BIO-CONTROL AGENTS AND BOTANICAL PRODUCTS FOR THE ECO-FRIENDLY MANAGEMENT OF STEM BORER ON HYBRID RICE

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BIO-CONTROL AGENTS AND BOTANICAL PRODUCTS FOR THE ECO-FRIENDLY MANAGEMENT OF STEM BORER ON HYBRID RICE

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CERTIFICATE

This is to certify that thesis entitled **"Bio-Control Agents and Botanical Products for the Eco-friendly Management of Stem Borer on Hybrid Rice"** 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 in ENTOMOLOGY,** embodies the result of a piece of bona fide research work carried out by **Md. Mahabub Alam**, **Registration No. 08-03173** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

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____

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ABSTRACT

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from June to November, 2009 to find out the most effective management practice(s) among *Trichogramma evanescens* egg parasitoid @ 0.25 gm and 0.50 gm plot^{-1}, *Bacillus thuriengiensis* bacterium suspension @ 0.1% and 0.2%, SafeClean @ 0.05%, SafeMax @ 0.05%, Neem oil @ 0.3% and chemical insecticide Furadan 5G @ 6 gm plot^{-1} for the eco-friendly management of rice stem borer on hybrid rice (Hira-2). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Considering the dead heart and white head infestation, among the treatments chemical insecticide Furadan 5G (T_8) performed as the most effective practice in reducing the dead heart (81.47%) and white head (91.44%) infestation over control followed by *Trichogramma* egg parasitoid @ 0.50% (T_2) treatment (73.64% and 82.34%, respectively). T_8 also gave the maximum yield contribution characters of the rice plants as well as produced the highest grain yield (7.67 ton ha^{-1}) followed by T_2 (7.23 ton ha^{-1}). Economically the most effective treatment was T_2, through which the highest benefit cost ratio (5.04) was achieved as compared with other treatments including Furadan 5G (3.80). Considering the ecological point of view, the T_2 comprising *Trichogramma evanescens* egg parasitoid @ 0.50 gm plot^{-1} was the most ecologically sound management practice applied against rice stem borer.

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CHAPTER I

INTRODUCTION

Rice is the most important food grain in the world. The geographical, climatic and edaphic conditions of Bangladesh are favorable for year round rice cultivation. However, the national average rice yield (2.34 t ha^{-1}) is very low compared to that of other rice growing countries such as in China is about 6.3 t ha^{-1}, Japan is 6.6 t ha^{-1} and Korea is 6.3 t ha^{-1} (FAO, 2002). But the beginning of modem rice cultivation technology including the introduction of high yielding varieties and the frequent use of insecticides appear to have increased the abundance of many rice pests (Quraishi *et al.*, 1990).

In Bangladesh, about 175 insect pest species have been reported, which cause damage to the rice plants (Mustafi *et al.*, 2007). In Bangladesh, stem borer, *Scirpophaga incertulus* is one of the major pest followed by *Sesamia inferens* and cause 20% yield loss (Khan *et al.*, 1991). Catling and Islam (1982) reported that more than 40% of deepwater rice stems were consistently damaged and yield losses were 20-40% in Bangladesh. To safeguard the food security of the continuous increasing population of Bangladesh, the introduction of hybrid rice is the new but time demanding innovation. But the information regarding the reactions of the hybrid rice against stem borer is scare. Hybrid rice variety was found to the most susceptible to stem borer and caused yield loss 22.19-27.09% (Rahman *et al.*, 2004).

The percentage yield loss due to stem borer's infestation was found the highest (27.09, 24.54, 25.32, 36.26, 17.74 and 22.19% by *C. polychrysa* (Meyrick), *C. suppressalis* (Walker), *C. partellus* (Swinhoe), S. *incertulas* (Walker), *S. innotata* (Walker) and *S. inferens* (Walker) respectively on the variety, BR31 and the lowest (11.17, 10.18, 10.54, 8.77, 8.10, and 7.07% by *C. polychrysa*, *C. suppressalis*, *C.*

partellus, S. incertulas, S. innotata and *S. inferens* respectively on the variety, Bansphul (Rahman *et al.,* 2004). Indrani (1988) reported that *Scirpophaga incertulas* is a common pest of rice in West Bengal, India. It was evident that *Telenomus* sp. was most common parasitoid and most dominating in the early summer crop and became highly adaptive under diverse crop growing situations. Among three species of *Telenomus, T. rowani* Gahan was the most abundant during the summer and winter seasons.

Various control strategies have been adopted against stem borers, one common method being the use of synthetic insecticides, which can be environmentally disruptive and can result in the accumulation of residues in the harvested produce and creating health hazards (Chinniah *et al.*, 1998). This is the prime crisis of rice growers over the country. Although some risks accompany the use of synthetic insecticides, some insecticides of plant origin are safer to handle and use. Neem products are examples of such plant-derived insecticides, which have been used in some Asian countries (Karim *et al.,* 1992). Amaugo and Emosairue (2005) reported that neem seed kernel extracts reduced 16.31% white head infestation and produced 158% more yield. Use of bio-control agents is another safe and hazards free tactic for the management of insect pests (Hasan, 1994).

Parasitic wasps viz. *Trichogramma* sp. egg parasitoid (Mohanraj *et al.*, 1995), *Bracon* sp. larval parasitoid, *Bacillus thuringiensis* insect pathogenic bacterium are the new introduction in Bangladesh for the management of rice stem borer. Many parts of the world use *Trichogramma* sp. successfully for crop production (Hasan, 1992). The egg parasitoid *Trichogramma* can achieve a level of control that is near 100% in some years or areas (Kim and Heinrichs, 1985; Kim *et al.,* 1986). Catling *et al.* (1983) reported that 61-89% egg masses of yellow stem borer were parasitized by

Trichogramma japonicum Ashmead and *Telenomus* sp. and clearly reduced the infestation of stem borer *(Scirpophaga incertulas). Bacillus thuringiensis* (Bt) is an insecticide with unusual properties that make it useful for pest control in certain situations. However, it was not commercially available until the 1950s. In recent years, there has been tremendous renewed interest in Bt. Neem products are examples of such plant-derived insecticides, which have been used in some Asian countries (Karim *et al.,* 1992).

Considering above context the present study was planned and designed with the following objectives:

1. To study the infestation level of hybrid rice caused by stem borer.
2. To find out the most effective management practice(s) among different bio-control agents *Trichogramma* egg parasitoid and *Bacillus thuriengiensis* pathogenic bacterium, botanical products and chemical insecticide for the eco-friendly management of rice stem borer.

CHAPTER II

REVIEW OF LITERATURE

Stem borer, *Scirpophaga incertulas* (Pyralidae: Lepidoptera) is a serious pest of rice in Bangladesh and elsewhere in the world. Several studies in relation to different aspects of this pest have been reported from many countries of the world. For better understanding and management of this pest by using bio-control agents, botanical products, chemical as well as their combined efforts have been made to review the available literature related to this study.

2.1 Rice stem borer

The rice stem borers are generally considered as the most serious pest of rice. They occur regularly and attack rice plants from seedling to maturity stages. About 16 different stem borer species are found in rice fields. Rahman *et al.* (2004) reported in Bangladesh that 6 species of rice stem borer *Chilo suppressalis, C. polychrysa, C. partellus, Scirpophaga. incertulas, S. innotata, Sesamia inferens* cause damage on rice and among which the yellow stem borer (*S. incertulas*), dark headed striped borer (*C. polychrysa*) and pink borer (*S. inferens*) are of major economic significance.

The common name of the above 3 species have been given according to their larval characteristics. In Bangladesh, the most

destructive and widely distributed species is yellow stem borer (Kapur, 1967.)

Life history of rice stem bores

Adult: The moth has yellowish forewings with a single dark spot in the center of each. The male is pale whitish yellow and spots on the forewings are not conspicuous. It is nocturnal and positively phototropic.

Egg: Eggs are laid on upper surface of leaf in masses, which are covered by buff-colored hair contributed by the anal tuft of the female moth. Each mass contains 50-80 eggs.

Larva: The first instar larva hatching out from the egg masses crawl upward toward the tip of the plants and stay for only short period. Then the larvae get dispersed with the aid of silken thread and wind. Soon there after they cut open a small hole in the stem and enter the plant tissue remaining there for the rest of their life as larva and pupa. During the vegetative stage of the plants, the larva generally enters the basal part usually 10 cm above the water. On the older plants, they bore through the upper nodes and make their way through the nodal septa toward the base. On a crop at heading stage, boring usually occurs at peduncle node or internode. The larva feed the internal tissues of the stem. The larva usually undergoes 4-5 instar to become full-grown. The larva of yellow stem borer hibernates to pass the over wintering. Since the full-grown larvae tend to feed in the basal parts of the plant all the larvae are usually left in the stubble after harvesting. The full-grown larva is 20 mm long and a smooth surface of pale yellowish colour at times with a greenish tinge.

Pupae: It pupates within the larval tunnel usually at the base of the plant where it constructs a white silken cocoon. Before pupating the full-grown larvae make an exit hole through which the emerging moths escape (Miah and Karim, 1984).

a. Species in Bangladesh

The principal Lepidopterous borers in the wet rice area were *Tryporyza incertulas* (Walk.), *Chilo suppressalis* (Walk.) and *Sesamia inferens* (Walk.), while *Tryporyza innotata* (Walk.) and *Chilo auricilius* Dudg were in dry rice area (Rothschild, 1971).

b. Distribution

Rice stem borers occur in different ecosystems. In Sri Lanka three species of stem borers attack deepwater rice, but the major pest is undoubtedly the yellow stem borer (*Scirpophaga incertulas*). It is completely dominant in the flood season; none of the other species are adapted to aquatic conditions. The yellow stem borer may be considered as one of mankind's worst pest, since in Asia it is the major pest of the most important staple food crop. Living exclusively on the *Oryza* cultigens and *Oryza* wild rice, it has been associated with cultivated rice for thousands of years (Yazumatsu, 1976) and probably originated within the broad belt stretching from Northern India to North Vietnam where rice is endemic. The highly specific insect – host plant relationship and the adaptive characteristics to an aquatic environment strongly suggest that yellow stem borer originated in the deepwater rice environment (Catling, 1992).

In Asia, yield losses due to the two most important species, the yellow and striped stem borers range from 1-20%. However, during outbreak conditions, yield losses may range from 30 to 100%. Except for the yellow stem borer, which is monophagous to rice, the other species also feed on corn, sorghum, sugarcane, wild rice and other species of grasses (IRRI website). In Sri Lanka stem borer damage had been estimated to reduce up to

50% of the potential harvest of rice. The stem borers belong to the Order Lepidoptera, which is characterized by the presence of sucking mouthparts in the form of a proboscis and scales on the wings. At present three species of Lepidopteran stem borers are known to occur in Sri Lankan paddy fields (Fernando, 1964). Two of them are pyralid moths, i.e. yellow stem borer, *Scirpophaga incertulas*, which comprises almost 90% of the stem borer populations and a *Crambus* sp., which is rare. A noctuid, *Sesamia inferens*, forms about eight percent of the local stem borer populations (Ranasinghe, 1992).

Maes (2005) listed 21 economically important lepidopteran stem borers of cultivated grasses in Africa, including 7 noctuids, 2 pyralids, and 12 crambids. Of these 21 species, 7 are primarily pests of rice, and one mainly attacks pearl millet in the Sahelian region. Among the noctuids, *Busseola fusca* and six *Sesamia* spp. are considered economically important. Two pyralids are serious pests: the rice borer, *Maliarpha separatella*, and *Eldana saccharina*, a pest of sugarcane and maize. The largest group (12 species) of injurious stem borers are crambids, with the majority (7 species) belonging to the genus *Chilo* Zincken. Within specific crops and geographic regions, fewer species are considered to be important pests (Table 1).In South Africa, *B. fusca* and *Chilo partellus* are the only important stem borers of maize and sorghum (94), while in sugarcane in the same region, only *E. saccharina* is considered to be a serious pest (47). In East Africa, *C. partellus*, *Chilo orichalcociliellus*, *E. saccharina*, *B. fusca*, and *Sesamia calamistis* are mentioned as important and widely distributed stem borers of maize and sorghum (168). Major stem borers of maize and sorghum in West Africa include *B. fusca*, *S. calamistis*, and *E. saccharina* (34). In the Sahelian zone, where pearl millet is the most important cereal crop, *Coniesta ignefusalis* is the dominant stem borer (73).

Distribution of stem borer larvae of all species was non-random and approximated to the negative binomial series. Clustering was greatest in *Chilo suppressalis*, and was attributed to lack of dispersal from the hatching sites. Infestation of the rice crop was usually high prior to the flowering phase. Light trapping was used to determine borer abundance, but the data obtained bore little relation to population trends in the crop as both the species and the sexes were unequally attracted. During the off-season there was evidence of diapause and quiescence in mature larvae of *Tryporyza innotata* and *T. incertulas*, respectively, but small breeding populations of these species, as well as of *Chilo suppressalis* and *Sesamia*, were present on volunteer and ratoon rice plants (Rothschild, 1971).

c. Life cycle

The life cycle period of stem borer is comprised with incubation period- 5-8 days, larval period- I.6-43 days, pupal period- 4-8 days and moth lives for 2 to 5 days.

The biology of yellow stem borer, *Scirpophaga incertulas* (Walk.) showed that eggs were oval, flattened and creamy white in both aerobic and transplanted rice reported by Hugar *et al*. (2010). However, average length and breadth varied slightly. It was 0.7+or-0.03 mm and 0.43+or-0.02 mm in transplanted paddy and 0.6+or-0.03 mm and 0.38+or-0.02 mm in aerobic paddy, respectively. The eggs were laid in masses having an average length and breadth of 5.9+or-1.41 mm and 3.41+or-0.36 mm, respectively on transplanted paddy and 5.6+or-1.36 mm and 3.37+or-0.0 mm, respectively on aerobic paddy. The newly hatched larva was yellowish green with dark head. It passed through five instars. The full grown larva was dirty white with the length of 20.3+or-1.21 mm on transplanted paddy and 19.9+or-0.30 mm on aerobic paddy. The average length of prepupa was 12.61+or-1.30 mm on transplanted paddy and 11.5+or-0.93 mm on aerobic paddy. The pupa was pale to dark brown and was longer and broader on transplanted paddy than on aerobic paddy. Fore-wings of the adult female were yellow in colour with a distinct black spot in the centre at each fore-wing. The fore-wings of the adult male were brown with numerous small light brown spots on them. Average length and breadth of the female and male moth and their longevity were higher on transplanted paddy than on aerobic paddy. Fecundity of the female was 159.3+or-39.8 eggs on transplanted paddy and 152.2+or-33.29 on aerobic paddy. Total life cycle of the pest was 42.8+or-1.73 and 43.8+or-0.67 days, respectively on transplanted paddy and aerobic paddy.

d. Extent of damage and yield loss caused by rice stem borer

Nature of damage

Scirpophaga incertulas could attack most of the growing stages of rice plant, beginning 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.

