 13–16.

Gordan, (1999). Rice ragged stunt a new virus disease occurring in tropical Asia. Rev. *Plant Prot. Res.* **12**: 98-120.

Grist, D.H. and Lever, R. B. A. W. (1969). Pests or rice, Longmans Green and Company Ltd., London, Xit.520 p.

Gupta, S. P., Prakash, A., Choudbury, A., Roa, J. and Gupta, A. (1989). Pentational bugs reduce rice grain quality in farmer’s fields in Orissa. *Int Rice Res. Newsl.* **14**(4): 38.

Hariprasad, Y. (1999).Studies on host plant resistance against rice leaf folder, *Cnaphalocrocis medinalis* (Guenee) P^{h} D. Thesis, Annamalai University, AnnamalainagarIndia. P. 259.

Harish, K. (1995). Varietal resistance, population dynamics and timing insecticidal application with peak oviposition by *Scirpophaga incertulas* (walker) (Lepidoptera:Pyralidae) on rice. Annls. Of Appl. Biol., **127**(2). 221-228.

Haque, M. A. and B. N. Islam. (1988). Effect of methanolic neem and chinaberry seeds extract on rice green leaf hopper, *Nephotettix nigropictus*. *Bangladesh J. of Agril.* **13**(10: 53-57.

Heinrichs, E. A., Reessing, W. H., Valencia, S. and Chelliah, S.(1985). Rates and effect of resurgence inducing insecticides on populations of *Nilaparvata lugens* (Homoptera: Delphacidae) and its *predators. Entomol.* **11**: 1269-1273pp.

Hirao, J. (1979). Forecasting brown plant hopper outbreaks in Japan. Brown Plant hoppe*r:* Threat to Rice Production in Asia. International Rice Research Institute.

Holt, J. A. J., Cook, T. J. and G. A. Norton. (1987). Simulation analysis of brown plant hopper *[Nilaparvata Lugens*] population dynamics on rice in the Philippines. *J. Appl. Ecol.* **24**; 87- 102.

Holt, J. A. J., Cook, T. J. and G. A. Norton. (1996). Risk assessment for rice plant hopper and tungro disease outbreaks. Crop Protection. **14**(4):359-368.

Hugar , S.V., Naik, M. I. and Manjunatha, M. (2009). Evaluation of new chemical molecules for the management of *Scirpophaga incertulas* (Lepidoptera:Pyralidae) in aerobic rice. Karnataka J. Agril. Sci., **22**(4): 911-913.

Isaac, P. V. and Venkatraman T. V. (1941). A key for the identification of the pupa of the known lepidopterous borers of sugar cane in India. Based on Morphological characteristics. *India J. Agr. Sci*. **11**: 804-15.

Kalshoven, I. G. E. (1950) . De plagen van de culturrgewassen in Indonesia. The Hague, van Hoeve, **1**:512.

Kamran, M. A. and Raros, E. S. (1967). Seasonal fluctuation in abundance of various rice stem borer on Luzon Island, *The Phillippines. J. Econ. Entomol***.** **61**(3): 650- 665.

Kapur, A. P. (1967). The mjor insect pests of rice plants. In Proc. Symp. Int. Rice. Res. Inst. IRRI, Philippines. pp. 3-43.

Karthikeyan, K. and Purushothaman, S. M. (2000). Efficacy of carbosulfan against rice yellow stem borer, *Scirpophaga incertulas* (walker) (Lepidoptera:Pyralidae). Indian J. Pl. Protc., **28**(2): 212-214.

Kaushik, C. (2010). Extent of damage by leaf folder, *Cnaphalocrocis medinalis* (Guenee) in paddy cultivars at Raiganj, Uttar Dinajpur, West Bengal. Current Biotica **4**: 365–367.

Kawada, A., Kato, S., Mukoo, H. and Fukunaga, V. (1934). Insect and diseases of rice plants in Japan. 4th Sess. Internet. Rice Comm., FAO, pp, 1-5.

Khan, Z. R., Barrion, A. T., Litsinger J. A., Castilla N. P. and Joshi, R .C.(1988). A bibliography of rice leaf folders (Lepidoptera: Pyralidae). Insect Science and its Application **9**: 129–174.

Kim, H. S., Heinrichs, E. A. and rapusas, H. R. (1986). Levels of resistance of rice cultivars and the weed *Leesia hexandra* I. to *Nephotettix malayanus* and *N. virescens* (Distant). *Crop Prot*. **5**(6):400-405.

