ECO-FRIENDLY MANAGEMENT OF OKRA SHOOT AND FRUIT BORER USING BIO-CONTROL AGENTS

A THESIS

BY

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MASTER OF SCIENCE
IN
ENTOMOLOGY

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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

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SHAHADAT HOSSAIN
Registration No. 04-1432

A Thesis

Submitted to the faculty of Agricultural,
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This is to certify that thesis entitled, **"ECO-FRIENDLY MANAGEMENT OF OKRA SHOOT AND FRUIT BORER USING BIO-CONTROL AGENTS"** submitted to the **DEPARTMENT OF ENTOMOLOGY**, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) in ENTOMOLOGY** embodies the result of a piece of bona fide research work carried out by **SHAHADAT HOSSAIN**, **Registration No. 04-1432** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2010
Place: Dhaka, Bangladesh

…………………………………

Professor Dr. Md. Razzab Ali
Supervisor

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ECO-FRIENDLY MANAGEMENT OF OKRA SHOOT AND FRUIT BORER THROUGH BIO-CONTROL AGENTS

ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka to evaluate the bio-control agents for the eco-friendly management of okra shoot and fruit borer. The experiment was comprised of seven treatments including untreated control following Randomized Complete Block Design (RCBD) with three replications. The treatments of the experiment were T_1= Application of *Trichogramma evanescense* @ 5 Tricho card / plot at 7 days interval, T_2= Application of *Trichogramma evanescense* @ 0.08 g / plot at 7 days interval, T_3= Application of *Bracon hebetor* @ 10 adults (Male: Female = 4: 6)/ plot at 7 days interval, T_4= Application of *Bracon hebetor* @ 15 adults (Male: Female = 6: 4)/ plot at 7 days interval, T_5= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension /liter water / plot at 7 days interval, T_6= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 1ml suspension /liter of water / plot at 7 days interval, T_7= Untreated control. The treatment (T_5) gave the best result in reducing the shoot infestation (57.90%), as well as fruit infestation by number and weight (55.28% and 48.97%, respectively). The highest yield (6310 kg/ha) as well as (43.50%) and girth (23.07%) of fruits and yield (54.85%) of okra was produced in T_5. Similarly, the highest BCR (11.41) was achieved by $T_{5,}$ which was higher than all other treatments.

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CHAPTER I

INTRODUCTION

Okra *(Abelmoschus esculentus)* locally known as ‘Bhendi’ or ‘Dherosh’ also known as lady’s finger is a popular and most common annual vegetable crop grown from seed in Bangladesh and in other tropical and subtropical parts of the world. It belongs to the family Malvaceae and originated in tropical Africa (Purseglove, 1987). Though okra is produced mainly in the kharif season it can be grown year round (Rashid 1976). Around 38508 metric tons of okra were produced in 2007-2008 in Bangladesh (BBS, 2008). Okra production in Bangladesh is mainly during February-July (Rashid 1995) its production is severely hampered due to the attack of more than three dozen of insect pests from seedling to fruiting stage (Nayar *et al.* 1976). Several insect pests have so far been recorded to attack okra but okra shoot and fruit borer (OSFB), is the most destructive insect pest responsible for considerable damage (Butani and Jotwani 1984). It is the most serious pest of okra in Bangladesh and both quantitative and qualitative losses happened due to its pest infestation.

According to Srinivasan *et al.* (1959) the OSFB cause up to 40-50% damage of okra fruit in some areas of South East Asian countries. Krishnaiah (1980) observed the attack of fruit borer to the extent of 35% in harvestable fruit of okra. In Madras 40-50% fruit were also found damaged by this pest (Srinivasan and Gowder 1959). The attack of fruit borer, *Earias vittella* on okra starts 4-5 weeks after the germination both in the kharif and summer seasons. The attacked top tender shoots dry up while flowers, buds and developing fruit fall down pre-maturely. Larvae of *Earias vittella* enter the shoot tips of young plants and bore into fruits. The affected fruits are unfit for human consumption.

Various control strategies have been adopted against shoot and fruit borer, 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 creating health hazards (Chinniah *et al*. 1998). Use of bio-control agents is safe and non-hazardous free tactic for the management of insect pests (Hasan 1994). Among which parasitic wasps viz. *Trichogramma* sp. egg parasitoid, *Bracon* sp. larval parasitoid, *Bacillus thuringiensis* pathogenic bacterium are the new introduction in Bangladesh for the management of insect pests of crops. Many parts of the world use *Trichogramma* sp.

successfully for crop production (Hasan 1992). But the grower of Bangladesh is far behind the use of bio-control agents for the management of okra shoot and fruit borer and even they are not familiar with them.

Objectives

Considering above points the experiment have been undertaken to fulfill the following objectives:

1. To study the infestation level of okra shoot and fruit borer.
2. To find out the effective bio-control agent(s) for the eco-friendly management of okra shoot and fruit borer.

CHAPTER II

REVIEW OF LITERATURE

An effort has been attempted to present a brief review of research in relation to ecofriendly management of okra shoot and fruit borer through bio-control agent. Okra *(Abelmoschus esculentus)* locally known as 'Bhendi' or 'Dherosh' also known as lady's finger is a popular and most common annual vegetable crop grown from seed in Bangladesh and in other tropical and subtropical parts of the world. Several insect pests have so far been recorded to attack okra but okra shoot and fruit borer (OSFB), is the major insect pest responsible for considerable damage (Butani and Jotwani 1984). It is the most serious pest of okra in Bangladesh and both quantitative and qualitative losses happened due to this pest infestation. Some of the pertinent findings of the research with ecofriendly management of okra shoot and fruit borer are reviewed in this chapter.

2.1 Okra shoot and fruit borer

Scientific Name : *Earias vittella*
Family : Noctuidae
Order : Lepidoptera

2.2 Biology of okra shoot and fruit borer

According to Butani and Jotwani (1984) the eggs are spherical in shape about half mm in diameter, light bluish green in colour and beautiful sculptured having 26 to 32 longitudinal ridges. The alternate ridges project upwards to form a crown thus the eggs look like tiny or miniature poppy fruit; full grown caterpillars are 18 to 24 mm long, stout, spindle shaped havin long stiff setae. Pupae are 13 to 16 mm long and chocolate-brown in colour bluntly rounded and enclosed in inverted boat shaped cocoons. Adults are medium sized moths, 13 to 15 mm long, head and thorax ochreous white; for wings pale white with a broad wedge shaped horizontal green patch in the, middle and hind wings silvery creamy white in colour. Wing expanse is 30 to 34 mm.

Report of Butani and Jotwani (1984) also indicated that the moth emerge at dusk; mating takes place 2 to 3 days after emergence and oviposition commences after 1 to 5 days of mating. A female lays on an average 400 egg (65 to 695). They also reported that incubation, larval and papal periods were 3 to 9, 9 to 20 (50 to 60 days during winter) and 8 to 12 days respectively. A single life cycle takes 22 to 25 days extending up to 74 day during winter and there may be 8 to 12 generations in a year. There is no true hibernation but development and activity is considerably slowed down during winter.