The yellow stem borer is a notorious pest of deep-water rice in the main flooding period in Bangladesh.

Yield loss

Major insect pests cause about 13, 24 and 28% yield loss to Boro, Aus and Aman crops, respectively (BRRI, 1985). The estimated annual loss of rice in Bangladesh due to insect pests and diseases amounts to 1.5 to 2.0 million tons (Siddique, 1992).

Rahman *et al.* (2004) reported that the hybrid variety was found the most susceptible against six borer species, and local varieties were resistant. The percentage yield loss due to stem borer's infestation was found the highest (27.09, 24.54, 25.32, 36.26, 17.74 and 22.19% by *C. polychrysa* Meyrick, *C. suppressalis* (Walker), *C. partellus* Swinhoe, S. *incertulas* Walker, *S. innotata* (Walker) and *S. inferens* (Walker) respectively) on the variety, BR31 and the lowest (11.17, 10.18, 10.54, 8.77, 8.10, and 7.07% by *C. polychrysa, C. suppressalis, C. partellus, S. incertulas, S. innotata* and *S. inferens*, respectively) on the variety, Bansphul.

Calting and Islam (1982) reported that the yellow stem borer, *Tryporyza incertulas* (Walker) is a major pest of flooded deepwater rice in Bangladesh. More than 40% of the rice stems are consistently damaged and yield losses are 20-40%. Preliminary surveys suggest that the borer is also an important pest of deepwater rice in Thailand, India and Burma. The pest is closely associated with Asian rice and may have originated in the deepwater rice areas of India and Bangladesh. Catling *et al.* (1978) studied a series of 17 crop-loss assessments under simulated farmers' field conditions in the three main rice cropping seasons of Bangladesh. They reported that the main insect pests were the rice stem borers *(Tryporyza incertulas, Chilo polychrysa, Sesamia inferens)* and in the monsoon rice gall midge (*Pachydiplosis oryzae*). In the winter and early monsoon yield losses averaged 4 and 6% respectively, but economic benefit was only derived from insecticide application in the monsoon season, when there was an average yield loss of 16%. An economic threshold of 5-10% damaged tillers ('dead hearts' and `onion shoots') was indicated for early attacks of stem borers and gall midge.

e. Management of rice stem borer

A field study was conducted by Chakroborti (2003) during 1999 and 2000 wet seasons to assess the effects of some integrated management approaches (involving neem [*Azadirachta indica*] oil, neem cake, neem seed kernel extract, azadirachtin, phosphamidon and triazophos) on the insect pests (*Scirpophaga incertulas*, *Dicladispa armigera* and *Nymphula depunctalis* [*Parapoynx stagnalis]*) in deep water rice at the University Farm in Mohanpur, West Bengal, India. Integrated treatments with neem components plus one or two synthetic chemical applications were very effective in controlling the pest population build up and kept the damages by insect pests at significantly low levels notably superior to the chemical controls. Integrated neem treatments also performed reasonably well. Neem treatments were quite safe, and integrated neem plus synthetic chemical treatments were moderately safe to natural enemies. However, the contribution of the natural enemies in controlling the pest population build up appeared only marginal.

The relationship among yellow stem borer (YSB; *Scirpophaga incertulas*) moth catch in a light trap, egg mass density, and parasitism (by *Telenomus digmus* [*T. dignus*] and *Tetrastichus schoenobii*) was determined by Manju *et al*. (2002) to correlate light trap data with levels of pest eggs in the field and to study whether parasites 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.

The efficacy of some granular and sprayable insecticides, a neem product and a Bt (*Bacillus thuringiensis*) formulation studied by Rath (2001) against stem borer revealed that thiocyclam hydrogen oxalate, chlorpyriphos and thiomethoxam were proved best and recorded more than 80% yield increase over control. The performance of granular fipronil (75 g a.i/ha) was on par with carbofuran granule (1 kg a.i./ha) against the pest. The efficacy of other insecticides was slightly inferior and registered 52.00-66.50% yield increase over control. However, the neem and Bt formulation were found to be effective to a limited extent against stem borer.

Field trials were conducted by Gururaj *et al*. (2001) in Andhra Pradesh, India during kharif 1995 and rabi 1997 to study the effects of integrating pheromone mass trapping and biological control for the management of rice yellow stem borer (*Scirpophaga incertulas*) and rice leaf folder (*Cnaphalocrocis medinalis*). The first treatment involved mass trapping with the use of 20 pheromone traps per ha and the inundative release of *Trichogramma chilonis* at 1000000 adults/ha. The second treatment consisted of granular and spray applications of insecticides once during rabi 1997 (farmers' practice). In 1995, lower stem borer (8.9%) and leaf folder (8.5%) damage, and higher grain yield (4747 kg/ha), were obtained with mass trapping, compared with the stem borer (28%) and leaf folder (22%) damage, and grain yield (3421 kg/ha), obtained with the farmers' practice. In 1997, lower stem borer (1.5%) and leaf folder (7.0%) damage were recorded for the mass trapping treatment compared with the farmers' practice (7.6 and 53.9%, respectively). The percentage of parasitism of stem borer egg mass was 56.7% in the mass trapping treatment, while no parasitism was observed for the farmers' practice. In both years, cost benefit ratios were higher with mass trapping than with farmers' practice.

2.2 Bio-control agents in controlling rice stem borer

2.2.1 *Trichogramma* egg parasitoid

Common name: *Trichogramma*

Scientific name: *Trichogramma* spp.

Family: Trichogrammatidae

Order: Hymenoptera

Trichogramma are extremely tiny wasps in the family Trichogrammatidae. While it is uncommon for an insect's scientific name, especially one so long and unusual as *Trichogramma*, to also become its common name, the commercial development of this natural enemy and the fact that it attacks so many important caterpillar pests has earned it a place in the popular vocabulary of many pest management advisors and producers.

Trichogramma wasps occur naturally in almost every terrestrial habitat, and some aquatic habitats as well. They parasitize insect eggs, especially eggs of moths and butterflies. Some of the most important caterpillar pests of field crops, forests, and fruit and nut trees are attacked by *Trichogramma* wasps. However, in most crop production systems, the number of caterpillar eggs destroyed by native populations of *Trichogramma* is not sufficient to prevent the pest from reaching damaging levels.

Recognizing the potential of *Trichogramma* species as biological control agents, entomologists in the early 1900s began to mass rear *Trichogramma* for insect control. Although a small commercial production of *Trichogramma* eventually developed in the U.S., insect control research and commercial efforts focused on the development of chemical pesticides following the discovery of DDT (73). This was not the case in the Soviet Union and China, both of which developed programs to control several crop pests with *Trichogramma*. In these countries, insectaries were less expensive and less sophisticated than production facilities for synthetic insecticides, and could be located on farms where labor was inexpensive and readily available. Also, control standards were not as stringent, and releasing *Trichogramma* was often better than no control at all (King, 1993).

2.2.1.1 Species and distribution of *Trichogramma* parasitic wasp

The genus *Trichogramma* is one of 80 genera in the family Trichogrammatidae. All members of this family are parasites of insect eggs. Trichogrammatidae includes the smallest of insects, ranging in size from 0.2 to 1.5 mm. Within the genus *Trichogramma*, there are 145 described species worldwide; 30 species have been identified from North America and an estimated 20 to 30 species remain to be described. The species most commonly collected from crops and orchards are *atopovirilia, brevicapillum, deion, exiguum, fuentesi, minutum, nubilale, platneri, pretiosum,* and *thalense* (Neil *et al*., 1998).

2.2.1.2 Life cycle of *Trichogramma* parasitic wasp

Adult: Trichogramma adults are extremely small. The female adult lays eggs on other moths' eggs. First, she examines the eggs by antennal drumming, then drills into the eggs with her ovipositor, and lays one or more eggs inside the moth's eggs. She usually stays on or near the host eggs until all or most of them are parasitized. When the parasitized moth's eggs turn black, the larvae parasite develop within the host eggs. The larva eats the contents of the moth's eggs. Adults emerge about 5-10 days later depending on the temperature. Adults can live up to 14 days after emergence.

Egg: Female adults can lay up to 300 eggs. The effect of temporary host deprivation on parasitization rates of *T. cacoeciae* (*T. cacaeciae*) and *T. dendrolimi* was investigated by Hegazi and Khafag (2001). The insect host in the experiments was *Sitotroga cerealella*. The study was conducted with females that we allowed to engage in 3 days of oviposition after various periods of host deprivation. It seems that the production and management of eggs by the two species is completely different. During the first day of oviposition, parasitization by *T. cacoeciae* was almost unaffected after 1 to 5 days of host deprivation. As deprivation time increased, however, the number of parasitized hosts decreased from an average of 28.6+2.0 hosts provided at emergence to an average of 12.5+2.3 hosts when the waiting time was 10 days. The number of hosts parasitized on the first day of parasitization by *T. dendrolimi* were not affected whatever the waiting test period. During the second or third days of oviposition, the lack of suitable hosts for *T. cacoeciae* did not depress egg-laying potentiality, whereas a strong reduction in parasitization rates by *T. dendrolimi* occurred in the next 2 days of oviposition whatever was the waiting period. This leads to ca. 50% reduction in total activity of 3 days of oviposition. Only in *T. cacoeciae* was it possible to distinguish between ageing and host deprivation. The data suggest that *T. dendrolimi* is a typical proovigenic species, while *T. cacoeciae* is neither definitely proovigenic nor synovigenic.

A slight decrease in rate of emergence of offspring of *T. cacoeciae* females that had waited 8 to 10 days for their hosts was observed.

The functional response of third generation of the *Trichogramma brassicae* reared in laboratory, was studied by Asgari *et al*. (2004) at various densities (5, 10, 20, 40, 80, 100, 120) of the *Sitotroga cerealella* eggs under 25+or-1 degrees C, %60+or-5 RH, and 16 L:8 D.h. photoperiod. One day old eggs of Angumous grain moth. *S. cerealella*, in 15 replications for 24 hours were exposed to one-day old female wasps. Functional response of *T. brassicae* was found to be type III. Searching efficiency (a) handling time and maximum attack rate were estimated, 0.168+or-0.055, 1.468+or-0.121 and 16.34, respectively.

2.2.1.3 *Trichogramma* parasitic wasp for the management of rice stem borer

Bio-intensive pest management of leaf folder and stem borer was demonstrated by Ramandeep *et al*. (2007) on basmati rice at village Karni Khera (District Ferozepur), Punjab over 60 hectares during 2002-2005. Bio-intensive management package included one application of cartap hydrochloride, (Padan @ 25 kg/ha) and seven weekly releases of *Trichogramma chilonis* and *T. japonicum* @ 100000/ha each starting from 30 days after transplantation. The mean per cent leaves folded (2.02), dead hearts (3.05), white ears (5.45) and yield (43.99 q/ha) in chemical control, mean per cent leaves folded (1.77), dead hearts (2.62), white ears (4.48) and yield (44.83 q/ha)), and both the treatments were significantly better than control. The cost:benefit ratio was 1:4.01 and 1:4.68 for bio-intensive management practice and chemical control, respectively.

Field evaluation of two egg parasitoids, *Trichogramma japonicum* Ashmead against rice stem borer, *Scirpophaga incertulas* (Walker), and *Trichogramma chilonis* Ishii against leaf folder, *Cnaphalocrocis medinalis (Guenee)*, was carried out in farmers' fields by Karthikeyan *et al*. (2007) in three locations at Karakkad village, Palakkad district, Kerala, during three seasons in 2003 and 2004 in comparison with insecticide application. Release of *T. japonicum* @ 100000/ha followed by application of azadirachtin 1 per cent against yellow stem borer reduced dead hearts from 12.21 to 91.02 per cent and from 27.4 to 58.2 per cent over insecticide application during kharif and rabi seasons, respectively. Incidence of white ears was reduced by 72.41 to 92.86 per cent. *T. chilonis* reduced leaf folder damage by 41.68-98.60 per cent over conventional insecticide application. Release of egg parasitoids in rice resulted in an increase of yield by 25.79-45.13 per cent over insecticide treated plots, with a mean cost-benefit ratio of 1:2.6 and 1:1.9 in parasitoid released and insecticide applied plots, respectively.

Indrani (1988) reported that *Scirpophaga incertulas* is a common pest of rice in West Bengal, India. It was evident that *Telenomus* spp. were most common and most dominating in the early summer crop and became highly adaptive under diverse crop growing situations. Among three species of *Telenomus, T rowani* Gahan was the most abundant during the summer and winter seasons. *Tetrastichus schoenobii* Ferriere was second in importance in regulating the borer population and its attack was heaviest on the later broods in rice crops cultivated during winter. *Trichogramma japonicum* Ashmead was very sporadic and had a particular preference for the dry period. Parasitism of egg masses by two or more species of the parasites was also common during the peak period of parasite activity.

Catling *et al.* (1983) reported in Bangladesh that 61-89% of the egg masses of the yellow rice borer, *Scirpophaga incertulas* (Walker) in deepwater rice, were attacked by hymenopterous parasites. Egg parasitism increased from 43-48% in broods 2-4 (May-August) to 64-88% in broods 5-6 (September-November). *Telenomus rowani*

(Gahan), active throughout the year, parasitized 64% of the eggs in the masses it attacked, 32 larvae/mass surviving. *Tetrastichus schoenobii* Ferrière first appearing at medium host densities, increased rapidly to attack half of the brood *5* and 6 masses. More than 98% of the eggs in the attacked masses were parasitized, leaving only 1.6 surviving larvae/mass. *Trichogramma japonicum* Ashmead and *Telenomus* sp. (a new record) were less important. Multiple parasitism of masses rose from 7% in brood 2 to 28% in brood *5.* Egg parasites clearly reduce the numbers of *S. incertulas,* a major pest, and thus probably improve the yields of deepwater rice.

Egg parasitoids in the genera *Telenomus, Tefrastichus* and *Trichogramma* can achieve a level of control that is near 100% in some years or areas (Rothschild, 1970; Catling *et a!.*, 1983; Kim and Heinrichs, 1985; Kim *et al.,* 1986).

Polaszek *et al.,* (2002) reported that *Trichogramma zahiri* Polaszek is described from Bangladesh. It has been recorded as important controlling impact on the eggs of the major pest of rice *Dicladispa armigera* (Olivier).