Kiritani, K. (1979). Pest management in rice. *Annual Review of Entomol*. **24**:279-312.

Kisimoto. R. (1976). Studies on the polymorphism and its role in the population growth. *Bull-Skikoku Agric. Exp. Sta.* pp. 131-106.

Koral, S., Kamran, M. A. and Raros, E. S. (1998). Screening for resistance to different insect pests. IRRI. **10**(2):6.

Korat, D. M., Patel, M. C., Dodia, J. F. and pathak, A. R. (1999). Evaluation of some new insecticides against major paddy pests. *Gujarat Agril. Uni. Res. J*. **24** (2) : 68-73.

Kulshreshtha, j. P. (1974). Brown plant hopper epidemic in kerala (india). *Rice Entomol. Newstel*. **1**: 3–4.

Kulshreshtha, j. P., Anjaneyulu, and S. Y. Padmanabhan.(1974). The disastrous brown Plant hopper attack in kerala. Reprinted from December, 1974. Issue of indian farming. 3 p.

Kuno,e.(1971). Population ecology of rice leafhoppers in Japan.Rev. Plant prot. Res. **6**: 1-16 .

Mal1ick, S. C. and Chowdhury, A. K. (2000). Population dynamics of Zigzag leaf hopper in rice ecosystems and its role on carryover of the tungro viruses. *J. Mycopath. Res*. **38**(2): 71-74.

Manju, S., Thangaraju, D. and David, P. M. M.(2002). Relationship among aboundance of yellow stem borer moth, egg population, and egg parasitism in rice. Internl. Rice Res. Notes. **27**(1): 41

McIntyre, A. N. H., Allison and D. R. Pebnab. (1989). Pesticides: Issues and options for New Zealand. Ministry of Environment, Wellington, New Zealand. pp.168.

Mcnaughton, E. J. (1917). Acrilical review of the world literature on the lepidopterous stalk borers of tropical graminaceous crops. London. Quotedby W.F. JEPSON, 1954.

Mishra, D. N., Kamlesh, K. and Singh, A. R. (2007). Comperative field efficacy of certain granular insecticide against leaf roller and stem borer in rice crop under Mid-Western Plain Zoom of UP. Environ. Ecol., **25**(4):938-940.

Misra, B.C. (1980). The leaf and plant hoppers of rice. Entomol. Dept. Central Rice Res. Inst. Cuttack 753006, India 182 p.

Misra, D. S., Israel. P. and Reddy. K. A. (1985). Seasonal population of rice Leaf hopper and plant hoppers at Varanasi, *india Int. Rice Res. Newsi.***10**(2): 24.

Misra, D. S. and Israel, P. (1991). The leaf and plant hopper problems in high yielding varieties of rice. Oryza. **7**(2): 127-130.

Misra, B. C. and Israel, P. (1970). The leaf and plant hopper problem in high yielding varieties of rice. Oryza. **7**(2): 127-130.Misra,K. A; R.D. and Qureshi, K.H. (2001). Evaluation of 27 cultivars for growth performance and pest and disease resistance. Indian J. Entomol. **55**(4): 607-609.

MOA, (2008) (Ministry of Agriculture), Bio control programme. Agriculture Department in collaboration of the central Integrated Pest Management Center, Port Blair, Andaman and Nicobar, Island, US page 1-6.

Mustafiz, B. A. A., Salam, M. A., Mondal, M. and Kalam, M. A. (eds.). (2007). Modern cultivation of rice (In Bangla) Bangladesh Rice Research Institute,Gazipur,Bangladesh. P[66].

Muriya, S. (1976). Chemical control of rice plant hoppers. Paper presented at a seminar on the rice Brown plant hopper, food and fertilizer technology center for the Asian and pacific region, October, 4–10. Tokyo. 12p.

Nasu, (1967) rice leaf hoppers. In: Major insect pest of the rice plant . John Hopkins Press, Baltimore, Maryland, USA. 16-30 p.

Nath, P. and Bhagabati, K. N. (2005). Population dynamics of leaf hopper vectors of Rice tungro virus in Assam. *Indian Phyto pathology*. **55**(1): 92-94.

Orita, F. (1935). Studies on the paddy borer, *schoenobiusincertulus*wlk. In japan [in japanese].(ii). Oyodobutuga kuzassi **7**:242–261.