Rehman and Ali (1983) reported that females of *E. vittella* mated for 34 to109 min for successful insemination and laid 82-378 eggs each in 4-7 days. The egg stage lasted 3-4 days, the larval stage 5-16 days, the prepupal stage I day the papal stage 6-13 days and the adult life span 8-18 days.

The biology of OSFB was studied on okra in laboratory and field (Singl and Bichoo, 1989). They stated that the egg, larval and pupal stages lasted- 3-4. 9-17 and 6-14 days, respectively in September - October. Sardana *et al*. (1990) observed the distribution of eggs of *E. vittella* if okra field in Karnataka, India. Result indicates that this border rows tended to receive more eggs than the central rows. Ovipositing females laid most of the eggs on the top of the plants. Krishna (1987) observed higher overall mean fecundity of female OSFB when larvae reared on okra seeds compared to those reared on whole fruit.

Tripathi and Singh (1990) reported that survival of larvae was negatively correlated with larval density. The crowding also resulted in poor development and reduced weight of larvae and pupae. Hiremath (1987) found the larval period of *E. vittella* to be 13.7 days and females laid an average of 303.2 eggs in July-August.

Sundararaj *et al*. (1987) stated that percentage survival of OSFB was higher on okra (68 days), followed by cotton (67 days) and *Ahrctilon indicium* (16.3 days). Okra and cotton had a higher reducing sugar and free amino acid and protein. On the other hand, *A. indicium* had lower non reducing sugar.

The biology of *E. vittella* on okra was also studied by Sharma *et al*. (1985) in the laboratory using individuals collected from the field of Bihar, India. The borer had 11 generation a year. The longest life cycle (49 days) was observed during January. While the shortest life cycle of 29 days was found during July.

2.3 Distribution of okra shoot and fruit borer

Okra shoot and fruit borer, *Earias vittella* (Fabricius) is widely distributed and is recorded from Pakistan, India, Srilanka, Bangladesh, Burma, Indonesia, New Guinea, and Fiji (Butani and Jotwani 1984). The pest *Earias vittella* is common oriental species found from India and China to North Australia. The genus *Earias* is confined to the old world including Australia (Hill, 1983). Atwal (1976) reported that the species are widely distributed in North Africa, India, Pakistan and other countries and are serious pest of okra and cotton.

2.4 Host range of okra shoot and fruit borer

Butani and Jotwani (1984) found okra shoot and fruit borer as an oligophagous pest though okra and cotton are its main hosts. They also found to feed on a large number of malvaceous plants, both wild as well as cultivated.

Rehman *et al*. (1983) reported that when OSFB were offered the choice of different parts of host plant, they preferred okra fruit and shoot the best followed by cotton balls, buds of *Gossipium hirsutum*, ball, flowers and buds of desi cotton *(G. arboreum*), buds and flower of Kenaf and milky maize grains, flower (*Abutilon indicum*), flowers (*Hibiscus rosasinensis*), sarson (*Brassica campestris* var. sarson), *Malvastrum tricuspidatum*, *Cassia fistula* and ears of pearl millet, pod of jute and soyabean

Nayar and Ananthakrishnan (1983) reported that a part from okra the also infest *Abutilon indicum*, *Abutilon hirtum, Althaea rosea*, *Hibiscus cannabinus*, *Hibiscus vitifolius* and *Malvastrum coromandelianum*.

Atwal (1976) mentioned that okra and cotton are the most favorite host of OSFB. Plant species including sonchal (*Malva parviflora*), Gulkhair (*Althaea officinalis*), holly hock (*Althaea rosea*) and some other malvaceous plants are appear to be its alternate hosts.

2.5 Nature and extent of damage by okra shoot and fruit borer

Butani and Jotwani (1984) reported that OSFB lays its eggs singly on buds and flowers and occasionally on fruits as well. But in absence of these parts i.e., at the early stage of crop growth, the eggs are laid on shoot tips. When the crop is only a few weeks old, the freshly hatched larvae bore into tender shoots and tunnel downwards resulting withering of shoots an ultimately killing the growing points. As a result the apical dominance is lost and side shoots may arise and giving the plants a bushy appearance. With the formation of buds, flowers and fruits, the caterpillars bore inside those and feed on inner tissues. They move from bud to bud and fruit to fruit thus causing damage to a number of fruiting bodies. The damaged buds and flowers wither and fall down without bearing any fruit. The affected fruits become deform in shape and remain stunted in growth and such fruits have hardly get any market value.

Mohan *et al*. (1983) and Atwal (1976) reported that OSFB bore into tender shoots, flower buds and fruits. As a result the attacked shoot dry up while the flower buds and developing fruits dropped prematurely. Affected fruits remain on the plants become unfit for human consumption. Karim (1992) stated that the larvae of OSFB bore into the shoots and feed inside and damage seeds. Singh and Bichoo (1989) reported that the first symptoms of attack were visible when the crop was 3 weeks old and the larvae bored into the shoots. Under severe attack, the top leaves wilted and the whole apex of the plant dropped down. As soon as fruiting began, the larvae moved to the flower buds, small fruits and even mature pods, causing reduction of yield.

A preliminary note on the control of OSFB was reported by Srinivasan *et al*. (1959) and they found 40-50% damaged okra fruit due to this pest in Madras. In another study Krishnaiah (1980) observed the attack of fruit borer to the extent of 35% in the harvestable fruit of okra.

The damage effects due to *E. vittella* on fruit number and weight in okra genotypes were studied by Sardana and Dutta (1989) in 1986. The result indicate that the least affected genotype (by fruit number) was IC 6653 with only 2.4% infestation compared to those of Bhindi 6 Dhari (2.8%) and La- Sel-1 (3.8%) with Sel 10 showed the highest infestation (38.7%). In 1989 (Bhindi 6 Dhari was least susceptible (2.4%). The infestation was on the bay of fruit weight was lowest in 1986 and 1987 in Bhindi 6 Dhari (1.2%) at Rajen 12 (1.8%), respectively.

2.6 Management of okra shoot and fruit borer

This borer is the major pest of okra, committing colossal losses to okra growers. Although various measures have been reported for controlling the pests, there is not a single such method that successfully be adopted to suppress the incidence and damage of the pests. This perhaps, is mainly due to the oligophagous nature of this pest that helps their year round population build up. Moreover, a thorough search of review reveals that the approaches that has ever been made in controlling this pest comprise mainly the use of chemicals. Although botanical management bears a lot of advantages, but unfortunately it got no global diffusion. Information regarding IPM for this pest is scant also. Some of the management approaches for these pests suggested by different workers are cited below.

2.6.1 Host plant resistance

Seventy two genotypes of okra were screened by Kashyap and Verma (1983) in Hariana, India against *Earias* spp. under field condition. Pest infestation and fruit yield were recorded on the basis both of numbers and weights. Less than 10% (on a weight basis) infestation was obtained in Parkins long green, *Clemson spineless*, White snow and Sel round cultivars compared to more than 50% in IC 12933, wild Bhindi and RI. The rest of the genotypes were intermediate.