A mass rearing system for *Trichogramma* spp. using host eggs killed before parasitization could improve current parasitoid production methods by making the system more efficient reported by Ozder (2002). Parasitism rates of *T. cacaeciae*, *T. evanescens* and *T. brassicae* reared on dead embryos of *E. kuehniella* kept at -20 degrees C during 1, 2 and 3 h were compared. The lowest parasitization rate was obtained on *E. kuehniella* eggs which had been kept at -20 degrees C for 3 h. Parasitization rates were 64, 65.60 and 63.60% for *T. cacaeciae*, *T. evanescens* and *T. brassicae,* respectively, reared on *E. kuehniella* eggs kept at -20 degrees C for 1 h. Subsequent trials focused on fitness of *T. cacaeciae*, *T. evanescens* and *T. brassicae* reared on killed embryos of *E. kuehniella*. Percentage of parasitized eggs and longevity of females were quantified. Exposure of eggs to low temperatures in a freezer reduced fecundity and longevity of females.

Life table parameter studies were conducted by Abd-El-Hafez *et al*. (2001) on four trichogrammatids, namely *Trichogramma embryophagum*, *T. brassicae, T. bactrae* and *T. evanescens* to compare their quality when reared on *P. gossypiella* eggs. The average number of progenies per female and female longevity differed significantly between the four parasitoid species. *T. embryophagum* female produced the most progenies (121.3) and survived the longest (5.04 days). On the other hand, *T. bactrae* female produced the lowest number of progenies (42.91) and survived the shortest (3.02 days). Survivorship of the four species was >93% and ranged between 93.76 and 95.25%. Female progeny always dominated the male. The mean generation duration (T) ranged between 10.24 days for *T. bactrae* and 11.52 days for *T. brassicae*, while it averaged 11.18 and 10.91 days for T. embryophagum and *T. evanescens,* respectively. Daily intrinsic rate of increase (rm) and finite rate of increase (exp. rm) ranged between 0.3049-0.3850 and 1.36-1.47 days, respectively. The population of *T. embryophagum*, *T. brassicae*, *T. bactrae* and *T. evanescens* had the capacity to multiply every 1.8, 2.24, 2.12 and 2.17 days, respectively. *T. embryophagum* had good qualities of a parasitoid, including a high net reproductive rate (Ro=74.08 female), a high intrinsic rate of natural increase (rm=0.3850), a high finite rate of increase (exp. rm=1.47 days) and a short population doubling time (1.8 days).

Reznik *et al*. (2001) carried out a laboratory experiments with *T. principium* females that were offered *Sitotroga cerealella* eggs demonstrated that less than half of the ovipositing females started oviposition during the first 2 days of the experiment, whereas the rest of the ovipositing females showed a delay in parasitization ranging from 2 to 10 days after contact with the host. Almost 10% of the wasps refused to parasitize the grain moth eggs over 12 days. The delay in parasitization may be as long as 6-8 days without any significant decrease in the number of mature ovarial eggs, in the number of eggs laid during the first 48 h of oviposition, and in the total lifetime fecundity. This egg retention is responsible for the fact that in spite of a relatively short mean duration of the oviposition period in each individual female (approximately 4 days), host parasitization by a group of simultaneously emerged wasps was almost uniformly distributed over 8-10 days. When induced, the parasitization state (i.e. the tendency to parasitize sequentially offered portions of host eggs) was stable both in the presence of a host and under host deprivation extended up to 8 days. These data provide further evidence for our hypotheses that the stability of the parasitization state in *Trichogramma* is based on endocrine mechanisms.

Grenier *et al*. (2001) reported that the size of some *Trichogramma* spp. adults and especially the ovipositor length depends on the species, but is also related to the host species and to the number of parasitoids per host. The length is greater in *T. evanescens* than in *T. pretiosum* itself greater than in *T. exiguum*, but the width is similar in the three species. For *T. evanescens*, the size obtained in *Mamestra brassicae* host when three or four insects emerged is similar to that obtained in *Ephestia kuehniella* host when singly parasitized. The size of the ovipositor is important because it may influence the possibility of in vitro egg laying in artificial host eggs. A shorter or a narrower ovipositor could cause difficulties in egg-laying into artificial host eggs composed of a membrane of unsuitable thickness.

2.2.2 The pathogenic bacterium *Bacillus thuringiensis*

Kingdom: Eubacteria

Phylum: Firmicutes

Class: Bacilli

Order: Bacillales

Family: Bacillaceae

Genus: *Bacillus*

Species: *thuringiensis*

Bacillus thuringiensis (or Bt) is a Gram-positive, soil-dwelling bacterium, commonly used as a biological alternative to a pesticide; alternatively, the Cry toxin may be extracted and used as a pesticide. *B. thuringiensis* also occurs naturally in the gut of

caterpillars of various types of moths and butterflies, as well as on the dark surface of plants (Wikipedia).

2.2.2.1 Distribution and use of *Bacillus thuringiensis*

B. thuringiensis was first discovered in 1902 by Japanese biologist Shigetane Ishiwatari. In 1911, *B. thuringiensis* was rediscovered in Germany by Ernst Berliner, who isolated it as the cause of a disease called *Schlaffsucht* in flour moth caterpillars (Roh *et.al*. In 1976, Zakharyan reported the presence of a plasmid in a strain of *B. thuringiensis* and suggested the plasmid's involvement in endospore and crystal formation. *B. thuringiensis* is closely related to *B .cereus*, a soil bacterium, and *B. anthracis*, the cause of anthrax: the three organisms differ mainly in their plasmids. Like other members of the genus, all three are aerobes capable of producing endospores. Upon sporulation, *B. thuringiensis* forms crystals of proteinaceous insecticidal δ-endotoxins (called crystal proteins or Cry proteins), which are encoded by *cry* genes In most strains of *B. thuringiensis* the *cry* genes are located on the plasmid. Cry toxins have specific activities against insect species of the orders Lepidoptera (moths and butterflies), Diptera (flies and mosquitoes), Coleoptera (beetles), hymenoptera (wasps, bees, ants and sawflies) and nematodes. Thus, *B.*

thuringiensis serves as an important reservoir of Cry toxins for production of biological insecticides and insect-resistant genetically modified crops. When insects ingest toxin crystals, the alkaline pH of their digestive tract activates the toxin. Cry inserts into the insect gut cell membrane, forming a pore. The pore results cell paralysis and eventual death of the insect.

Bacillus thuringiensis Berliner isolates were detected by Theunis *et al*. (1998) in 57% of 801 samples of rice grain dust, soil, rice field arthropods, and miscellaneous habitats (rice straw compost and mammal faeces) collected at 100 sites in the Philippines. The collection yielded 3950 isolates of *B. thuringiensis* (8.7 isolates/ positive sample). Grain dust from rice mills was the richest source (63%) of the samples were positive, with 10.2 isolates/positive sample), followed by rice field arthropods, soil, and miscellaneous habitats. Polyclonal antibodies to six o-endotoxin groups (Cry1A, Cry1B, Cry1C, Cry1D, Cry1E, and Cry3A) were used in enzyme-linked immunosorbent assays (ELISA) to characterize the toxins produced by each isolate. Sub samples of isolates representing the diversity of isolate sources and o-endotoxin profiles were bioassayed against the yellow stem borer, *Scirpophaga incertulas* (walker) and striped stem borer, *Chilo suppressalis* (Walker).

2.2.2.2 *Bacillus thuringiensis* for the management of rice stem borer

A laboratory experiment was conducted by Loganathan *et al*. (2000) to evaluate the toxicity of a local *Bacillus thuringiensis*-based insecticide, Spicturin (*B. thuringiensis* subsp. galleriae), and the commercially available Delfin (*B. thuringiensis* subsp. *kurstaki*) against the beneficial predator, *Chrysoperla carnea*. *Corcyra cephalonica* eggs were treated with Spicturin at 2, 3 or 4 ml/litre, Delfin at 2 g/litre or chlorpyrifos at 2 ml/litre and fed to second instar *Chrysoperla carnea* for 24 h. *Chrysoperla carnea* adults were fed with 10% honey solutions containing the formulations at the concentrations mentioned above. *Chrysoperla carnea* larval pupation, adult emergence, fecundity and egg hatchability were observed. Spicturin at 2 and 3 ml/litre was less toxic to *Chrysoperla carnea* larvae (84.00 and 83.75% pupation, respectively) and resulted in pupation percentages similar to that of the untreated control (88.75% pupation), while Delfin at 2 g/litre resulted in 62.5% pupation, while chlorpyrifos resulted in 0.00% pupation. The adult emergence from treated larvae was significantly lower than the untreated control in all cases (53.75 to 56.25% with Spicturin, 33.75% with Delfin and 0.00% with chlorpyrifos, compared to 80.00%). The fecundity and egg hatchability of the treated adult predators were not affected by Spicturin or Delfin, while fecundity and egg hatchability were 0.00% in the chlorpyrifos treatment.

2.3 Botanical products

Field studies were conducted by Korat *et al* (2009) during three successive wet seasons (1995-97) in rice fields in Gujarat, India, to determine the efficacy of various concentrations of azadirachtin (Nimbicidine, Neemax, and Neem Gold (all 300 ppm), Econeem (3000 ppm), Neem Azal T/S (10 000 ppm) and Fortune Aza (1500 ppm)) compared to chlorpyrifos for the control of *Cnaphalocrocis medinalis*, *Sogatella furcifera* and *Scirpophaga incertulas*. Results showed that although all neem formulations were effective against pests and resulted in an increased yield none were superior in efficacy to chlorpyrifos.

2.3.1 Concept about SafeClean, SafeMax and Neem oil

SafeClean, SafeMax, and neem oil are the botanicals products use for controlling insect and pests. Safe clean is a detergent type products and safe max produced from mehogoni plant oil, whereas neem oil prepared from leaf of neem plant. (Anonymous. 2010)

2.3.2 Botanical products for the management of rice stem borer

Amaugo and Emosairue (2005) conducted an experiments in 2000 and 2001 in Amakama, Abia, Nigeria, to evaluate the effects of the application frequency of 5% neem seed kernel extract (NSKE) on rice stem borer damage (caused by *Diopsis thoracica* [*D. longicornis*], *Chilo zacconius*, *C. diffusilineus*, *Maliarpha separatella* and *Sesamia calamistis*) and grain yield of the medium-duration upland rice cultivar FARO 48. NSKE was applied at: (T_1) early tillering; (T_2) maximum tillering; (T_3) early booting; (T_4) early tillering and early booting; (T_5) maximum tillering and early booting; (T_6) early tillering, maximum tillering and early booting stages. Data on percent whitehead (WH) and grain yield were collected. The application of NSKE at different plant growth stages reduced WH incidence but the values were not significantly different from that of the untreated control (T_7) in 2000. However, application from T_2 onwards reduced WH significantly compared with that of T_7 in 2001. The application of NSKE resulted in significantly higher grain yield than that of T_7 in 2000, except for the application at T_1. A similar trend was observed in 2001, except that the plots treated at T_2 did not produce significantly higher yield than T_7. NSKE applied at T_5 gave the highest grain yield of 1083.3 kg/ha in 2000, while NSKE applied at T_6 gave the highest grain yield of 1416.7 kg/ha in 2001. The reduction of WH from 2.5 to 16.31% in 2000 and from 0.6 to 19.8% in 2001 from the control plots produced 8.3-158.3% more yield in 2000 and 4-70% more in 2001.

Alagar and Sivasubramanian (2007) find out the prey consumption pattern of Chrysoperla carnea grubs was I instar < II instar < III instar. Among all the treatments, the prey consumption was highest in botanical-treated prey followed by botanicals + insecticide, insecticide alone treated prey. Among the botanicals, *Catharanthus roseus* G-Don 5% registered highest prey consumption of 714.00

Corcyra cephalonica eggs followed by Eucalyptus tereticornis 5% (707.34). Among the botanicals + insecticide treated prey, the prey consumption was highest in E. tereticornis 2.5%+endosulfan 0.035% (644.25) followed by E. tereticornis 2.5%+dimethoate 0.03% (642.75) and it was the lowest in dimethoate 0.06% (580.78) treated prey. All the three instars of C. carnea grubs showed significantly prolonged grub (9.70 days) and pupal developmental period (8.50 days) when fed with NSKE 5% treated prey. The total developmental period of C. carnea ranged from 19.54 to 21.20 days and it was higher (21.20 days) when NSKE 5% treated prey was offered as food followed by *Tribulus terrestris* 5% (20.70 days) compared to untreated check (19.40 days).

Neem products are examples of such plant-derived insecticides, which have been used in some Asian countries (Karim *et al.*, 1992).

Amaugo and Emosairue (2005) reported that neem seed kernel extracts reduced 16.31% white head infestation and produced 158% more yield.

Four high potency azadirachtin-based neem formulations, 1% Rakshak, 1 and 5% Neem Azal and 0.03% Nimbecidine were evaluated by Dhaliwal (2005) against two major insect pests of rice, namely rice leaffolder (RLF), C. medinalis and yellow stem borer (YSB), S. incertulas for two kharif seasons. The incidence of RLF was minimum in the case of monocrotophos, which was at par with 5% Neem Azal at 1.00 and 2.00 ml/litre. Similarly, the incidence of YSB was also minimum in monocrotophos and was at par with 5% Neem Azal 5% at 0.50 ml/litre. The highest yield was obtained with monocrotophos followed by 1% Neem Azal at 1.25 ml/litre. The highest paddy yield (50.5 q/ha) was recorded in monocrotophos, followed by 46.4 q/ha in 5% Neem Azal at 2.00 ml/litre compared with 34.3 q/ha in the untreated control.

2.4 Chemical insecticides for the management of rice stem borer

The efficacy of fipronil and other insecticides against rice stem borer (*Tryporyza incertulas* (*Scirpophaga incertulas*) were studied by Saljoqi *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 ml/ha, Regent 300 EC mixed with fertilizer at 197.6 ml/ha and Furadan 3G (carbofuran) 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 buprofezin 25 WP (0.5 kg a. i./ha) followed by acephate 75 sp. (0.75 kg a. i./ha). A relatively low (3.91%) incidence of the leaf folder, *Cnaphalocrocis* *medinalis* Guen, was found in the plots treated with monocrotophos 36=WSC (0.75 kg a. i./ha), acephate 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 m2) 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 3G (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-transplanting 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 BRH, Nimbecidine, BRH +

Nimbecidine + *T. japonicum*, 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 -cyfluthrin 25 EC (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 (750 g a.i./ha; control), carbosulfan 6G (1000 g a.i./ha), cartap hydrochloride 4 G (1000 g 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 G 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 4G against stem borers at CCS Haryana Agricultural University, Rice Research Station, Kaul for two consecutive kharif seasons during 2001 and 2002. Cartap hydrochloride 4G 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 DAT. 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:benefit 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 thelowest 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, IR22, IR60, IR66 and IR74 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 IR66 were susceptible to dead heart damage by *S. incertulas*. When the rice varieties TKM6, BPIRi2, BPIRi4, IR22, IR36, IR60, IR66 and IR74 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 population 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 the 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 Medchal 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 83 and 40% in Medchal and Nellore, respectively. In Medchal, 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 plots, 6400 and 6733 kg/ha. In Warangal, the level of 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 smallholders 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 smallholder 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 (*Tryporyza incertulas* (*Scirpophaga incertulas*) on rice. The treatments were Cartap 4G, Carbofuran 3G, Phorate 10G, Fenthion 5G and Fenitrothion 5G. Maximum grain yield was obtained using cartap at 1.0 kg/ha, which was statistically at par with that of carbofuran and phorate at 1.0 kg/ha.