Pagden, H.T. (1930). A preliminary account of three stem borer. *Sci. Ser. Dept. Agril. S.S. and F.M.S.*, Bull. No. 1, pp. 1-30.

PateI, R. K., Janoria, M. P. and Bhowmik, A. K. (1987). Leaf folder (LF) population on rice under drought. Inlernational Rice *Res. Newslet.***12**(3):30.

Pathak , M.D., Andres, F., Galacgnac and Anos,N.(1970). Resistance of rice cultivar to the striped stem borer. Int.Res. Inst. Tech. Bull., **11**:9-15

Phillp Sridhar, R. (1988). Bio-ecology of rice leaf folder and screening of rice accessions for leaf folder resistance. M.Sc. (Ag.).Thesis, Annamalai University. 168 p.

Puttarudriah, M. (1945). Some observations made on the biology. Habits and control of the paddy stem borer. (S*choenobius incertulas* Walker). Mysore Agr. 124-167.

Quing, M. P. and Biswas, K. P. (2000). Relative abundance of different species of white backed plant hopper in deep water rice in north Bihar. *Oryza. Intl. Rice Res. Newslet.* **26**(3): 282-284.

Raddy, D. K., Misra, D. S. and Singh T.V. K. (1993). Special distnbubon of rice leaf and plant hoppers. *Indian J. Ent.* **55**(1): 1-10.

Rahman, M.T., Khalequzzaman, M. and Khan, M. A. R. (2004). Assesment of infestation and yield loss by stem borer on veriety of rice, J. Asia Pacific Entomol., **7**(1): 89-95.

Rai, A. K., Singh, A. K., Hameed, S. F. and Mehto, D. N. (1989). Relative abundance of different species of stem borers in deep water rice in north Bihar. Oryza. **26**(3): 282-284.

Rao and Israel (2004). The 100 rice cultivars screened to leaf folder infestation, only twenty- two showed a consistent damage. *Indian*, *J. Agric*. *Sci.* **41**(2): 112-119.

Ranasinghe, W. (l992). Relative abundance of different species of stem borer in deep water rice in north Bihar Oryza. **26**(3)282-284.

Rangini, J. *C., Thangaraju*, D. and David, P. M. M. (2005). Relative abuundance of rice stem borer species in Tamil Nadu. *Madras Agril. J. Publ*. **87**(4-6): 228-234.

Rath , P. C. (2001). Efficacy of insecticides, neem and Bt formulation against stem borer on rice yield in *West Bengal. j. Appl. Zool. Res.*, **12**(2/3): 191-193.

Razzaque, Q. M. A., Heinriches, E. A. and Rapusas, H. R. (1985). Mass rearing technique for rice green leaf hopper *Philipines Entomol*. **6**(4): 398-404.

Reddy. K. D. and Misra. D. S. (1995). Varietal response of rice against brown plant hopper *Nilaparvaia . indian J. Entomol.* **57**(3): 169-178.

Reissig, W., Heinrichs, E. A., Litsinger, J. A., Mooders, K., Fiedler, L., Mews, T. W.and Barrion, A. T. (1985). Hustrated guide to Integrated Pest Management in Rice in Tropical Asia. IRRI, Philippines.79p.

Ripper, W. E. (1956). Effects of pesticides on balance of arthropod populations. *Annu. Rev. Entomol.* 1:403–38.

Roshan. L. (2006). A novel use of cartap hydrochloride 4G for management of stem borers in aromatic rice in Haryana. *Indian J. Entomol.,* **68**(3): 230-234.

Sachan, J. N. and Gangwar, S. K. (1980). Insect pests of soybean in Khasi Hills of Meghalaya and their control. *Bull Ent.* **21**(1-2): 105-112.

Saha N. N. and Saharia, D. (1970). Effect of dates of transplanting and levels of niteogen on the Sarhad J. incidence of stem borer. *Scirpophaga incertulas* in paddy in Assam. *Indian Entomol*. **32**(3): 225-229.

Saijoqi, A. U. R., Muhammad. K., Khalid, A. and Latif, A. (2002). Evaluation of fipronil for the management of rice stem borer (*Tryporyza incertulas*, Lepidoptera:Pyralidae). *J.* Agric., **18**(1): 59-61.

Sarode, S.V., Deotale, R.O. and Thakure, H. S.(1995). Evaluation of neem seed kernel extract for the management of *Helicoverpa armigera* on pegion pea. *Indian J. Ent*.**57**(4) :385-388.