Madav and Dumbre (1985) studied the reaction of 14 okra varieties against OSFB grown in the hot weather season of 1981 in Maharashtra. Varieties AE 75, Pusa sawani, Long green, Indo American hybrid and White valvet showed tolerance to shoot infestation by *E. vittella*. Indo American hybrid and Koparwadi local were found resistant to fruit infestation out of 25 varieties tasted in Rabi season of 1981-82. Bhalla *et al*. (1989) screened some okra germplasm to find out the field resistant against this borer during the Karif seasons of 1986 and 1987. Some 1000 okra germplasm were evaluated for this purpose, of which only 50 were moderately resistant and none was completely resistant.

2.6.2 Cultural control

Atwal (1976) reported that OSFB can be suppressed by clean cultivation and destruction of alternate host plants. Kashyap and Verma (1987) suggested that control of OSFB may be achieved through field sanitation, early sowing and resistant varieties when cotton is not growing in a locality.

The effect of nitrogen, phosphorus and potassium fertilizers on the incidence of noctuid *E. vittella* on okra was studied by Kumar and Urs (1988) in the field in Karnataka, India. The highest infestations were recorded in the plots treated with 250 and 30 kg of nitrogen and potassium per hectare, respectively. There were positive correlations between nitrogen uptake by the plant and E. vittella infestation. But there was negative correlation between potassium uptake by the plants and its infestation.

2.6.3 Botanical Control

Mallik and Lal (1989) reported that application of neem oil cake and fertilizer (2.5 kg of each on 200 square meter plot) or of neem oil cake alone (5 kg/plot) reduced *Earias spp*. of okra infestation and increased yield

Weekly application of neem (*Azadirachta indica*) oil at 2% was effective for controlling *E. vittella* on okra (Sardana and Kumar, 1989). They observed that the plots having lower fruit damage and increased yields in treated plots as compared those of untreated ones. Neem oil was found as effective as monocrotophos at 0.05%, and can therefore, be recommended for the use in an integrated control scheme for the pest.

Samuthiraveiu and David, (1991) reported that application of neem oil (at 0.1, 0.3 and 0.5%) and endosulfan at (0.035 and 0.07%), alone and together against the OSFB reduced damage and maximum yield was oB. t.ained with 0.07% endosulfan

Owusu *et al.* (2001) evaluated the performance of Aqueous Neem Seed Extract (ANSE) at 75 g/L of water (22.5 kg/ha) on Legon I variety of local garden egg in the field. The effect of ANSE was compared with a registered *Bacillus thuringiensis* Berl. (Biobit), a synthetic insecticide (Karate 2.5 EC) and an untreated control (water only). Karate and Biobit were applied at rate of 2.5 ml/L (800 ml/ha) and 0.8 g/L (0.24 kg/ha), respectively. The effect of each treatment on insect abundance, defoliators, shoot, bud and fruit borers were determined. Water traps were used to monitor the effect of the three products on the abundance of insect fauna associated with crop. Insects from seven major orders (Coleoptera, Lepidoptera, Odonata, Orthoptera, Diptera, Hemiptera and Hymenoptera) were found associated with the local garden egg. The major insect pests of the crop included the shoot and fruit borer, *Earias vittella*, which attacked the shoots and fruits, the bud borer (budworm) Scrobipalpa blapsigona (Meyrick), which oviposited into the buds and the feeding activities of the larvae, led to the abortion of buds, Pachnoda cordata (Drury) which scraped and chewed stem and shoot and defoliators comprising Acraea peneleos peneleos (Ward.), *Acraea pharsalus pharsalus* (Ward.), *Zonocerus variegatus* L., *Eulioptera* sp., *Urentius hystericellus* (Richter) and *Phaneroptera nana* (Stal.). Karate and ANSE significantly ($p<0.05$) reduced population levels of some major pests such as *P. cordata* and *Z. variegatus* than Biobit. The mean number of *E. vitella* in the shoots and buds, respectively were significantly higher ($p>0.05$) on plots treated with ANSE and Biobit than Karate. This suggests that neem seed extract and Biobit had little or no systemic action against shoot and bud borers of the crop in the field. Significantly fewer ($p<0.05$) numbers of predators mainly ants and ladybird beetles were collected from plants treated with Karate compared to either ANSE- or Biobit- treated plots. This indicates that Karate had adverse effects on beneficial insects in the garden egg ecosystem. Karate and ANSE also significantly ($p<0.05$) reduced percentage fruit damage, number of borers per fruit and the activities of leaf feeders. Although ANSE could not effectively control the shoot and bud borers as Karate, it performed better in reducing borer damage than either Biobit or control. With proper timing and innovative methods of application, aqueous neem seed extract can be used as alternative or supplement to synthetic insecticide for the management of vegetable pests of local garden eggs by resource poor farmers.

Mishra and Mishra (2002) conducted a field experiment during the wet season of 1995 and 1996 in Udayagiri, Orissa, India, to evaluate the efficacy of some biopesticides against the insect pests (*Amrasca biguttula biguttula* and *Aphis gossypii*) and defenders of okra. The botanical insecticides Neemax (neem seed kernel extract) at 1.0 kg/ha and Multineem (neem oil) at 2.5 litres/ha; and bioinsecticides Biotox (*Bacillus thuringiensis* subsp. *thuringiensis* serotype) at 1.0 kg/ha alternated with Malathion at 0.5 kg a.i./ha in different combinations were sprayed thrice over the crop at 20 days interval, starting from 20 days after germination. The results revealed lowest fruit borer incidence (8.6% fruit bored on weight basis) when Biotox was applied to the crop 2 times alternated with one Malathion application, followed by the treatment where Malathion was applied twice alternated with one Biotox application (10.6%). Multineem and Neemax combined with Malathion or sole Malathion application also lowered the fruit borer incidence (11.7-13.3%) compared to the untreated control, which had the highest incidence of 16.9%. The aphid population remained very low (50.7/top 3 leaves) in treatment where Biotox, Neemax and Multineem were applied once in succession, which was at par (52.2) with treatment where Multineem was applied in between 2 Malathion applications. The control plants maintained the highest aphid population (125). The predatory coccinellids and spiders were the main defenders existed in the field in both years. The predatory coccinellids were active in the biopesticide-treated plants and in the untreated plants. Their population remained extremely low in Malathion-treated plot. The spider population was found unaffected by the treatments. The application of Multineem and Neemax alternated with Malathion was as remunerative as the 3 applications of Malathion (7.83-8.67 thousand rupees/ha), except in Biotox application where the yield was found low due to higher aphid population. The untreated plot was the least remunerative (2.65 thousand rupees/ha).

Patil *et al.* (2002) carried out a field experiment in okra (cv. Arka Anamika) field, grown during the summer season of 1995 in Rahuri, Maharashtra, India, was sprayed with neem seed extract (2% NSE), *Bacillus thuringiensis* (0.03% B. t.) and cypermethrin 25 EC (0.0075%), applied alone, in combination or alternately, to control the fruit borers *Earias vittella* and *E. insulana*. Cypermethrin 25 EC was highly effective against okra fruit borers, recording only 15.55% fruit damage and resulting in a yield of 42.11 q/ha (compared with 52.82% damage and a yield of 22.88 q/ha in untreated control plants). The combination treatment NSE+cypermethrin controlled okra fruit borers effectively and recorded the lowest fruit damage of 14.48% and highest pod yield (67.22 q/ha). The cypermethrin-NSE-B. t.-cypermethrin sequence treatment recorded 15.33% fruit damage and a 50.77 q/ha fruit yield.