CHAPTER III

MATERIALS AND METHODS

The study was conducted to find out the effectiveness of bio-control agent(s) viz. *Trichogramma evanescens* egg parasitoid (Trichogrammatidae: Hymenoptera) and *Bacillus thuriengiensis* pathogenic bacterium and botanical products for the eco-friendly management of rice stem borer over traditional insecticidal control. This chapter deals with a brief description on experimental site, climate, land preparation, layout of the experimental design, intercultural operations, data recording and their analyses under the following sub-headings:

3.1 Location and duration of the study

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from June to November, 2009.

3.2 Climate

The area has subtropical climate, characterized by high temperature, high relative humidity and heavy rainfall with occasional gusty winds in Kharif season (July to November). Weather information regarding temperature, relative humidity, rainfall and sunshine hours prevailed at the experimental site during the study period was presented in Appendix I.

3.3 Land preparation and fertilization

The plot selected for the experiment was opened in the first week of July 2009 with a power tiller, and was exposed to the sun for a week, after which the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth. Weeds and stubble were removed, and finally obtained a desirable tilth of soil for transplanting of seedlings. During land preparation 10 t/ha decomposed were mixed with soil. The fertilizers N, P, K, Zn and S in the form of urea, TSP, MP, Zinc oxide and Gypsum, respectively were applied @ 150 kg, 60 kg, 80 kg, 8 kg and 80 kg/ha. The entire amount of TSP, MP, Zinc oxide and Gypsum were applied during the final preparation of land. Urea was applied at top dressing in three equal splits at maximum tillering, panicle initiation and flowering stage.

3.4 Treatments of the experiment

The parasitic wasp viz. *Trichogramma evanescens* egg parasitoid, the pathogenic bacterium *Bacillus thuringiensis* suspension, and botanical products viz., neem oil and neem based insecticide Safe clean and SafeMax were evaluated as following treatment combinations:

Agents	**Treatments**	**Availability**
Bio-control agents	T_1: Trichogramma @ 0.25 gm	Protegra Crop Care Ltd., Mirpur, Dhaka
	T_2: Trichogramma @ 0.50 gm	
	T_3: *B. thuringiensis* @ 0.1%	
	T_4: *B. thuringiensis* @ 0.2 %	
Botanical products	T_5: Safe clean @ 0.05%	
	T_6: SafeMax @ 0.05%	
	T_7: Neem oil @ 0.3%	Local market
Chemical insecticide	T_8: Furadan 5G (Carbofuran) @ 6 g plot^{-1}	Local market
Control	T_9: Untreated Control	

3.5 Planting material

Seeds of hybrid variety of rice, Hira-2 were collected from local market of Dhaka and used as the planting materials in the present study.

3.6 Collection of seeds and seedling raising

The collected rice seeds were used for seedling raising. Before sowing seeds, the germination test was done to ensure standard viability of the seed, accordingly more or less 90% germination of the seeds was observed. Pre-soaked, for 48 hrs to ensure germination, seeds were sown in the mud of nursery bed during 20 June (Kharif II season) of 2009 as recommended by Mustafi *et al*. (2007).

3.7 Experimental design and layout

The study was conducted in randomized complete block design (RCBD) with 3 replications. A good tilth area was divided into 3 main blocks. Each main block was sub-divided into 9 sub plots, each of which was of 4 m × 3 m with maintaining 0.75 m borders and the distance between hill to hill and row to row was kept 15 cm and 25 cm, respectively.

3.8 Seedling transplanting

Single seedling of 30 days old seedling was transplanted per hill in the respective plots of the main field on 20 July of 2009. The crop was raised following standard agronomic practices.

3.9 Intercultural operations

During the cropping season of the rice the necessary intercultural operations were done as described below:

3.9.1 Weeding

The land of the each plot was kept free from weeds for Aman season and two times weeding was done. The first weeding was done after 25 days of transplanting and second weeding after 50 days of transplanting. Weeding was done by uprooting and using Japanese rice weeder etc.

3.9.2 Irrigation and drainage

Irrigation and other intercultural operations were also done as required. After transplanting the rice seedling, water was kept in the field in such a level that the seedlings were not submerged or the field entirely dried. It was not needed to keep water always in the field. About 7-10 cm height water was maintained from transplanting to maximum tillering stage. After 40 days after transplanting (DAT), the water level was increased to 12-15 cm to stop late tiller production. The enough water was maintained up to milking stage of the rice plant. During the application of fertilizer, the water was removed from the field and after 2-3 days the field was irrigated again to increase the effectiveness of fertilizer.

3.10 Stock culture of the bio-control agents

The bio-control agents *Trichogramma evanescens* egg parasitoid and pathogenic bacterium *Bacillus thuringiensis* were purchased from Protega Agro BioTech Ltd., Dhaka, commercial traders of bio-control agents, where *T. evanescens* reared on the eggs of rice moth, *Sitotroga cerealella* (Gelechidae: Lepidoptera). *T evanescens* was purchased in the form of parasitized eggs of rice moth, within *Trichogramma* retained as pupal stage. The parasitized eggs of rice moth with the *T. evanescens* were collected in the form of TrichoCard, where eggs of rice moth glued on the paper card and the glued eggs were parasitized by releasing the *T. evanescens* within a glass vial. The *B. thuringiensis* was purchased as B.T. suspension.

3.10 Preparation of botanical products

The neem oil was collected from local market. The oil was preserved in the refrigerator at 4°C until use. The preserved oil was mixed with water to prepare 0.3% suspension during each treatment application time. The neem based insecticide SafeMax and SafeClean were also purchased from Protega Crop Care Ltd. The SafeMax, SafeClean and neem oil were mixed with trix liquid detergent @ 0.1% to make the extract and oil easy to soluble in water.

3.11 Treatment application

The assigned treatments were started to apply in the respective plots with the first incidence of the adult moth of the rice stem borer in the field. The incidence of the adult moth was detected by setting up the locally made light trap in the field. Treatments comprising different bio-control agents were applied in the respective plots at 7 days interval up to crop maturity. The parasitized eggs of rice moth by *Trichogramma evanescens* were collected in the form of TrichoCard from the traders every day just before releasing in the field.

3.11.1 *Trichogramma* release

The treatments comprising *T. evanesense* egg parasitoid (T_1 and T_2) were released in the form of TrichoCard in the assigned plots of the rice field. The release of parasitized host's eggs was done in the middle of the plot.

Plate 1. Parasitizing process of *Trichogamma*

3.11.2 Spraying of pathogenic *B. thuringiensis*

The treatments comprising *B. thuringiensis* suspensions (T_6 & T_7) were mixed with water and sprayed at 7 days interval in the respective plots with the help of Knapsack sprayer.

3.11.3 Application of botanical products

The neem based treatments (T_3, T_4 & T_5) were sprayed mixing with water with the help of Knapsack sprayer. All sprays were done in the afternoon to avoid bright sunlight. Caution was taken to avoid any drift of the spray mixture to the adjacent plots at the time of the spray applied. The untreated control plot (T_9) was sprayed only with water.

3.11.4 Application of insecticide

The granular systemic insecticide Furadan 5G (Carbofuran) was applied in the assigned plot (T_8) of the rice field at 7 days interval in the presence of irrigated water.

3.12 Data collection and calculation

The data on dead heart, white head infestation caused by rice stem borer, incidence of larvae and adult rice stem borer, yield contributing characters of rice plant and yield were collected from each of the plots treated with different management practices. The data were collected from randomly selected 5 hills of each plot at 7 days interval and continued up to harvest. The infestation was expressed as percent dead hearts and white ear heads calculated by using the formula as suggested by Shafiq *et al.* (2000).

Plate 2. The experimental plots of the present study at SAU, Dhaka

3.12.1 Borer infestation

Five hills were selected at random per replicate for each treatment. The dead hearts and white heads were counted. In case of dead heart it was counted at tillering, panicle initiation and milking stage of the rice plants and converted into per plant. On the other hand, white head infested panicle was counted at panicle initiation, milking and grain filing stages. The observation was recorded at the first observation of symptom and was continued up to maturity of the grains at 7 days interval.

3.12.1.1 Percent dead heart infestation

Number of dead heart infested tillers (Plate 3) were counted at tillering, panicle initiation and milking stage from total tillers per five hills and converted into per plant and percent dead heart was calculated by using the following formula:

$$\% \text{ dead heart tillers} = \frac{\text{No. of dead heart infested plant}}{\text{Total no. of plant per five hills}} \times 100$$

Plate 3. The rice plants showing dead heart symptom

3.12.1.4 Percent white head infestation

Number of white head infested panicles was counted at panicle initiation, milking stage and grain filing stage from total tillers per five hills and percent white head was calculated by using the following formula:

$$\% \text{ white head panicle} = \frac{\text{No. of white head infested plant}}{\text{Total no. of plants per five hills}} \times 100$$

Plate 4. Rice plants showing white head symptoms

3.12.1.3 Treatment effects on borer infestation

The percent dead heart and white head reduction over control was calculated by using the following formula (Khosla, 1997):

$$\text{Percent reduction over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where, X_1 = the mean value of treated plots

X_2 = the mean value of untreated plots

3.12.1.4 Number of adult and larvae of stem borer

Number of adult moth (Plate 5) and larvae of stem borer was counted at 20, 30. 40, 50, 60 and 70 DAT from five selected hills and converted into per hill.

Plate 5. Adult moth of rice stem borer resting on rice leaf

Plate 6. Egg mass of rice stem borer laid on rice leaf

3.12.2 Yield contributing characters and yield of rice

The yield contributing characters of the rice plants for each treatment and the yield of the respective plots were recorded on the following parameters:

3.12.2.1 Length of panicle

The length of panicle was measured with a meter scale from 10 selected plants and the average value was recorded as per plant.

3.12.2.2 Filled grain panicle^{-1}

The total number of filled grains was collected randomly from selected 10 plants of a plot on the basis of grain in the spike let and then average number of filled grains panicle^{-1} was recorded and expressed in percentage.

3.12.2.3 Unfilled grains panicle^{-1}

The total number of unfilled grains was collected randomly from selected 10 plants of a plot on the basis of not grain in the spikelet and then average number of unfilled grains panicle^{-1} was recorded and expressed in percentage.

3.12.2.4 Weight of 1000 seeds

One thousand seeds were counted randomly from the total cleaned harvested seeds and then weighed in grams and recorded.

3.12.2.5 Grain yield

Grains obtained from each unit plot were sun-dried and weighed carefully. The dry weight of grains of central 1 m^2 area and five sample plants were added to the respective unit plot yield to record grain yield $plot^{-1}$ and converted to t ha^{-1}.

3.13 Economic analysis of the treatments

Economic analysis in terms of Benefit Cost Ratio (BCR) was analyzed on the basis of total expenditure of the respective management treatment along with the total return from that particular treatment. In this study BCR was analyzed for a hectare of land. For this analysis following parameters were considered which are given in Appendix III:

Treatment wise management cost/variable Cost: This cost was calculated by adding all costs incurred for labours and inputs for each management treatment including untreated control during the entire cropping season. The plot yields (kg/plot) for each treatment was converted into ton/ha yield.

Gross Return (GR): The yield in terms of money that was measured by multiplying the total yield by the unit price of rice grains (Tk 20/kg).

Net Return (NR) = The Net Return was calculated by subtracting treatment wise management cost from gross return.

Adjusted Net Return (ANR): The ANR was determined by subtracting the net return for a particular management treatment from the net return with control plot. Finally, BCR for each management treatment was calculated by using the following formula described by Elias and Karim (1984):

$$\text{Benefit Cost Ratio (BCR)} = \frac{\text{Adjusted net return}}{\text{Total management cost}}$$

3.15 Statistical analysis

The data collected on different parameters were statistically analyzed using the MSTAT computer package program. Mean values were ranked by Duncan's Multiple Range Test, DMRT at 5% level of significance and it was used to compare the mean differences among the treatments (Gomez and Gomez, 1984).

CHAPTER IV

RESULTS AND DISCUSSION

The results of the present study regarding the effect of bio-control agents and botanical products for the eco-friendly management of stem borer on hybrid rice conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during June-November 2009 have been discussed and presented with interpretations under the following sub-headings:

4.1 Infestation level of dead heart

The infestation level of dead heart tillers caused by rice stem borer at tillering, panicle initiation and milking stage of the rice plants were significantly varied during the management of rice stem borer by the application bio-control agents, botanical products and systemic insecticides in the hybrid rice as depicted in the Table 1 to 4.

4.1.1 Dead heart infestation at tillering stage

Statistically significant variations were observed in terms of healthy, dead heart and percent dead heart tiller at tillering stage of the rice plants during the management of rice stem borer (Table 1). In case of healthy tiller, the highest number of healthy tiller hill^{-1} (18.60) was recorded in T_8 comprised with Furadan 5G @ 6 gm plot^{-1} at 7 days interval, which was statistically similar (18.20 and 17.87 tiller hill^{-1}) with T_2 (*Trichogramma* egg parasitoid @ 0.50 gm) and T_1 (*Trichogramma* egg parasitoid @ 0.25 gm), respectively and closely followed (17.20 and 17.07 tiller hill^{-1}) by T_7 (Neem oil @ 0.3%) and T_4 (*Bacillus thuringiensis* bacterial suspension @ 0.2%), while the lowest number of healthy tiller hill^{-1} (15.20) was observed in T_9 (Untreated control), which was closely followed (16.20 tiller hill^{-1}) by T_5 (Safe clean @ 0.05%). In case of dead heart infested tiller, the lowest number of infested tiller hill^{-1} was recorded in T_8 (1.00 tiller hill^{-1}), which was statistically similar with T_2 (1.20 tiller hill^{-1}) and T_1 (1.40 tiller hill^{-1}), respectively and closely followed by T_7 (1.60 tiller hill^{-1}), T_4 (1.80

tiller hill^{-1}) and T_3 (1.80 tiller hill^{-1}), where as the highest number was recorded in T_9 (2.80 tiller hill^{-1}), which was closely followed by T_5 (2.40 tiller hill^{-1}). Considering the percent dead heart infested tiller, the lowest infestation was recorded in T_8 (5.07 %) which was statistically similar with T_2 (6.20%) and T_1 (7.26%), respectively. This was closely followed by T_7 (8.53%), T_4 (9.49%) and T_3 (9.74%). On the other hand, the highest infestation was recorded in T_9 (15.52%), which was closely followed by T_5 (12.90%).