Sato, T. and Kishino, K. (1978). Ecological studies on the occurrence of the paddy leaf roller, *Cnaphalocrocis medinalis* (Guenee).Bulletin of the Tohoku National Agricultural Experiment Station 58: 47–80.

Saxena, R. C., Liquido, N. S. and Justo, H. D. (1981). Neem oil a potential antifeedant forthe control of brown plant hopper, *Nilapatvata lugens*. Proc. 1st Int. Neem Conf. Rootach, June, 1980. Egern. pp.171-188.

Sherawat. S. M., Manzoor, I., Tanvir, A. and Maqsood, M. K.(2007). Determination of economic threshold levels (ETL) for the chemical control of rice stem borers. J. Agril. Res. Lahore. **45**(1):55-59.

Shiraki,T.(1917).Paddy borer(*Schoenobiusin certullus* Walker). Taihoku Agr.Expt. Sta., Formosa. 256 p.

Shrinavasa, (1989). The effect of infestation of leaf folder, C. medinalis in different rice varieties. *Indian I. Entomol*. **69**(3): 17 1-174.

Shrivastava, S., Shukia, B. C., Gupta. R. and Agrawal, R. K. (2000). Seasonal abundance and activity of rice green leaf hoppers in Chhattisgarh region of Madhya Pradesh *Indian J. Ecol.* **14**(1): 116-122.

Siddique, A. K. M.T. (1992). “An overview of the ETL of rice pest and 1PM scope in the content of M.V. Rice production” In Proc. of the Workshop on Experiences with Modern Rice Cultivation in Bangladesh. BRRI, Gazipur, pp. 33-45.

Shanmugam J., Gupta, R. and Agrawal, R. K. (2006). Antibiosis mechanism of rice resistance to brown plant hopper, *N. lungens. Stal International Rice Res. Newslet*. **32**(3): 285-288.

Stapley, J. H. (1975). The problem of the brown plant hopper (*nilaparvata lugens*) on rice in the Solomon islands. Rice Entomol. Newsl. 2:37.

Tobin, C. P., Nagarkatti, S. and Saunders M.C. (2003).Phenology of grape berry moth (Lepidoptera:Tortricidae) in cultivated grape at selected geographic locations. *Environ. Entomol.* **32**: 340–346.

Tsueda, H., Yajima, M., Taguchi, Y. and Suzuki, T. (2002). Occurrent tendency of rice sting bugs in South flat area of Gifu Prefecture. Proc. The Kansai *Plant Protection Soc.* **4**:13-20.

Tu, C.C. and Chang, Y. C. (1992). Plant breeding for disease resistance. In : Proceedings of Symposium on Techniques of Non- chemical Measures in Control of Plant Pest. Pp.233-250. Taichung, Taiwan, November 28-29, 1991(in Chinese).

Varea, A. S. and Feuer, L. (1976). The brown plant hopper and its bio type in the Philippines *Plant Prof. Newstel*. **5**(35): 38-41.

Velusamy, R. (1988). Resistance of wild rice, *Oryza sativa*, to brown plant hopper, *Nilaparvata lugens* stal. (Homoptera: Delphacidae). Crop Prot**.** **7**(6): 403-408.

Wada, T. (1979). Influence of the temperature and the growing stages of rice plant on the number of larval instars in the rice leaf roller, *Cnaphalocrocis medinalis* Guenee. Japanese *J. of Appl. Entomol. and Zool.* **23**: 178–182 (in Japanese with an English summary).

Walker and coot (*1925). Effects of temperature on development of the rice leaf roller, Cnaphalocrocis medinalis* Guenee (Lepidoptera: Pyralidae). *Appl. Entomol. and Zool*. **15**: 207–214.

Watanabe, T. M., Matsumura and Otuka, A.(2009). Recent occurrences of long-distance migratory plant hoppers and factors causing outbreaks in Japan. Planthoppers*: New Threats to* the Sustainability of Intensive Rice Production Systems in Asia. 179-189.

Woodhead, S. and Padgham, E. E. (1988). The effect of plant surface characteristics on resistance of rice to brown plant hopper, *Nilaparvata lugens* Stal. *Entomol. Exp*. *Appl*. **47**:15-22.

Zhang L.Y., Wu, R. Z. and Yang, X.Q. (1984). Evaluation of the resistance of new rice lines Hong-Yuan and Tainuo-Xuan to the brown plant hopper, *Nilaparvata lugens. J. South-China Agric. Univ.* **15**(2): 67-72.