Sumathi and Balasubramanian (2002) conducted two field experiment during 1998 and 1999 to test the efficacy of different treatments viz., the egg parasitoid *Trichogramma chilonis* (TC), neem oil (NO), Palmarosa oil (PRO), neem seed kernel extract (NSKE) and endosulfan at varying economic threshold levels to reduce the fruit borers, *Earias vittella* Fabricius and *E. insulana* Boisduval damage. In both the experiments, spraying of endosulfan 0.07% was significantly superior in reducing the fruit borer damage on weight basis and the order of efficacy of different treatments in reducing the fruit damage was with endosulfan 0.07% (67.55 and 63.90%)>NSKE 5% (47.56 and 44.60%)>PRO 5% (42.40 and 37.15%)>NO (C) 3% (28.91 and 31.29%)>release of *Trichogramma chilonis* (T. C.) at 50 000/ha at 100% ETL i. e. 10.0% fruit damage (29.90 and 29.40%)>NO (A) 3% (28.91 and 31.29%)>T. C. at 7.5% fruit damage (24.65 and 22.62%)>T. C. at 5.0% fruit damage (20.63 and 17.96%)>T. C. at 2.5% fruit damage (15.26 and 13.33%). The cost:benefit ratio was maximum in endosulfan treatment and minimum with release of *T. chilonis* at 2.5% fruit damage.

Sasikala *et al.* (1999) studied during Rabi 1998-99 at the Agricultural College Farm, Bapatla for the management of the okra shoot and fruit borer, *Earias vittella*, involving eco-friendly methods. The treatments included 5% neem seed kernel extract (NSKE), neem oil (0.2%), *Bacillus thuringiensis* var. (B.t.) *kurstaki* (0.15%), lufenuron (0.02%), carbaryl (0.15%), their combinations (except NSKE), mechanical removal and destruction of infested shoots and fruits with larvae, and release of egg parasitoid, *Trichogramma japonicum* Ashm. Treatment by mechanical destruction of infested shoots and fruits with larvae, neem oil (0.2%) and release of the egg parasitoid, *T. japonicum* resulted in very good control of shoot and fruit borer as compared to control. The respective percentage of shoot infestation and fruit damage (on number basis) in these treatments were 14.46, 20.24; 21.06, 23.35; and 23.36 & 28.00 vis-a-vis 52.60 & 52.55 per cent in control plots. Plots treated with neem oil (0.2%), neem oil (0.1%) + B.t. (0.075%), neem oil (0.1%) + lufenuron (0.01%), and neem oil (0.1%) + carbaryl (0.075%) gave higher fruit yield (40.76, 33.80, 31.35 and 29.07 kg/plot, respectively, compared with 17.5 kg/plot oB. t.ained from control plots).

2.6.4 Bio-control agents for the management of okra shoot and fruit borer

2.6.4.1 *Trichogramma* egg parasitoid

Common name: Trichogramma

Scientific name: *Trichogramma evanescens*

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).

2.6.4.1.1 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).

2.6.4.1.2 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 develops 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* was not affected whatever the waiting tests 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 Anguimous 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, handling time and maximum attack rate were estimated, 0.168+or-0.055, 1.468+or-0.121 and 16.34, respectively.

2.6.4.2 The pathogenic bacterium *Bacillus thuringiensis*

Kingdom	: Eubacteria
Phylum	: Firmicutes
Class	: Bacilli
Order	: Bacillales
Family	: Bacillaceae
Genus	: *Bacillus*
Species	: *thuringiensis*

Bacillus thuringiensis (or B. t.) 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 caterpillars of various types of moths and butterflies, as well as on the dark surface of plants (Wikipedia).

2.6.4.2.1 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) 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 is 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.

Patel and Vyas (1999) reported that the compatibility of *B. t.* subsp. *kurstaki* (as Cutlass) with cypermethrin was studied against *E. vittella* and *S. litura*. Laboratory tests were carried out to determine the toxicity of the mixtures to the insects by feeding larvae okra pod slices (*E. vittella*) and castor leaves (S. litura) dipped in mixtures of insecticides at different concentrations. *B. t*. subsp. *kurstaki* was less effective against *S. litura* than *E. vittella*. It is suggested that B. t. subsp. *kurstaki* was compatible with cypermethrin.

Mandai *et al.* (2007) reported that combinations of bio-pesticides and eco-friendly chemicals were field evaluated in Samastipur, Bihar, India, during the summer seasons of 2000 and 2001 against the spider mite (*T. neocaledonicus*) for sustainable production of okra. The treatments comprised: *Bacillus thuringiensis* (B. t.)+endosulfan 35 EC (500 g+250 g/ha), B. t.+acephate 75 SP (500 g+300 g/ha), neem [*Azadirachta indica*] cake+neem oil+endosulfan 35 EC (200 kg+0.5 l+250 g/ha), N:P:K (69:72:90 kg/ha), endosulfan 35 EC (0.5 kg/ha), acephate 75 SP (300 g/ha), neem cake (200 kg/ha), neem oil (0.5 l/ha), and control. The pooled data revealed that neem cake+neem oil+endosulfan was the most effective, exhibiting the minimum mite population (6.8/leaf) and proved to be the best. It was followed by B. t.+endosulfan (9.8/leaf) and B. t.+acephate (11.9/leaf), which was at par with each other. The sole treatments, i.e. N:P:K, endosulfan, acephate, neem cake and neem oil, were also effective against the mite and showed population of 18.2, 19.3, 15.7, 23.8 and 28.8 per leaf, respectively, compared to the control (36.9/leaf).

Yadav *et al.* (2008) reported that a field experiment was conducted in Kanpur, Uttar Pradesh, India, during the 2005 and 2006 kharif seasons, to determine the yield and cost benefit ratio of okra cv. Azad bhindi-1 including economics of IPM modules against okra pests. The treatments comprised: 1.0 kg *Bacillus thuringiensis*/ha; 4.0 litres Neemarin/ha; 2.0 litres endosulfan/ha; 3 cards Trichogramma/ha. Maximum economic return was oB. t.ained with the application of *B. thuringiensis* followed by endosulfan; the return of Rs. 5888.0 was oB. t.ained in B. t. alone, Rs. 16 726.50 in neemarin - Trichogramma; Rs. 21 151.36 in B. t. - neemarin - Trichogramma spraying schedule. In overall treatments of combination, B. t. - neemarin - Trichogramma and B. t. - neemarin - endosulfan - Trichogramma module gave the highest economic return (Rs. 231 151.36 and Rs. 210 315.00). An increase in yield up to 15.8% were oB. t.ained in B. t. alone; 29.34% in B. t. - Trichogramma; 35.0% in neemarin - endosulfan - Trichogramma and 37.5% in B. t. - neemarin - endosulfan - Trichogramma module. The application of endosulfan - Trichogramma followed by application of neemarin - Trichogramma recorded the highest cost-benefit ratio of 1:15.3 and 1:13.3, respectively.