Considering the percent reduction of dead heart infestation over control, the highest reduction was achieved in T_8 (67.33%) followed by T_2 (60.05%), T_1 (53.22%), T_7 (45.04%). On the other hand, the lowest percent reduction of dead heart infestation over control was recorded in T_5 (16.88%) followed by T_6 (30.61%), T_3 (37.24%) and T_4 (38.85%).

Table 1. Effect of different bio-control agents, botanical products and systemic insecticide against dead heart infestation of hybrid rice caused by stem borer at tillering stage

Treatment	Healthy tiller (No./hill)	Dead heart at tillering stage		% reduction of dead heart over control
		Dead heart tiller (No./hill)	Dead heart infestation (%)	
T_1	17.87 ab	1.40 def	7.26 de	53.22
T_2	18.20 a	1.20 ef	6.20 e	60.05
T_3	16.67 cd	1.80 cd	9.74 c	37.24
T_4	17.07 bcd	1.80 cd	9.49 c	38.85
T_5	16.20 d	2.40 ab	12.90 b	16.88
T_6	16.53 cd	2.00 bc	10.77 c	30.61
T_7	17.20 bc	1.60 cde	8.53 cd	45.04
T_8	18.60 a	1.00 f	5.07 e	67.33
T_9	15.20 e	2.80 a	15.52 a	--
$LSD_{(0.05)}$	0.908	0.461	2.123	--
CV (%)	7.07	15.00	12.91	--

In column, numeric data represent the mean value of 3 replications; each replication is derived from the number of tillers for 5 selected hills per plot. In column, means having similar letter(s) are statistically similar at 0.05 level of probability.

T_1: *Trichogramma* egg parasitoid @ 0.25 gm; T_2: *Trichogramma* egg parasitoid @ 0.50 gm; T_3: *Bacillus thuringiensis* bacterial suspension @ 0.1%; T_4: *B. thuringiensis* suspension @ 0.2 %; T_5: Safe clean @ 0.05%; T_6: SafeMax @ 0.05%; T_7: Neem oil @ 0.3%; T_8: Furadan 5G 6 gm/plot and T_9: Untreated control

4.1.2 Dead heart infestation at panicle initiation stage

Statistically significant variations were observed on the efficiency of different management practices applied against rice stem borer in respect of number of healthy, dead heart tiller per hill and percent dead heart infestation at panicle initiation stage of the rice plants (Table 2). In case of healthy tiller, the highest number of healthy tiller hill^{-1} (16.80) was recorded in T_8 comprised with Furadan 5G @ 6.0 gm plot^{-1} sprayed at 7 days interval, which was statistically similar (16.27 tiller hill^{-1}) with T_2 (*Trichogramma* @ 0.50 gm) and closely followed (16.00 tiller hill^{-1}) by T_1 (*Trichogramma* @ 0.25 gm), where as the lowest number of healthy tiller per hill was recoded from T_9 (12.87 tiller hill^{-1}) followed by T_5 (14.00 tiller hill^{-1}). In case of dead heart infestation, the lowest number of infested tiller per hill (0.13) was recorded in T_8 which was statistically similar with T_2 (0.33 infested tiller hill^{-1}) and closely followed (0.60 infested tiller hill^{-1}) by T_1, while the highest number of infested tiller hill^{-1} was observed in T_9 (2.00 infested tiller hill^{-1}), which was closely followed (1.33 infested tiller hill^{-1}) by T_5 . Considering the percent infestation of dead heart, the lowest dead heart infestation at panicle initiation stage was recorded in T_8 (0.78%), which was statistically similar with T_2 (1.99%) and closely followed by T_1 (3.61%). On the other hand, the highest dead heart infestation was recorded in T_9 (13.44%), which was closely followed by T_5 (8.69%). Considering the percent reduction of dead heart infestation over control at panicle initiation stage was estimated and the maximum reduction (94.20%) was recorded in T_8 followed by T_2 (85.19%), T_1 (73.14%), T_7 (56.70%), T_4 (56.25%), T_3 (52.60%). On the other hand, the minimum reduction of dead heart infestation was observed in T_5 (35.34%) followed by T_6 (39.43%) as depicted in Table 2.

Table 2. Effect of different bio-control agents, botanical products and systemic insecticide against dead heart infestation of hybrid rice caused by stem borer at panicle initiation stage

Treatment	Healthy tiller (No./hill)	Dead heart at panicle initiation stage		% reduction of dead heart over control
		Dead heart tiller (No./hill)	Dead heart infestation (%)	
T_1	16.00 b	0.60 de	3.61 e	73.14
T_2	16.27 ab	0.33 ef	1.99 ef	85.19
T_3	14.67 cd	1.00 bc	6.37 cd	52.60
T_4	14.93 c	0.93 cd	5.88 d	56.25
T_5	14.00 e	1.33 b	8.69 b	35.34
T_6	14.27 de	1.27 bc	8.14 bc	39.43
T_7	15.07 c	0.93 cd	5.82 d	56.70
T_8	16.80 a	0.13 f	0.78 f	94.20
T_9	12.87 f	2.00 a	13.44 a	--
LSD $_{(0.05)}$	0.634	0.319	1.802	--
CV (%)	5.45	9.36	17.11	--

In column, numeric data represent the mean value of 3 replications; each replication is derived from the number of tillers for 5 selected hills per plot. In column, means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: *Trichogramma* egg parasitoid @ 0.25 gm; T_2: *Trichogramma* egg parasitoid @ 0.50 gm; T_3: *Bacillus thuringiensis* bacterial suspension @ 0.1%; T_4: *B. thuringiensis* suspension @ 0.2 %; T_5: Safe clean @ 0.05%; T_6: SafeMax @ 0.05%; T_7: Neem oil @ 0.3%; T_8: Furadan 5G 6 gm/plot and T_9: Untreated control

4.1.3 Milking stage

Statistically significant variations were observed on the efficiency of different management practices applied against rice stem borer in respect of number of healthy, dead heart tiller per hill and percent dead heart infestation at milking stage of the rice plants (Table 3). In case of healthy tiller, the highest number of healthy tiller hill^{-1} (15.13) was recorded in T_8, which was statistically similar (14.47, 14.33 and 13.60 tiller hill^{-1})) with T_2, T_1 and T_7, respectively. On the other hand, the lowest number of healthy tiller per hill was recorded in T_9 (9.60 tiller hill^{-1}), which was closely followed (11.00 tiller hill^{-1}) by T_5. In case of dead heard infested tiller, the lowest number of infested tiller per hill at milking stage was recorded in T_8 (0.07 tiller hill^{-1}), which was statistically similar with T_2 (0.13 tiller hill^{-1}) and T_1 (0.20 tiller hill^{-1}) and closely followed by T_7 (0.27 tiller $hill^{-1}$), while the highest number of dead heart infested tiller $hill^{-1}$ was recorded in T_9 (0.60 tiller $hill^{-1}$), which was closely followed by T_5 (0.47 tiller $hill^{-1}$). Considering the percent dead heart infested tiller, the lowest was recorded in T_8 (0.46%), which was statistically similar with T_2 (0.91%) and T_2 (1.38%) closely followed by T_7 (1.91%). On the other hand, the highest dead heart infestation was recorded in T_9 (5.92%), which was closely followed by T_5 (4.13%). Considering the percent reduction of dead heart infestation over control at milking stage of rice plants, more or less similar trend of results was observed, where the maximum reduction (92.33%) was recorded in T_8 followed by T_2 (84.63%), T_1 (76.69%), T_7 (67.74%), T_4 (66.72%), T_3 (49.32%). On the other hand, the minimum reduction of dead heart infestation at milking stage was observed in T_5 (30.24%) followed by T_6 (45.78%) as depicted in Table 3.

Table 3. Efficiency of different bio-control agents and botanical products against dead heart infestation of hybrid rice caused by stem borer at milking stage

Treatment	Healthy tiller (No./hill)	Dead heart at milking stage		% reduction of dead heart over control
		Dead heart tiller (No./hill)	Dead heart infestation (%)	
T_1	14.33 ab	0.20 de	1.38 de	76.69
T_2	14.47 ab	0.13 de	0.91 de	84.63
T_3	13.00 bc	0.40 bc	3.00 bc	49.32
T_4	13.27 bc	0.27 cd	1.97 cd	66.72
T_5	11.00 de	0.47 ab	4.13 b	30.24
T_6	12.13 cd	0.40 bc	3.21 bc	45.78
T_7	13.60 abc	0.27 cd	1.91 cd	67.74
T_8	15.13 a	0.07 e	0.46 e	92.23
T_9	9.60 e	0.60 a	5.92 a	--
$LSD_{(0.05)}$	1.561	0.155	1.247	--
CV (%)	6.96	8.35	12.33	--

In column, numeric data represent the mean value of 3 replications; each replication is derived from the number of tillers for 5 selected hills per plot. In column, means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: *Trichogramma* egg parasitoid @ 0.25 gm; T_2: *Trichogramma* egg parasitoid @ 0.50 gm; T_3: *Bacillus thuringiensis* bacterial suspension @ 0.1%; T_4: *B. thuringiensis* suspension @ 0.2 %; T_5: Safe clean @ 0.05%; T_6: SafeMax @ 0.05%; T_7: Neem oil @ 0.3%; T_8: Furadan 5G 6 gm/plot and T_9: Untreated control

4.1.4 Average of dead heart infestation

More or less similar trends of results among different management practices applied against rice stem borer in respect of mean number of healthy and dead heart infested tiller per hill as well as percent dead heart infested tiller and percent reduction of dead heart infestation over control was observed (Table 4). The trend of results is $T_8 > T_2 > T_1 > T_7 > T_4 > T_3 > T_5$.

From the above findings it was revealed that T_8 comprised with the spraying of systemic insecticide Furadan 5G @ 6.00 gm plot^{-1} performed as the best treatment in reducing (81.47%) the dead heart infestation applied against rice stem borer in the field of hybrid rice followed by T_2 (73.64%) comprised with release of *Trichogramma* egg parasitoid @ 0.50 gm plot^{-1}. But with the context of environment pollution free management, *Trichogramma evanescens* egg parasitoid based management practices would be the best treatment in reducing the dead heart infestation caused by rice stem borer. About similar works were also conducted by several workers. Mishra *et al.* (2007) reported that the the granular insecticide Cartap 4G @ 1.0 kg/ha gave the maximum grain yield of

rice applied against rice yellow stem borer, *Scirpophaga incertulas* in Uttar Pradesh, India. Roshan (2006) was also reported the about similar results in India and he stated that Cartap 4G @ 1.0 kg a.i./ha showed the significant reduction of the incidence of Rice stem borers, *Scirpophaga incertulas*, *Scirpophaga innotata* and *Sesamia inferens*. But Karthikeyan *et al.* (2007) reported that the release of *Trichogramma japonicum* @ 100000/ha followed by application of azadirachtin 1 per cent against yellow stem borer reduced dead hearts from 12.21 to 91.02 per cent and from 27.4 to 58.2 per cent over insecticide application during kharif and rabi seasons, respectively in Kerala, India. Polaszek *et al.* (2002) reported that *Trichogramma zahiri* Polaszek had been recorded as important controlling impact on the eggs of the major pest of rice, *Dicladispa armigera* in Bangladesh.

Table 4. Effect of different bio-control agents and botanical products against average dead heart infestation of hybrid rice caused by stem borer through out the cropping season

Treatment	**Healthy tiller (No./hill)**	**Mean dead heart infestation**		**% reduction of dead heart over control**
		Dead heart tiller(No./hill)	**Dead heart infestation (%)**	
T_1	16.06 b	0.73 ef	4.37 e	65.10
T_2	16.29 ab	0.56 fg	3.30 ef	73.64
T_3	14.78 cd	1.07 cd	6.73 cd	46.25
T_4	15.10 c	1.00 cd	6.20 d	50.48
T_5	13.73 e	1.40 b	9.26 b	26.04
T_6	14.30 de	1.22 bc	7.87 c	37.14
T_7	15.29 c	0.93 de	5.74 d	54.15
T_8	16.83 a	0.40 g	2.32 f	81.47
T_9	12.56 f	1.80 a	12.52 a	--
LSD $_{(0.05)}$	0.605	0.219	1.180	--
CV (%)	6.33	12.31	10.52	--

In column, numeric data represent the mean value of 3 replications; each replication is derived from the number of tillers for 5 selected hills per plot. In column, means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: *Trichogramma* egg parasitoid @ 0.25 gm; T_2: *Trichogramma* egg parasitoid @ 0.50 gm; T_3: *Bacillus thuringiensis* bacterial suspension @ 0.1%; T_4: *B. thuringiensis* suspension @ 0.2 %; T_5: Safe clean @ 0.05%; T_6: SafeMax @ 0.05%; T_7: Neem oil @ 0.3%; T_8: Furadan 5G 6 gm/plot and T_9: Untreated control

4.2 Infestation level of white head

The infestation level of white head caused by rice stem borer at panicle initiation and milking stage of the rice plants were significantly varied among different management practices of rice stem borer by the application bio-control agents, botanical products and systemic insecticides in the hybrid rice as depicted in the Table 4 to Table 8.

4.2.1 White head infestation at panicle initiation stage

Statistically significant variations were observed on the efficiency of different management practices applied against rice stem borer in respect of number of healthy, wheat head panicles per hill and percent white head infested panicles at panicle initiation stage of the rice plants (Table 5). In case of healthy panicle, the highest number of healthy panicles per hill (14.40) was recorded in T_8, which was statistically similar with T_2 and T_1 (14.00 and 13.67 panicle hill^{-1}, respectively) closely followed (13.00 panicle hill^{-1}) by T_7, while the lowest number of healthy panicle hill^{-1} was observed in T_9 (11.00 panicle hill^{-1}) followed by T_5 (12.00 healthy panicle hill^{-1}). In case of white head infested panicle, there were no white head panicle hill^{-1} by number at panicle initiation stage was recorded at all in T_8, which was statistically similar (0.13 white head panicle hill^{-1}) with T_2 and T_1 and closely followed by T_7 (0.33 white head panicle hill^{-1}). On the other hand, the highest number of white head panicle hill^{-1} was recorded in T_9 (1.07), which was closely followed by T_5 (0.73 white head panicle hill^{-1}). Considering the percent white head infested panicle, there were no white head infested panicle at panicle initiation stage was recorded at all in T_8 (0.00%), which was statistically similar with T_2 (0.96%) and T_1 (0.97%) followed by T_7 (2.50%). On the other hand, the highest white head infestation was recorded in T_9 (8.83%), which was closely followed by T_5 (7.21%). Considering the percent reduction of white head infestation over control at panicle initiation stage, the highest reduction over control was recorded in T_8 (100%) followed by T_2 (89.13%), T_1 (89.01%), T_7 (71.69%), T_4 (60.59%), T_3 (48.13%). On the other hand, the minimum reduction of white head infested panicle was observed in T_5 (18.35%) followed by T_6 (36.35%) as depicted in Table 5.

Table 5. Efficiency of different bio-control agents and botanical products against white head infestation of hybrid rice caused by stem borer at panicle initiation stage

Treatment	Healthy panicle (No./hill)	White head at panicle initiation stage		% reduction of white head over control
		White head panicle (No./hill)	White head infestation (%)	
T_1	13.67 ab	0.13 fg	0.97 fg	89.01
T_2	14.00 a	0.13 fg	0.96 fg	89.13
T_3	12.47 cd	0.60 cd	4.58 cd	48.13
T_4	12.87 bcd	0.47 de	3.48 de	60.59
T_5	12.00 d	0.93 ab	7.21 b	18.35
T_6	12.33 cd	0.73 bc	5.62 c	36.35
T_7	13.00 bc	0.33 ef	2.50 ef	71.69
T_8	14.40 a	0.00 g	0.00 g	100.00
T_9	11.00 e	1.07 a	8.83 a	--
$LSD_{(0.05)}$	0.908	0.219	1.554	--
CV (%)	4.08	15.96	13.67	--

In column, numeric data represent the mean value of 3 replications; each replication is derived from the number of tillers for 5 selected hills per plot. In column, means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: *Trichogramma* egg parasitoid @ 0.25 gm; T_2: *Trichogramma* egg parasitoid @ 0.50 gm; T_3: *Bacillus thuringiensis* bacterial suspension @ 0.1%; T_4: *B. thuringiensis* suspension @ 0.2 %; T_5: Safe clean @ 0.05%; T_6: SafeMax @ 0.05%; T_7: Neem oil @ 0.3%; T_8: Furadan 5G 6 gm/plot and T_9: Untreated control

4.2.2 White head infestation at milking stage

Statistically significant variations were also observed among different management practices in terms of healthy, white head panicle and percent white head panicle at milking stage of the rice plants applied against rice stem borer in the field of hybrid rice (Table 6). More or less similar trends of results were observed in case of the number of healthy and white head infested panicles per hill as well as percent white head infested panicles at milking stage of the rice plants. In case of healthy panicle, the highest number of healthy panicle per hill (13.80) was recorded in was recorded in T_8, which was statistically similar with (13.27 and 13.00 white head panicle hill^{-1}) T_2 and T_1, respectively. On the other hand, the lowest number of healthy panicle per hill was recorded in T_9 (9.87 white head panicle hill^{-1}), which was closely followed by T_5 (11.00 white head panicle hill^{-1}). In case of white head infested panicle per hill, the lowest number of white head panicle per hill (0.07) at milking stage was recorded in T_8, which was statistically similar (0.27 and 0.33 white head panicle hill^{-1}) with T_2 and T_1, respectively and closely followed (0.47 white head panicle hill^{-1}) by $T_{7.}$ On the other hand, the highest number of white head panicle hill^{-1} (1.53) was recorded in T_9, which was closely followed by T_5 (1.07 white head panicle hill^{-1}). Considering the percent white head infested panicle, Considering the percent white head infested panicle, the lowest percent white head infested panicle at panicle initiation stage was recorded in T_8 (0.48%), which was statistically different from all other treatments followed by T_2 (1.97%) and T_1 (2.50%) followed by T_7 (3.77%). On the other hand, the highest percent white head panicle was recorded in T_9 (13.45%), which was closely followed by T_5 (8.83%), T_3 (5.91%) and T_4 (4.79%). Considering the percent reduction of white head infested panicle over control at panicle initiation stage, the highest reduction over control was recorded in T_8 (96.43%) followed by T_2 (85.35%),

T_1 (81.41%), T_7 (71.97%), T_4 (64.39%), T_3 (56.06%). On the other hand, the minimum reduction of white head infested panicle was observed in T_5 (34.35%) followed by T_6 (43.20%) as depicted in Table 6.

Table 6. Effect of different bio-control agents and botanical products against white head panicle of hybrid rice caused by stem borer at milking stage

Treatment	Healthy panicle (No./hill)	White head at milking stage		% reduction of white head over control
		White head panicle (No./hill)	White head infestation (%)	
T_1	13.00 b	0.33 e	2.50 ef	81.41
T_2	13.27 ab	0.27 e	1.97 f	85.35
T_3	11.67 cd	0.73 c	5.91 c	56.06
T_4	11.93 c	0.60 cd	4.79 cd	64.39
T_5	11.00 e	1.07 b	8.83 b	34.35
T_6	11.27 de	0.93 b	7.64 b	43.20
T_7	12.07 c	0.47 de	3.77 de	71.97
T_8	13.80 a	0.07 f	0.48 g	96.43
T_9	9.87 f	1.53 a	13.45 a	--
LSD $_{(0.05)}$	0.634	0.197	1.479	--
CV (%)	7.06	16.96	15.59	--

In column, numeric data represent the mean value of 3 replications; each replication is derived from the number of tillers for 5 selected hills per plot. In column, means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: *Trichogramma* egg parasitoid @ 0.25 gm; T_2: *Trichogramma* egg parasitoid @ 0.50 gm; T_3: *Bacillus thuringiensis* bacterial suspension @ 0.1%; T_4: *B. thuringiensis* suspension @ 0.2 %; T_5: Safe clean @ 0.05%; T_6: SafeMax @ 0.05%; T_7: Neem oil @ 0.3%; T_8: Furadan 5G 6 gm/plot and T_9: Untreated control

4.2.3 White head infestation at grain filling stage

Significant variation was recorded among different management practices in terms of healthy, white head panicle and percent white head panicle at grain filling stage of the rice plants applied against rice stem borer in the field of hybrid rice (Table 7). More or less similar trends of results were observed in case of the number of healthy and white head infested panicles per hill as well as percent white head infested panicles at grain filling stage of the rice plants. In case of healthy panicle, the highest number of healthy panicle per hill (13.13) at grain filling stage was recorded in T_8, which was statistically similar (12.47 and 12.33 white head panicle hill^{-1}) with T_2 and T_1, respectively closely followed (11.60 white head panicle hill^{-1}) by T_7, whereas the lowest number of healthy panicle per hill (7.67) was recorded in T_9, which was closely followed (9.00 white head panicle hill^{-1}) by T_5. In case of white head infested panicle, the lowest number of white head infested panicle per hill (0.33) at grain filling stage was recorded from the treatment T_8, which was statistically similar with T_2 (0.40 white head panicle hill^{-1}) closely followed by T_1 (0.60 white head panicle hill^{-1}). On the other hand, the highest number of white head panicle per hill (1.00) was recorded in T_9, which was closely followed by T_5 (0.87 white head panicle hill^{-1}). Considering the percent white head infested panicle, the lowest white head panicle (2.44%) at grain filling stage was recorded in T_8, which was statistically similar with T_2 (3.10%) and closely followed by T_1 (4.64%), while the highest white head panicle (11.66%) was recorded in T_9, which was closely followed by T_5 (8.89%). Considering the percent reduction of white head infested panicle over control, and the highest reduction was recorded in T_8 (79.07%) followed by T_2 (73.41%), T_1 (60.21%), T_7 (53.52%), T_4 (52.14%), T_3 (41.60%). On the other hand, the minimum reduction of white head infested panicle was observed in T_5 (23.76%) followed by T_6 (36.79%) as depicted in Table 7.

Table 7. Effect of different bio-control agents and botanical products against white head infestation of hybrid rice caused by stem borer at grain filling stage

Treatment	Healthy panicle (No./hill)	White heart at grain filling stage		% reduction of white head over control
		White head panicle (No./hill)	White head infestation (%)	
T_1	12.33 ab	0.60 d	4.64 de	60.21
T_2	12.47 ab	0.40 e	3.10 ef	73.41
T_3	11.00 bc	0.80 bc	6.81 c	41.60
T_4	11.33 bc	0.67 cd	5.58 cd	52.14
T_5	9.00 de	0.87 ab	8.89 b	23.76
T_6	10.13 cd	0.80 bc	7.37 bc	36.79
T_7	11.60 abc	0.67 cd	5.42 cd	53.52
T_8	13.13 a	0.33 e	2.44 f	79.07
T_9	7.67 e	1.00 a	11.66 a	--
$LSD_{(0.05)}$	1.586	0.173	1.902	--
CV (%)	8.36	14.94	17.69	--

In column, numeric data represent the mean value of 3 replications; each replication is derived from the number of tillers for 5 selected hills per plot. In column, means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: *Trichogramma* egg parasitoid @ 0.25 gm; T_2: *Trichogramma* egg parasitoid @ 0.50 gm; T_3: *Bacillus thuringiensis* bacterial suspension @ 0.1%; T_4: *B. thuringiensis* suspension @ 0.2 %; T_5: Safe clean @ 0.05%; T_6: SafeMax @ 0.05%; T_7: Neem oil @ 0.3%; T_8: Furadan 5G 6 gm/plot and T_9: Untreated control

4.2.4 Average white head infestation

More or less similar trends of results among different management practices applied against rice stem borer in respect of mean number of healthy and white head infested panicles per hill as well as percent white head infested panicle and percent reduction of white head infestation over control was observed and the trend of results is $T_8 > T_2 > T_1 > T_7 > T_4 > T_3 > T_5$ (Table 8).

Table 8. Effect of different bio-control agents and botanical products againstaverage white head infestation of hybrid rice caused by stem borer through out the cropping season

Treatment	Healthy panicle (No./hill)	Mean white head infestation		% reduction of white head over control
		White head panicle (No./hill)	White head infestation (%)	
T_1	13.00 b	0.36 f	2.66 f	76.27
T_2	13.24 ab	0.27 f	1.98 f	82.34
T_3	11.71 cd	0.71 d	5.73 d	48.88
T_4	12.04 c	0.58 e	4.58 e	59.14
T_5	10.67 e	0.96 b	8.22 b	26.67
T_6	11.24 de	0.82 c	6.82 c	39.16
T_7	12.22 c	0.49 e	3.84 e	65.74
T_8	13.78 a	0.13 g	0.96 g	91.44
T_9	9.51f	1.20 a	11.21 a	--
$LSD_{(0.05)}$	0.605	0.110	0.848	--
CV (%)	5.92	10.16	9.59	--

In column, numeric data represent the mean value of 3 replications; each replication is derived from the number of tillers for 5 selected hills per plot. In column, means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: *Trichogramma* egg parasitoid @ 0.25 gm; T_2: *Trichogramma* egg parasitoid @ 0.50 gm; T_3: *Bacillus thuringiensis* bacterial suspension @ 0.1%; T_4: *B. thuringiensis* suspension @ 0.2 %; T_5: Safe clean @ 0.05%; T_6: SafeMax @ 0.05%; T_7: Neem oil @ 0.3%; T_8: Furadan 5G 6 gm/plot and T_9: Untreated control

4.3 Effect of management practices on the incidence of rice stem borer

The significant variations among different management practices were observed on the incidence of adults and larvae of rice stem borer in the field of hybrid rice during the data recording period from 20 to 70 days after transplanting (DAT) the rice (Table 9).

4.3.1 Number of adult incidence

In case of adult incidence at different DAT, the lowest number of adults per hill (1.00. 1.00, 0.67, 1.06, 0.00 and 0.00) was recorded in T_8 at 20, 30, 40, 50, 60 and 70 DAT, respectively followed by T_2 (1.40, 1.66, 1.33, 1.11, 0.33 and 0.33 adults hill^{-1}) and T_1 (1.20, 1.66, 1.22, 1.11, 0.33 and 0.33 adults hill^{-1}), respectively. On the other hand, the highest number (2.80, 3.11, 2.22, 2.13, 1.10 and 1.33 adults hill^{-1}) of adult per hill was recorded in T_9, which was followed by T_5 (2.40, 2.44, 2.11, 1.34, 1.00 and 0.67 adults hill^{-1}) and T_6 (2.00, 2.67, 1.56, 1.33, 0.67 and 1.00 adults hill^{-1}), respectively at 20, 30, 40, 50, 60 and 70 DAT (Table 9).

Table 9. Efficiency of different bio-control agents and botanical products on number of adult of stem borer in hybrid rice

Treatment	Incidence of adult stem borer (No./Plot) at different DAT					
	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
T_1	1.20 ef	1.66 f	1.22 d	1.11 cd	0.33 e	0.33 e
T_2	1.40 def	1.66 f	1.33 cd	1.11 cd	0.33 e	0.33 e
T_3	1.80 cd	2.00 e	1.44 bc	1.32 b	0.39 d	0.33 e
T_4	1.60cde	2.22 d	1.44 bc	1.40 b	0.39 d	0.35 d
T_5	2.40 ab	2.44 c	2.11 a	1.34 b	1.00 b	0.67
T_6	2.00 bc	2.67 b	1.56 b	1.33 b	0.67 c	1.00 b
T_7	1.80 cd	2.66 b	1.33 cd	1.27 bc	0.67 c	0.67 c
T_8	1.00 f	1.00 g	0.67 e	1.06 d	0.00 f	0.00 e
T_9	2.80 a	3.11 a	2.22 a	2.13 a	1.10 a	1.33 a
$LSD_{(0.05)}$	0.461	0.190	0.122	0.164	0.055	0.017
Significance level	0.01	0.01	0.01	0.01	0.01	0.01
CV(%)	15.00	5.12	4.61	6.75	6.30	3.26

In column, numeric data represent the mean value of 3 replications; each replication is derived from the number of tillers for 5 selected hills per plot. In column, means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: *Trichogramma* egg parasitoid @ 0.25 gm; T_2: *Trichogramma* egg parasitoid @ 0.50 gm; T_3: *Bacillus thuringiensis* bacterial suspension @ 0.1%; T_4: *B. thuringiensis* suspension @ 0.2 %; T_5: Safe clean @ 0.05%; T_6: SafeMax @ 0.05%; T_7: Neem oil @ 0.3%; T_8: Furadan 5G 6 gm/plot and T_9: Untreated control