Mandal *et al.* (2006) reported that the efficacy of *Bacillus thuringiensis* (500 g/ha) applied alone or in combination with cartap (150 g/ha), acephate (300 g/ha), chlorpyrifos (250 g/ha), endosulfan (250 g/ha) and 0.5% Amrutguard in controlling pests infesting okra was determined in a field experiment conducted in Bihar, India during the summer of 2000-01. Treatment with *B. thuringiensis* in combination with endosulfan resulted in the lowest percentage of shoot infestation (9.10%) and percentage of fruit infestation by number

(17.35%) and by weight (16.03%), as well as the highest marketable fruit yield (123.14 q/ha), net income (Rs. 13 635.50/ha) and cost benefit ratio (1:2.96).

Sunitha *et al.* (2004) reported that field experiments were conducted during the 2002-03 rabi season in Bapatla, Andhra Pradesh, India, to study the relative toxicity of different groups of chemicals, viz. dichlorvos, nimbecidine, *Bacillus thuringiensis* (*B.t.*; Delfin), novaluron (IGR), spinosad and imidacloprid (neonicotinoid) and combination of dichlorvos, spinosad and imidacloprid with novaluron and *B.t.* against predatory coccinellid beetles *Cheilomenes sexmaculata* and *Micraspis univittata*. The results indicated that dichlorvos and imidacloprid alone were found to be toxic compared to their combination with eco-friendly chemicals. The treatments *B. t.* and nimbecidine were found to be relatively safe to coccinellids.

Mahapatro and Gupta (1999) reported that field collected spotted bollworm *Earias vittella* third instar larvae were reared on okra fruit pieces (previously dipped in different concentrations of commercial formulation of *Bacillus thuringiensis* subsp. *kurstaki* (*B. t.*) and dried) in crystal vials at 5 larvae per fruit per vial. Choice test for avoidance of *B. t.*-treated okra was conducted in crystal vials with one okra fruit treated with *B. t.* (Biobit) and the other left untreated. Spatial distribution of larvae in treated and untreated diet at 24 and 48 h was about 50% both in control, indicating no impact of the environment. Avoidance of the *B. t.*-treated okra by *E. vittella* increased as the *B. t.* concentration (Biobit, 32 000 IU/ml) increased. However, at higher concentrations, particularly above the LC< sub>50</ sub> (0.498% or 15.94 x 103 IU/ml at 24 h and 0.0166% or 5.31 x 102 IU/ml at 48 h) value, this specific effect was marked by its lethal action on the target insect.

Gurnam *et al.* (1998) reported that field studies were conducted in Udaipur, Rajasthan, India, during summer 1994 to determine the efficacy of insecticides (endosulfan, Malathion, neem seed oil, fenvalerate and *Bacillus thuringiensis* subsp. *kurstaki*) for the control of *Earias vittella* and *E. insulana* infesting okras (*Abelmoschus esculentus*). The results showed that the most effective level of control was achieved by adopting a spraying schedule consisting of fenvalerate 5 weeks, endosulfan 7 weeks, and fenvalerate 9 weeks after crop germination.

2.6.5 Management of okra shoot and fruit borer using microbial agents

Rabindra *et al.* (2007) conducted field experiments during 2003 and 2004 in Ranchi, Bihar, India, and the overall findings revealed that fruit damage caused by *Earias vitella* to the five promising okra cultivars (Pant Samarat, Muktakeshi, Pusa Purple Cluster, Pusa Purple Round, and Neelum Round) were drastically reduced by six foliar sprayings of Delfin WG (*Bacillus thuringiensis* var. *kurstaki)* at 1000 g/ha applied at 3-week intervals. The extent of fruit damage ranged from 4.66 to 23.54% and 5.14 to 25.97% in terms of weight and number, respectively, that in turn enhanced yield from 24.87 to 69.72% giving rise to extra production of marketable fruits of aubergine ranging from 5.03 to 9.14 t/ha. The overall findings indicated that adoption of protection measures is always profitable and promising, irrespective of cultivars of okra.

Anjali and Nidhi (2006) conducted a field study in Rajasthan, India, during 2002-04 to evaluate cypermethrin, carbaryl, endosulfan, Malathion, triazophos, *Bacillus thuringiensis* (B. t.) and B. t.+carbaryl for the control of okra shoot and fruit borer (*Earias vitella*). The results revealed that cypermethrin (0.007%) and carbaryl (0.02%) were at par with each other and were significantly superior to all other treatments in terms of percent shoot damaged, fruit damage on number and weight basis and on yield basis.

Nadaf *et al.* (2006) carried out a field experiment to study the effect of sequential applications of *Helicoverpa armigera* nuclear polyhedrosis virus (HaNPV) at 250 LE/ha, *Bacillus thuringiensis* subsp. *kurstaki* (*B. t.*k; Dipel) at 2 ml/l, Nimbecidine (5%) and carbaryl 50 WP on *H. armigera* on chilli (*Capsicum annuum cv. byadagi*) in Dharwad, Karnataka, India, during kharif 2001. *B. t.*k-HaNPV-B. t.k recorded significantly the lowest larval population (1.3 larvae per plant) after the first, second and third sprays. The main fruit damage was lowest (9.21%) and the yield of green chilli was significantly highest (14.34 q/ha) in B. t.k-HaNPV-B. t.k, with benefit:cost ratio of 1:93.

Swaroop *et al.* (2005) carried out a field experiment in Rajasthan, India, during the rabi seasons of 2002-03 and 2003-04 and integrated pest management modules were evaluated for the management of the fruit borer, *E. vittella*, infesting okra. The pooled results for the 2 seasons revealed that module-5 (M5) comprising 3-spray schedule of Ha nuclear polyhedrosis virus (HaNPV) (Helicide; 1.5x1012 POB/ha), *Bacillus thuringiensis* subsp. *kurstaki* (B. t.k) (Dipel 8L; 1500 ml/ha) and endosulfan (Endocel 35EC; 1250 ml/ha) at 15-day interval, starting at 45 days after transplanting (50% flowering), gave the maximum protection from the borer (9.1% fruit damage) compared to 33.98% in the untreated control

(M12) and the highest yield (91.98 q/ha) compared to 41.7 q/ha in M12. Cost-benefit (CB) analysis showed that the maximum C:B ratio was evident in module M4 (1:18.57) comprising 3 fortnightly sprays of endosulfan (Endocel 35EC; 1250 ml/ha), followed by M6 (1:16.89) comprising 3 sprays of 10% neem [*Azadirachta indica*] seed kernel extract at 50 kg/ha (NSKE), M9 (1:16.64) comprising one spray each of HaNPV, endosulfan and NSKE at their usual doses, M2 (1:16.38) comprising 3 sprays, i.e. HaNPV, endosulfan and HaNPV at 15-day interval, while the least C:B ratio was found in M8 (1:4.43) comprising 3-spray schedule of B. t.k, NSKE and endosulfan at their usual doses. The other treatments were: HaNPV + NSKE + B. t.k (M1), diflubenzuron (Dimilin 25WP; 300 g/ha) + endosulfan + diflubenzuron (M3), diflubenzuron + HaNPV + B. t.k (M7), DC-Tron Plus oil (2000 ml/ha) + endosulfan + DC-Tron Plus oil (M10), and novaluron (Rimon 10EC; 750 ml/ha)+endosulfan+novaluron (M11).