4.3.2 Number of larvae incidence

During the management of rice stem borer, the significant variation of the incidence of stem borer larvae was also recorded at different DAT. The lowest number of larvae per hill (1.40, 0.80, 0.00, 0.33, 0.00 and 0.00) was observed in T_8 at 20, 30, 40, 50, 60 and 70 DAT, respectively followed by T_2 (1.80, 1.00, 0.67, 0.33, 0.33 and 0.21 larvae hill^{-1}) and T_1 (1.60, 1.60, 1.00, 0.67, 0.38 and 0.33 larvae hill^{-1}), respectively. On the other hand, the highest number (3.20, 3.20, 1.67, 1.33, 1.53 and 1.20) of larvae hill^{-1} was recorded in $T_{9,}$ which was followed by T_5 (2.60, 2.40, 1.33, 1.00, 1.33 and 1.00 larvae hill^{-1}) and T_6 (2.40, 2.20, 1.35, 0.67, 1.10 and 0.67 larvae hill^{-1}), respectively (Table 10)

Table 10. Efficiency of different bio-control agents and botanical products on number larvae of stem borer in hybrid rice

Treatment	Incidence of stem borer larvae (No./hill)					
	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT
T_1	1.60 ef	1.60 ef	1.00 c	0.67 c	0.38 f	0.33 d
T_2	1.80 def	1.00 g	0.67 d	0.33 d	0.33 f	0.21 e
T_3	2.20 bcd	1.80 de	1.38 ab	0.67 c	1.00 d	0.35 d
T_4	2.00 cde	2.00 cd	1.33 b	0.67 c	1.10 c	0.67 d
T_5	2.60 b	2.40 b	1.33 b	1.00 b	1.33 b	1.00 b
T_6	2.40 bc	2.20 bc	1.35 b	0.67 c	1.10 c	0.67 c
T_7	2.00 cde	1.40 f	1.18 bc	0.67 c	0.67 e	0.38 d
T_8	1.40 f	0.80 g	0.00 e	0.33 d	0.00 g	0.00 f
T_9	3.20 a	3.20 a	1.67 a	1.33 a	1.53 a	1.20 a
$LSD_{(0.05)}$	0.458	0.330	0.305	0.205	0.095	0.077
CV(%)	12.40	10.43	16.41	15.53	6.45	7.70

In column, numeric data represent the mean value of 3 replications; each replication is derived from the number of tillers for 5 selected hills per plot. In column, means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: *Trichogramma* egg parasitoid @ 0.25 gm; T_2: *Trichogramma* egg parasitoid @ 0.50 gm; T_3: *Bacillus thuringiensis* bacterial suspension @ 0.1%; T_4: *B. thuringiensis* suspension @ 0.2 %; T_5: Safe clean @ 0.05%; T_6: SafeMax @ 0.05%; T_7: Neem oil @ 0.3%; T_8: Furadan 5G 6 gm/plot and T_9: Untreated control

4.4 Effect of management practices on the yield and yield attributes of rice

The statistically significant variations among different management practices were observed on the yield contributing characters and yield of rice during the management of rice stem borer in the field of hybrid rice as depicted the results in the Table 10.

4.4.1 Length of panicle

Length of panicle varied significantly the rice plants during the management of rice stem borer (Table 10). The longest length of panicle was recorded from the treatment T_8 (24.69 cm) which was statistically identical with T_2 (23.70 cm) and T_1 (23.50 cm) and closely followed by T_7 (22.67 cm), while the shortest panicle was observed from T_9 (20.26 cm) which was statistically identical with the treatment T_5 (20.96 cm).

4.4.2 Number of filled grain

Number of filled grain varied significantly in the rice plants during the management of rice stem borer (Table 10). The maximum number of filled grain per plant was found from the treatment T_8 (93.74) which was statistically identical with T_2 (92.53) and T_1 (91.33) and closely followed by T_7 (90.17), again the minimum number was recorded from T_9 (84.77) which was followed by the treatment T_5 (88.57).

4.4.3 Number of unfilled grain

Statistically significant variation was recorded for number of unfilled grain varied significantly during the management of rice stem borer (Table 10). The minimum number of unfilled grain per plant was obtained from the treatment T_8 (6.26) which followed by T_2 (7.47) and T_1, consequently the maximum number was recorded from T_9 (9.39) which were followed by the treatment T_5 (26.30).

4.4.4 Weight of 1000 seeds

Weight of 1000 seeds varied significantly the rice plants during the management of rice stem borer (Table 9). The highest weight of 1000 seeds was recorded from the treatment T_8 (22.34 g) which was statistically similar with T_1 (22.23 g), T_2 (21.90 g) and T_3 (21.50 g) and closely followed by T_7 (21.30 g), whereas the lowest weight was observed from T_9 (19.83 g) which was followed by the treatment T_5 (20.17 g).

4.4.5 Grain yield

Grain yield varied significantly the rice plants during the management of rice stem borer (Table 10). The highest grain yield was found from the treatment T_8 (7.67 t/ha) which was statistically identical with T_2 (7.23 t/ha) and T_1 (7.02 t/ha) and closely followed by T_7 (6.90 t/ha), while the lowest grain yield was recorded from T_9 (5.35 t/ha) followed by T_5 (5.90 t/ha). Hybrid rice variety was found to be most susceptible to stem borer which causes 22.19-27.09% yield loss.

4.4.6 Yield increase over control

Yield increase over control was estimated and the highest increase over control was recorded from T_8 (43.36%) and the lowest was recorded from T_5 (10.28%).

Table 11. Efficiency of different bio-control agents and botanical products on yield contributing characters and yield of hybrid rice

Treatment	Yield attributes and yield of rice						
	Panicle length (cm)	Filled grain by number (%)	Unfilled grain by number (%)	1000 seed weight (g)	Grain yield (kg/plot	Grain yield (t/ha)	% Yield increase over control
T_1	23.70ab	91.33abc	8.67 e	22.23 a	8.40 abc	7.02abc	31.21
T_2	23.50ab	92.53 ab	7.47 f	21.90ab	8.42 ab	7.23 ab	35.14
T_3	22.87bc	78.93 f	21.07 b	21.50ab	7.26 bcd	6.51bcd	21.68
T_4	22.52bc	88.33 d	11.67 d	21.07bc	7.23 cd	6.29 cd	17.57
T_5	20.96de	73.70 g	26.30 a	20.17 d	6.10 de	5.90 de	10.28
T_6	21.75cd	88.57 cd	11.43 d	20.53cd	7.27 bcd	6.56bcd	22.62
T_7	22.67bc	90.17bcd	9.83 e	21.30bc	7.30 abc	6.90abc	28.97
T_8	24.69 a	93.74 a	6.26 g	22.34 a	8.48 a	7.67 a	43.36
T_9	20.26 e	84.77 e	15.23 c	19.83 d	6.04 e	5.35 e	--
$LSD_{(0.05)}$	1.283	2.636	0.576	0.814	0.796	0.796	--
CV(%)	6.78	8.22	5.67	4.55	7.04	7.04	--

In column, numeric data represent the mean value of 3 replications; each replication is derived from the number of tillers for 5 selected hills per plot. In column, means having similar letter(s) are statistically similar at 0.05 level of probability

T_1: *Trichogramma* egg parasitoid @ 0.25 gm; T_2: *Trichogramma* egg parasitoid @ 0.50 gm; T_3: *Bacillus thuringiensis* bacterial suspension @ 0.1%; T_4: *B. thuringiensis* suspension @ 0.2 %; T_5: Safe clean @ 0.05%; T_6: SafeMax @ 0.05%; T_7: Neem oil @ 0.3%; T_8: Furadan 5G 6 gm/plot and T_9: Untreated control

From the above findings it was revealed that among different management practices T_8 comprised with the application of systemic insecticide Furadan 5G @ 6 gm $plot^{-1}$ contributed to the maximum panicle length, minimum unfilled grains by producing maximum filled grains, the maximum weight of 1000 grains and yield over control followed by T_2 comprised with *Trichogramma* egg parasitoid @ 0.25 g $plot^{-1}$.

4.5 Relationship between mean dead heart infestation and yield attributes of the rice

The significant relationships were observed between the dead heart infestations caused by the rice stem borer and the different yield attributes of rice plants viz. unfilled grains, 1000 grain weight and grain yield of rice during the management of rice stem borer comprised with bio-control agents, botanical products and insecticides (Figure 1 to Figure 3).

4.5.1 Dead heart infestation and unfilled grain

The data on dead heart infestation in average were regressed against number of unfilled grain and a positive relationship was obtained. It was evident from the Figure 1 that the equation $y = 1.3692x + 4.2324$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.415$) showed that, fitted regression line had a significant regression co-efficient. It is evident that, the number of unfilled grain increased with the increased of average dead heart infestation.

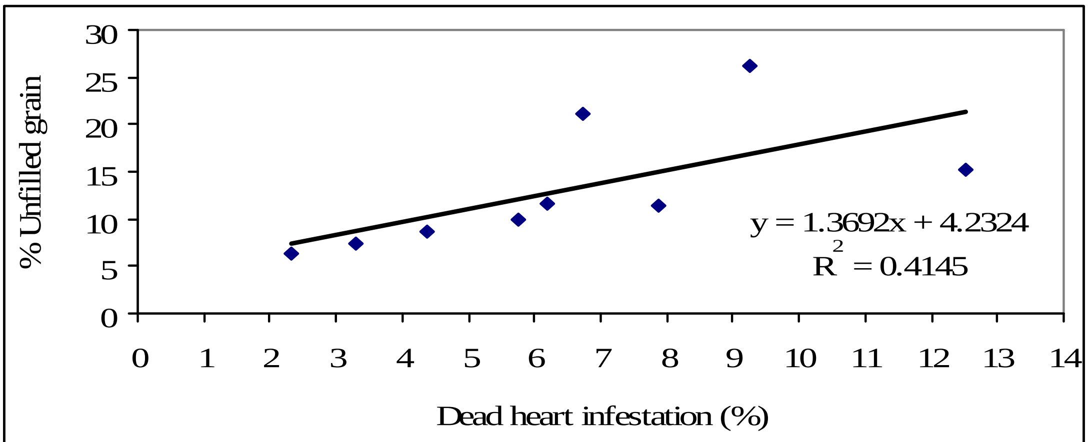

Figure 1. Relationship between dead heart infestation and unfilled grain of rice during the management of rice stem borer

4.5.2 Dead heart infestation and weight of 1000 seeds

Correlation study was done to establish a relationship between dead heart infestation and weight of 1000 seeds. From the study it was revealed that significant correlations existed between the characters (Figure 2). The regression equation y = -0.269x + 22.951 gave a good fit to the data and the value of the co-efficient of determination (R^2 = 0.897). It was found that there were a significant relationship between dead heart infestation and weight of 1000 seeds.

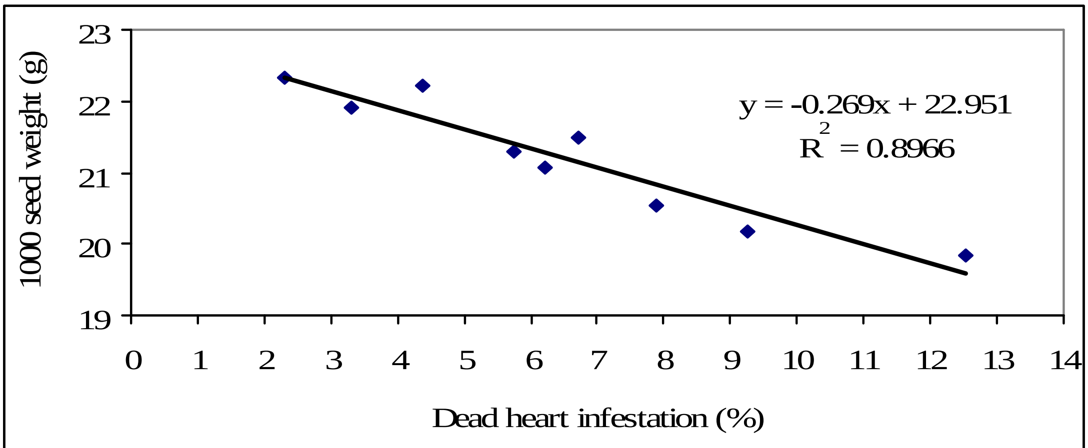

Figure 2. Relationship between dead heart infestation and 1000 seed weight of rice during the management of rice stem borer

4.5.3 Dead heart infestation and grain yield of rice

The data on dead heart infestation were regressed against grain yield and a positive linear relationship was obtained between them. It was evident from the Figure 3 that the equation y = -0.2166x + 8.0069 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9313) showed that, fitted regression line had a significant regression co-efficient. It is evident from the equation that, the grain yield decreased significantly with the increased of dead heart infestation.

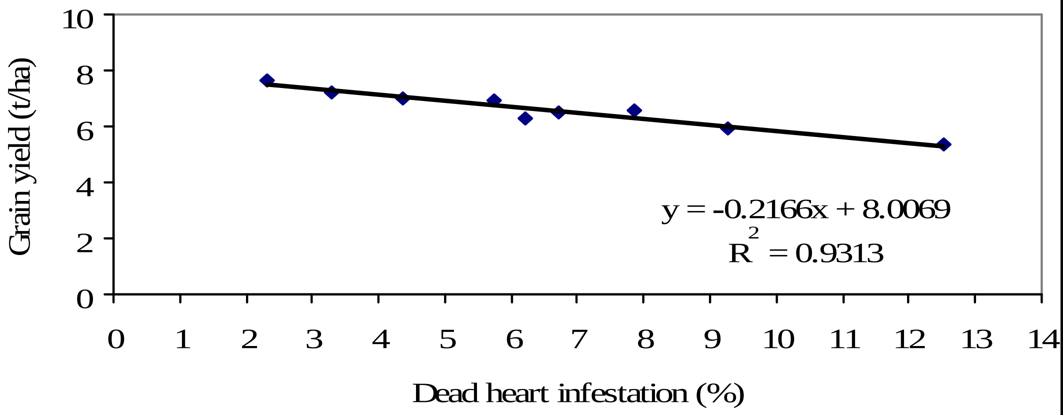

Figure 3. Relationship between dead heart infestation and grain yield of rice during the management of rice stem borer

4.6 Relationship between mean white head infestation and yield attributes and yield of rice

The significant relationships were observed between the white head infestations caused by the rice stem borer and the different yield attributes of rice plants viz. unfilled grains, 1000 grain weight and grain yield of rice during the management of rice stem borer comprised with bio-control agents, botanical products and insecticides (Figure 4 to Figure 6).

4.6.1 White head infestation and unfilled grain

A positive relationship was obtained for the data on white head infestation in average were regressed against number of unfilled grain. It was evident that the equation y = 1.3854x + 6.0226 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.459) showed that, fitted regression line had a significant regression co-efficient (Figure 4). It is evident that, the number of unfilled grain increased with the increased of average white head infestation.