Mishra and Mishra (2002) conducted a field experiment during the wet season of 1995 and 1996 in Udayagiri, Orissa, India, to evaluate the efficacy of some biopesticides against the insect pests (*Amrasca biguttula biguttula* and *Aphis gossypii*) and defenders of okra. The botanical insecticides Neemax (neem seed kernel extract) at 1.0 kg/ha and Multineem (neem oil) at 2.5 litres/ha; and bioinsecticides Biotox (*Bacillus thuringiensis* subsp. *thuringiensis* serotype) at 1.0 kg/ha alternated with Malathion at 0.5 kg a.i./ha in different combinations were sprayed thrice over the crop at 20 days interval, starting from 20 days after germination. The results revealed lowest fruit borer incidence (8.6% fruit bored on weight basis) when Biotox was applied to the crop 2 times alternated with one Malathion application, followed by the treatment where Malathion was applied twice alternated with one Biotox application (10.6%). Multineem and Neemax combined with Malathion or sole Malathion application also lowered the fruit borer incidence (11.7-13.3%) compared to the untreated control, which had the highest incidence of 16.9%. The aphid population remained very low (50.7/top 3 leaves) in treatment where Biotox, Neemax and Multineem were applied once in succession, which was at par (52.2) with treatment where Multineem was applied in between 2 Malathion applications. The control plants maintained the highest aphid population (125). The predatory coccinellids and spiders were the main defenders existed in the field in both years. The predatory coccinellids were active in the biopesticide-treated plants and in the untreated plants. Their population remained extremely low in Malathion-treated plot. The spider population was found unaffected by the treatments. The application of Multineem and Neemax alternated with Malathion was as remunerative as the 3 applications of Malathion (7.83-8.67 thousand rupees/ha), except in Biotox application where the yield was found low due to higher aphid population. The untreated plot was the least remunerative (2.65 thousand rupees/ha).

Patil *et al.* (2002) carried out a field experiment in okra (cv. Arka Anamika) field, grown during the summer season of 1995 in Rahuri, Maharashtra, India, was sprayed with neem seed extract (2% NSE), *Bacillus thuringiensis* (0.03% B. t.) and cypermethrin 25 EC (0.0075%), applied alone, in combination or alternately, to control the fruit borers *Earias vittella* and *E. insulana*. Cypermethrin 25 EC was highly effective against okra fruit borers, recording only 15.55% fruit damage and resulting in a yield of 42.11 q/ha (compared with 52.82% damage and a yield of 22.88 q/ha in untreated control plants). The combination treatment NSE+cypermethrin controlled okra fruit borers effectively and recorded the lowest fruit damage of 14.48% and highest pod yield (67.22 q/ha). The cypermethrin-NSE-B. t.-cypermethrin sequence treatment recorded 15.33% fruit damage and a 50.77 q/ha fruit yield.

Sumathi and Balasubramanian (2002) conducted two field experiment during 1998 and 1999 to test the efficacy of different treatments viz., the egg parasitoid *Trichogramma chilonis* (TC), neem oil (NO), Palmarosa oil (PRO), neem seed kernel extract (NSKE) and endosulfan at varying economic threshold levels to reduce the fruit borers, *Earias vittella* Fabricius and *E. insulana* Boisduval damage. In both the experiments, spraying of endosulfan 0.07% was significantly superior in reducing the fruit borer damage on weight basis and the order of efficacy of different treatments in reducing the fruit damage was with endosulfan 0.07% (67.55 and 63.90%)>NSKE 5% (47.56 and 44.60%)>PRO 5% (42.40 and 37.15%)>NO (C) 3% (28.91 and 31.29%)>release of *Trichogramma chilonis* (T. C.) at 50 000/ha at 100% ETL i. e. 10.0% fruit damage (29.90 and 29.40%)>NO (A) 3% (28.91 and 31.29%)>T. C. at 7.5% fruit damage (24.65 and 22.62%)>T. C. at 5.0% fruit damage (20.63 and 17.96%)>T. C. at 2.5% fruit damage (15.26 and 13.33%). The cost: benefit ratio was maximum in endosulfan treatment and minimum with release of *T. chilonis* at 2.5% fruit damage.

Molina *et al.* (2005) carried out a field study and the purpose of this work was to evaluate the potential of *T. atopovirilia* and *T. pretiosum* as agents for the control of E. aurantiana, an important pest of citrus in Sao Paulo (southeastern Brazil). Biology under different temperatures, thermal requirements and parasitism capacity were carried out. The temperatures (18, 20, 22, 25, 28, 30 and 32 degrees C) did not affect the sex ratio; however, female longevity in both species was higher at 22 and 25 degrees C. A temperature of 25 degrees C tended to be more suitable for emergence rate and female longevity. The egg-to-adult period for both *Trichogramma* species was inversely proportional to temperature. The thermal requirements of the 2 species were very similar, approximately 108 degree days. Neither the natural rearing host, *E. aurantiana*, nor the alternative host Anagasta kuehniella [*Ephestia kuehniella*], affected the number of parasitized eggs per Trichogramma female. The parasitism rate and the number of emerged adults per egg on *E. aurantiana* eggs were higher than on *A. kuehniella* eggs. However, the emergence rate was higher when the parasitoids were reared on *A. kuehniella* eggs. Both Trichogramma species could be tested in the field for citrus fruit borer control. The thermal requirements and the parasitism capacity could be good parameters for the selection of Trichogramma species/strains.

2.6.6 Chemical control

Misra (1989) studied the bio-efficacy of some insecticides against the pest complex of okra. The author reported that percent shoot infestation in insecticide treated plots varied from 1.74-10.03% compared to 15.23% in untreated control plots.

Gopalan *et al*. (1974) reported that the best result can be achieved to control *E. vittella* with two applications of sevimol I %, monocrotophos 0. 1 % or endosulfan 0.9% at the 45 and 60 days after sowing the crop.

Mote and Pokharkar (1974) recommended that endosulfan 0.05% at 15 days intervals starting at fruit setting stage is the safest treatment to control OSFB.

Venkatanarayanan *et al*. (1974) tried different insecticides in combination with urea in controlling OSFB and oB. t.ained that urea at 2% and 3% concentration could be safely mixed with 0.07 % endosulfan, 0.1 % sevimol and 0.1 % nuvacron without affecting their insecticidal properties. However, urea at 4 and 6% with or without insecticides scorched the leaves.

Krishnakumar and Srinivasan (1985) reported that a significant reduction in *E. vittella* incidence on okra was obtained with fenvalerate, cypermethrin and deltamethrin at 50, 30 and 10 gill/ha, respectively when applied at 25 days intervals compared to those applied at 35 days intervals. However, there were no significant differences in marketable yield among the treatments applied at 25 and 35 days intervals suggesting a possibility of extending the spray interval.

Sardana and Tewari (1987) reported that dipping the pupae of OSFB in diflubenzuron suspension of 125 ppm or more for 30 second resulted in papal mortality. The effectiveness of the chemical decreased with increase of papal age.

Dhamdhere *et al*. (1988) stated that 0.15 % thiodicarp was more effective than the other carbamate tested for the control of OSFB on the basis of percent fruit infestation, yield and economic considerations and was as effective as 0.03% oxydemeton methyl.Pawar *et al*. (1988) reported that single spray of endosul fan at 500 gm/ha followed by 3 applications of cypermethrin or fenvalerate at 50 gm/ha at intervals of 14 days were the most effective for the control of *E. vittella* of okra.

Chauhan (1989) recommended 2.03 % endrin as early as possible in the infested crop for the control of the noctuid OSFB and to be repeated one or twice if necessary.Ratanpara and Bharodia (1989) reported that application of fenvalerate at 0.015% for the control of okra fruit and shoot borer gave lowest infestation levels and highest yield

Sarkar and Nath (1989) conducted a field trial in Tripura, India, and indicated that decamethrin, Malathion, endosulfan and carbaryl were effective to control the OSFB but fenvalerate (0.5 ml/1 and 750 ml/ha) gave the greatest reduction in number of infested fruits.Konar and Rai (1990) found that two applications of Malathion at 1000 inl/ha for the control of OSFB provided significant control ofthe pest followed by carbaryl. David and kumaraswami (1991) stated that cypermethrin at 0.016%, deltamethrin at 0.003 % or 0.002 % and fenvalerate at 0.01 % were the most effective treatments for the control of *Earias* spp. on okra.

A field experiment was conducted by Patil *et al*. (1991) in India for the control of the okra fruit and shoot borer (*E. vittella*). They treated okra plants with cypermethrin (15 gm/ha), fenvalerate (50 gm/ha), acephat (375 gm/ha), quinaphos (250 gm/ha) and endosulfan (250 gm/ha). All treatments reduced pod damage but cypermethrin treated plants were the least infested and gave the best yield.

Krishnakumar and Srinivasan (1987) reported that treatment with endosulfan at 500 g/ha sprayed 15 days after germination followed by 3 applications of fenvalerate at 50 g/ha 40, 55 and 70 days after germination were most cost effective is controlling insect pests of okra (*Earias vittella*) for summer and winter.

Chaudhury *et al*. (1989) reported that if the insecticidal protection was not given the OSFB infested fruits were as much as 57.1 % with a yield of 9.83 kg/plot. But the plots protected with alternate weekly sprays of 0.03 % phosphamidon and 0.05 % endosulfan provided yield of 15.65 kg/plot with 10 % fruit infestation.

The economics of pest management of OSFB were studied by Srinivasan and Krishnakumar (1983) in Karnataka, India, for 3 growing seasons. Disulfotorl granules at 1 kg ai/ha applied at the time of sowing, followed by 0.1% carbaryl sprays at 40, 50 and 60 plays alter germination in the rainy and late summer growing seasons, or 40 and 55 days after germination in the winter season, gave the maximum crop yield and net income.

CHAPTER III

MATERIALS AND METHODS

The present study for the eco-friendly management of okra shoot and fruit borer through bio-control agents was carried out using a variety of BARI Dherosh-I in the experimental farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, during February to June, 2009. The materials and methods adopted in the study are discussed under the following sub-headings:

3.1 Description of the field experimental site

3.1.1 Experimental site

The research work was carried out at the experimental field of Entomology Department of Sher-e- Bangla Agricultural University, Dhaka during the period from February to June 2009 for the eco-friendly management of okra shoot and fruit borer through bio-control agents. The soil of the experimental site was well drained and medium high. Physical and chemical properties of soil, climatic condition (monthly) during the experimental period has been plotted in Appendix I and Appendix II. The soil of the experimental plots belonged to the agro ecological zone Madhupur Tract (AEZ-28).

3.1.2 Climate

The climate of the experimental site is sub-tropical characterized by heavy rainfall during March to June and sporadic during the rest of the year. The detail record of monthly total rainfalls, temperature, and humidity during the period of experiment were noted from the Bangladesh Meteorological Department (climate division), Agargaon, Dhaka-1212 and has been presented in Appendix I.

3.1.3 Design of the experiment and layout

The experiment was conducted in randomized complete block design with three replications. A good tilth area was divided into three main blocks. Each main block was sub-divided into 2l sub-plots each of which was of 2m × 3m with maintaining 0.75m borders and used experimental units where the treatments were assigned randomly.

3.1.4 Land preparation

The experimental land was first opened with a country plough. Ploughed soil was then brought into desirable final tilt by four operations of ploughing followed by laddering. The stubbles of the crops and uprooted weeds were removed from the field and the land was properly leveled. The field layout was done on accordance to the design, immediately after land preparation. The plots were raised by 10 cm from the soil surface keeping the drain around the plots.

3.1.5 Manures, fertilizer and their methods of application

Manures and fertilizers with their doses and their methods of application followed in this study recommended by Haque (1993) are shown in Appendix III.

3.1.6 Collection and sowing of okra seeds

Seeds were collected from the BARI, Joydebpur, Gazipur. Before sowing seeds, the germination test was done to ensure standard viability measuring; approximately 90% germination. Pre-soaked, for 48 hrs to ensure germination, seeds were sown in the experimental plots. Irrigation and other intercultural operations were done as required.

3.1.7 Stock culture of bio-control agents

The bio-control agents viz. parasitic wasps (*Trichogramma evanescens* egg parasitoid and *Bracon hebetor* larval parasitoid) and pathogenic bacterium *Bacillus thuringiensis* were purchased from Safe Agro Bio Tech Ltd. The egg parasitoid *T. evanescens* were reared on the eggs of rice moth *(Sitotroga cerealla). Trichogramma evanescens* was purchased in the form of parasitized rice moth’s (host) egg. The larval parasitoid *B. hebetor* was reared on the larvae of Galleria moth and was purchased, as adult bracon. Adult bracon was carried out from the traders with big size test tube. The open mouth of the test tube containing adult bracon was closed with cotton plug. The pathogenic bacterium *B. thuringiensis* was purchased as B. T. suspension.

3.1.8 Treatment application

The assigned treatments was started to apply in the plots with the first incidence of the adult okra shoot and fruit borer in the field.

3.1.9 Application of bio-control agents

Treatments comprising different bio-control agents were applied in their respective plots at 7 days interval up to crop maturity. All the parasitic wasps were collected from the traders every day just before releasing in the field.

i) Trichogramma release: The treatments comprising *Trichogramma evanescens* egg parasitoid (T_1= Application of *Trichogramma evanescense* @ 5 Tricho card / plot at 7 days interval and T_2 = Application of *Trichogramma evanescense* @ 0.08 g / plot at 7 days interval) was released in the plots in the paper chocolate form of their parasitized host's eggs. The release of parasitized host's eggs was done in the middle of the plot.

Plate 1. Parasitizing process of Trichogramma on host's eggs

ii). Bracon release: The treatments comprising adults of *Bracon hebetor* (T_3 = application of *Bracon hebetor* @ 10 adults (Male : Female = 4 : 6)/ plot at 7 days interval and T_4= application *Bracon hebetor* @ 15 adults (Male : Female = 6 : 4)/ plot at 7 days interval) was released directly in the middle of the plots. The Bracon treated plot was surrounded at least for 24 hours by fine mosquito net supported by bamboo sticks to protect the drift flying effect.