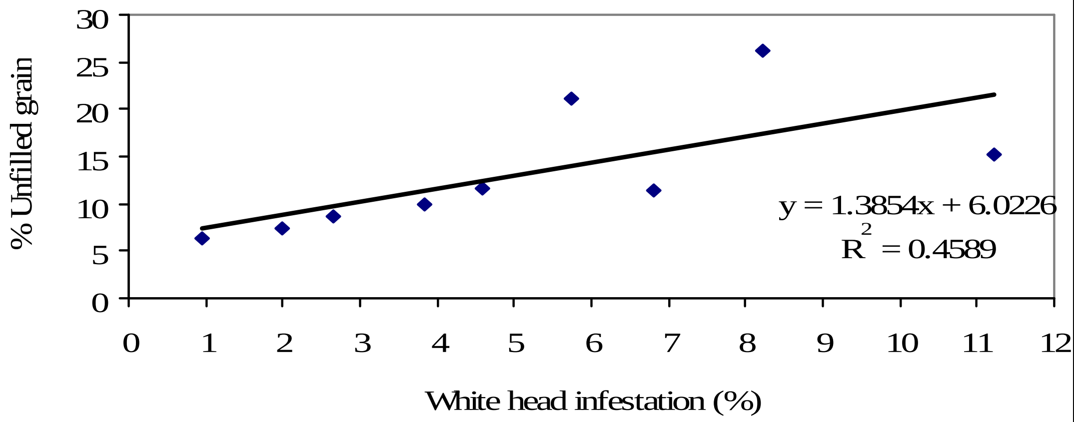

Figure 4. Relationship between white head infestation and unfilled grain of rice during the management of rice stem borer

4.6.2 White head infestation and weight of 1000 seeds

To establish a relationship between white head infestation and weight of 1000 seeds correlation study was done and it was revealed that significant correlations existed between the characters (Figure 5). The regression equation y = -0.2588x + 22.53 gave a good fit to the data and the value of the co-efficient of determination (R^2 = 0.897). It was found that there was a significant relationship between white head infestation and weight of 1000 seeds.

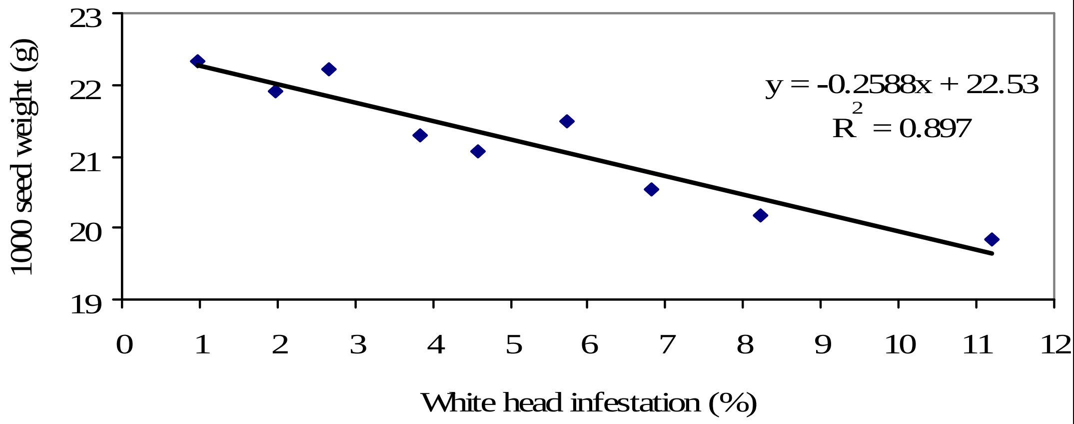

Figure 5. Relationship between white head infestation and weight of 1000 seeds of rice during the management of rice stem borer

4.6.3 White head infestation and grain yield of rice

White head infestation was regressed against grain yield and a positive linear relationship was obtained between them. It was evident from the equation y = -0.2066x + 7.6594 gave a good fit to the data, and the co-efficient of determination (R^2 = 0. 0.916) showed that, fitted regression line had a significant regression co-efficient (Figure 6). It was evident from the equation that, the grain yield decreased with the increased of white head infestation.

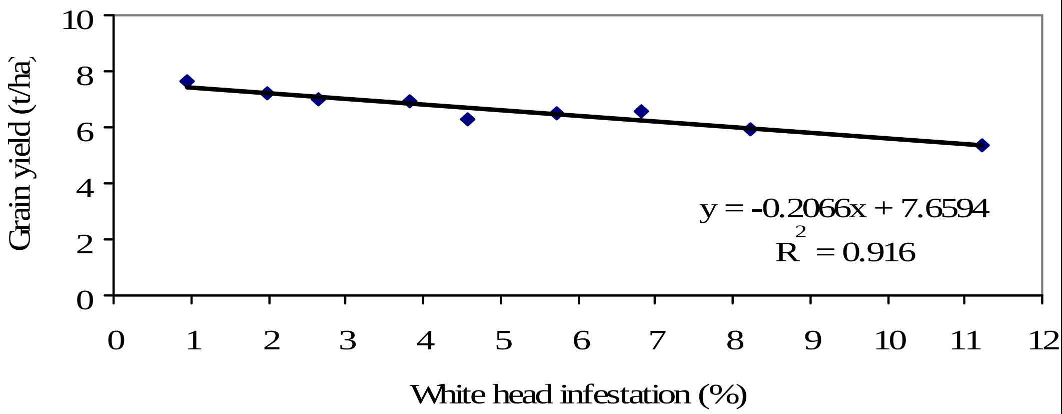

Figure 6. Relationship between white head infestation and grain yield of rice during the management of rice stem borer

From the above findings it was revealed that the dead heart and white head infestation caused by the rice stem borer positively influenced on the unfilled grains of rice but resulting in the negatively influenced on the 1000 grain weight and grain yield of rice during the management of rice stem borer. This result indicates that the different management practices specially $T_{8,}$ T_2 and T_1 increased the yield of rice by decreasing the dead heart and white head infestation as well as by decreasing the unfilled grains.

4.7 Economic analysis of the treatments applied against rice stem borer

Economic analysis of different bio-control agent, botanicals and also chemical insecticides applied against rice stem borer were calculated and presented in Table 11. The untreated control treatment did not incur any pest management cost. The labor costs were involved in the application of bio-control agents as well as spraying of the botanicals and chemical insecticides and the costs were also involved for the procurement of the items (Appendix 2). Thus the maximum benefit cost ratio (BCR) 5.04 was achieved for T_2 followed by T_1 (4.32). On the other hand the lowest cost benefit ratio (1.67) was calculated recorded in T_5. From the above findings it was found that the bio-control agent comprised with *Trichogramma* egg parasitoid was most economic in controlling the stem borer of hybrid rice and also gave the highest BCR. Considering the ecological point of view, bio-control based control treatment also performed as the most effective, economic as well as environment pollution free for controlling rice stem borer.

Table 12. Cost benefit analysis for different treatment using during the management of rice stem borer on hybrid rice

Treatments	Cost of pest Management (Tk./ha)	Grain yield (t/ha)	Gross return (Tk.)	Net Return (Tk.)	Adjusted net return (Tk.)	Benefit cost ratio (BCR)
T1	47223.00	7.02	139045.00	91822.00	22822.00	4.32
T2	52778.00	7.23	145560.00	92818.00	23818.00	5.04
T3	48611.00	6.51	130200.00	81589.00	12589.00	2.58
T4	50000.00	6.29	125800.00	78800.00	9800.00	1.97
T5	51388.80	6.1	118000.00	77611.00	8611.00	1.67
T6	51666.00	6.56	131200.00	79534.00	10534.00	2.03
T7	52778.00	6.9	138000.00	85222.00	19222.00	3.64
T8	55555.00	7.27	145400.00	89845.00	21000.00	3.80
T9	0.00	3.35	69000.00	69000.00	0.00	--

T_1: *Trichogramma* egg parasitoid @ 0.25 gm; T_2: *Trichogramma* egg parasitoid @ 0.50 gm; T_3: *Bacillus thuringiensis* bacterial suspension @ 0.1%; T_4: *B. thuringiensis* suspension @ 0.2 %; T_5: Safe clean @ 0.05%; T_6: SafeMax @ 0.05%; T_7: Neem oil @ 0.3%; T_8: Furadan 5G 6 gm/plot and T_9: Untreated control

*Market price of rice grains 1 kg = 20.00 Tk during the study period

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from June to November, 2009 to find out the effectiveness of bio-control agent(s) viz. parasitic wasps (*Trichogramma* sp.) and *Bacillus thuriengiensis* pathogenic bacterium for the eco-friendly management of rice stem borer over traditional insecticidal control. The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on incidence of insects pests were recorded and the collected data were analyzed statistically and the mean differences were adjusted by Duncan's Multiple Range Test (DMRT).

For dead heart in case of healthy tiller, the highest number of healthy tiller per hill was recorded from T_8 (16.83), while the lowest number of healthy tiller per hill was observed from T_9 (12.56). In case of infested tiller, the lowest number of infested tiller per hill was recorded from T_8 (0.40), consequently the highest number of infested tiller was found from T_9 (1.80). Considering percentage (%) infestation of dead heart tiller, the lowest infestation was recorded from T_8 (2.32%), whereas the highest infestation from T_9 (12.52%). For white head in case of healthy tiller, the highest number of healthy tiller per hill was recorded from T_8 (13.78), again the lowest number of healthy tiller per hill was recorded from T_9 (9.51). In case of infested tiller, the lowest number of infested tiller per hill was recorded from T_8 (0.13), whereas the highest number of infested tiller was recorded from T_9 (1.20) which was closely followed by T_5 (0.96). Considering percentage(%) infestation of dead heart tiller, the lowest infestation was found from the treatment T_8 (0.96%), while the highest infestation from T_9 (11.21%). The incidence of adult, at 20, 30, 40, 50, 60 and 70 DAT, the lowest number of adult per hill (1.00. 1.00, 0.67, 1.06, 0.00 and 0.00) recorded from T_8 and the highest number (2.80, 3.11, 2.22, 2.13, 1.10 and 1.33) from T_9. The incidence of larvae, at 20, 30, 40, 50, 60 and 70 DAT, the lowest number of larvae per hill (1.40, 0.80, 0.00, 0.33, 0.00 and 0.00) again, the highest number (3.20, 3.20, 1.67, 1.33, 1.53 and 1.20) from T_8.

The longest length of panicle was recorded from T_8 (24.69 cm), while the shortest panicle was observed from T_9 (20.26 cm). The maximum number of filled grain per plant was found from T_8 again the minimum number was recorded from T_9 (84.77). The minimum number of unfilled grain per plant was obtained from T_8 (4.56), consequently the maximum number was recorded from T_9 (9.39). The highest weight of 1000 seeds was recorded from T_8, whereas the lowest weight was observed from T_9 (19.83 g). The highest grain yield was found from T_8 (7.67 t/ha), while the lowest grain yield was recorded from T_9 (5.35 t/ha). The highest straw yield was recorded from the treatment T_8 (7.90 t/ha) and the lowest straw yield was obtained from T_9 (6.24 t/ha). Bio-control agent, botanicals and also chemical treatments cost were taken as per market price. Considering the controlling of stem borer of rice the highest benefit cost ratio (4.64) was recorded in T_2 and next highest BCR was found in T_4 (5.04). On the other hand the lowest benefit cost ratio (1.67) was recorded in T_5. From the above findings it was found that the bio-control agent was effective in best in controlling the stem borer of hybrid rice and also gave the highest BCR.

Considering the present experiment, further studies in the following areas may be suggested:

1. Such study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability;
2. Other bio-agent and botanical may be included in the future study.

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APPENDICES

Appendix I. Characteristics of agronomy farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Agronomy Farm Field , SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained

B. Physical and chemical properties of the initial soil

Characteristics	Value
% Sand	27
% Silt	43
% clay	30
Textural class	silty-clay
pH	5.6
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20.00
Exchangeable K (me/100 g soil)	0.10
Available S (ppm)	45

Source: SRDI

Appendix II. Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during the period from June to November 2007

Month (2007)	*Air temperature (^{0}c)		*Relative humidity (%)	*Rain fall (mm) (total)	*Sunshine (hr)
	Maximum	Minimum			
June	27.1	16.7	67	30	8.6
July	31.4	19.6	54	11	7.9
August	33.6	23.6	69	163	8.1
September	22.4	13.5	74	00	7.6
October	29.18	18.26	81	39	7.4
November	25.82	16.04	78	00	8.1

* Monthly average, **Source:** Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix III. Cost incurred per hectare in different control measures applied against rice stem borer on hybrid rice during Kharif II, 2009 at SAU, Dhaka.

Treatment	Items of expenditure	Cost (Tk)
T_1	Total no. of labors for spraying (Trichograma @ 0.25 gm) 6 x 25.00 Trichograma @ .25 gm (for 6 sprays) **Total cost**	150.00 20 **170.00**
T_2	Total no. of labors for spraying (Trichograma @ 0.5 gm) 6 x 25.00 Trichograma @ 0.5 gm (for 6 sprays) **Total cost**	150.00 40 **190.00**
T_3	Total no. of labors for spraying *(B. thuringiensis* @ 0.1%) 6 x 25.00 *B. thuringiensis* @ 0.1% (for 6 sprays) **Total cost**	150.00 25 175.00
T_4	Total no. of labors for spraying *(B. thuringiensis* @ 0.1%) 6 x25.00 *B. thuringiensis* @ 0.1% (for 6 sprays) **Total cost**	150.00 **30** **180.00**
T_5	Total no. of labors for spraying (Safe clean @ 0.05%) 6 x 25.00 Safe clean @ 0.05% (for 6 sprays) **Total cost**	150.00 **35** **185.00**
T_6	Total no. of labors for spraying (Safe Max @ 0.05%) 6 x 25.00 Safe Max @ 0.05% (for 6 sprays) **Total cost**	150.00 **36** **186.00**
T_8	Total no. of labors for spraying (Furadan 5G @ 6 gm/plot) 6 x 25.00 Furadan5G 108gm(for 6 sprays) **Total cost**	150.00 **50** **200.00**
T_9 (Untreated control)	No management cost at all	00.00

T_1: *Trichogramma* egg parasitoid @ 0.25 gm; T_2: *Trichogramma* egg parasitoid @ 0.50 gm; T_3: *Bacillus thuringiensis* bacterial suspension @ 0.1%; T_4: *B. thuringiensis* suspension @ 0.2 %; T_5: Safe clean @ 0.05%; T_6: SafeMax @ 0.05%; T_7: Neem oil @ 0.3%; T_8: Furadan 5G 6 gm/plot and T_9: Untreated control

Labor cost 200.00 Tk/day; *Trichogramma* egg parasitoid 1 gm=80Tk; *Bacillus thuringiensis* bacterial suspension 100gm=250Tk, Safe clean 100ml=35Tk, SafeMax 100ml= 36Tk, Neem oil 250ml=40Tk, Furadan 5G = 150Tk/kg