Plate 2. Parasitizing process of Bracon

iii. Spraying of *B. thuringiensis:* The treatments comprising *B. thuringiensis* suspension (T_5 =application of *Bacillus thuringiensis* Serovar k*urstaki* @ 2ml suspension /liter water / plot at 7 days interval and T_6= application of *Bacillus thuringiensis* Serovar k*urstaki* @ 1ml suspension /liter water / plot at 7 days interval) mixing with water was sprayed in the plots with the help of knapsack sprayer.

3.1.10 Cultural operation

After sowing seeds light irrigation was given to each plot. Supplementary irrigation was applied at an interval of 2-3 days. Dead or damaged seedlings were replaced immediately by new one from the stock. Weeding was done five times to break the soil crust and to keep the plot free from weeds. Stagnant water was drained out at the time of heavy rain. The area was top dressed in two splits as mentioned earlier.

3.1.11 Data collection

Data were collected on different parameters as per requirement under the present study.

Infestation of okra plants by okra shoot and fruit borer were monitored during both vegetative and reproductive stages. Number of infested shoots from 10 randomly selected plants per plot were counted and recorded at weekly interval after careful examination on the presence of borer and excreta at both vegetative and reproductive stage. Moreover, at reproductive stage, the infested fruits from 10 randomly selected plants were also checked for OSFB infestation and recorded at 3 days interval (during the time of harvesting). The procedure and measurement of data collection were maintained as mentioned below:

3.1.11.1 Shoot infestation

The total number of shoots and the number of infested shoots were recorded from 2 plants from each plot at 7 days intervals. Shoot infestation was calculated in percent using the following formula:

$$\% \text{ Shoot infestation} = \frac{\text{Number of infested shoots}}{\text{Number of total shoots}} \times 100$$

$$\% \text{ reduction or increase over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where, X_1= the mean of treated plot

X_2= the mean of untreated control plot

Plate 3. The experimental plots at SAU, Dhaka

3.1.11.2 Number of borer infested fruits

Mean number of borer infested fruits from randomly selected 10 plants were measured at each plot of the experiment.

The percent infestation of fruit was calculated with the following procedures

$$\% \text{ Infested fruit} = \frac{\text{Number of infested fruits}}{\text{Total number of fruits}} \times 100$$

Plate 4. Okra showing borer infestation symptom

3.1.11.3 Weight of borer infested fruits

Mean weight of borer infested fruits from randomly selected 10 plants were measured at each plot of the experiment.

3.1.11.4 Weight of healthy fruits

Mean number of healthy fruits from randomly selected 10 plants were measured at each plot of the experiment.

3.1.11.5 Total number of fruits/plot

Mean weight of healthy fruits from randomly selected 10 plants were measured at each plot of the experiment.

3.1.11.6 Total fruit weight/plot

Total fruit weight/plot was taken from randomly selected 10 plants and converted to per plot measurement of total population of 6 m^2 plot.

Plate 5. Okra showing healthy fruit

3.1.11.7 Length of healthy fruit/plant

Length of healthy fruit from randomly selected 10 plants was taken and then averaged.

3.1.11.8 Girth of healthy fruit/plant

Girth of healthy fruit from randomly selected 10 plants was taken and then averaged.

3.1.11.9 Length of infested fruit/plant

Length of infested fruit from randomly selected 10 plants was taken and then averaged.

3.1.11.10 Girth of infested fruit/plant

Girth of infested fruit from randomly selected 10 plants was taken and then averaged.

3.1.11.11 Total fruit yield/ha

Total fruit yield/ha was measured from total yield of 6 m^2 plot.

3.1.11.12 Total healthy fruit yield/ha

Total weight of healthy fruit/ha was calculated from total healthy fruit recorded per plot.

3.1.11.13 Infestation intensity per fruit

The infestation intensity expressed in terms of number of bores per fruit has also been considered as one of the parameters for differentiating the effectiveness of the treatments. The reason behind this is that although even a single number of bore in the fruit designates it as infested fruit, the extent of damage and market price are likely to vary depending on the number of bore per fruit i. e., infestation intensity per fruit. For convenience of expression of infestation intensity per fruit, four scales corresponding to the number of bores per fruit have been used as follows.

Scale 1 (Low intensity)	:	1-2 bores per fruit
Scale 2 (Moderate intensity)	:	3-4 bores per fruit
Scale 3 (High intensity)	:	5-6 bores per fruit
Scale 4 (Very high intensity)	:	> 7 bores per fruit.

Such type of scale also reported by Rahman (1999). The infested fruits per 6 sample plants at each harvest were counted and then sorted out into 4 scales based on the number of bores per fruit as above. The total number of infested fruit was obtained by summing up those of the 08 harvests altogether while the total number of' infested fruits belonging to each of the above 4 scales was obtained by summing up those of 08 harvests scale wise. Then the percent of each of above 4 scales was calculated using the following formula:

$$\% \text{ of scale i} = \frac{\text{Number of infested fruits belonging to scale i}}{\text{Total number of' infested fruits}} \times 100$$

where i = ranged from scale 1 to scale 4.

3.2 Details of the treatments for okra shoot and fruit borer

T_1 = Application of *Trichogramma evanescense* @ 5 Tricho card / plot at 7 days interval

T_2 = Application of *Trichogramma evanescense* @ 0.08 g / plot at 7 days interval

T_3 = Application of *Bracon hebetor* @ 10 adults (Male : Female = 4 : 6)/ plot at 7 days interval

T_4 = Application of *Bracon hebetor* @ 15 adults (Male : Female = 6 : 4)/ plot at 7 days interval

T_5 = Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension /liter water / plot at 7 days interval

T_6 = Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 1ml suspension /liter water / plot at 7 days interval

T_7 = Untreated control

3.3 Economic analysis of different management practice

For benefit cost analysis record of costs incurred in each treatment and that of control we maintained, similarly, the price of the harvested fruits of each treatment and that of control were calculated at market rate. Benefit-Cost analysis was expressed in terms of Benefit-Cost ratio (BCR).

3.4 Statistical analysis of data

The recorded data were compiled and tabulated for statistical analysis. Analysis of variance was done with the help of computer package program MSTAT-C software. The treatment means were separated by Duncan's Multiple Range Test (DMRT) and Least Significant Difference (LSD) (Gomez, 1984).

CHAPTER IV
RESULTS AND DISCUSSION

The comparative effectiveness of different bio-control agents applied for eco-friendly management of okra shoot and fruit borer in the experimental field of Sher-e-Bangla Agricultural University, Dhaka during kharif I season from February to June of 2009 was evaluated. The results of the study and discussion under different tables containing results of different parameters have been presented in the following sections.

4.1 Effect of bio-control agents on the shoot infestation

Significant variation was observed in terms of percent shoot infestation at different growth stages of okra during the management of okra shoot and fruit borer (Table 1). The lowest shoot infestation was recorded in T_5 (5.17%) comprised with the application of 2ml suspension of *Bacillus thuringiensis* Serovar *kurstaki* /litre water at 7 days interval, where as the highest (14.25%) shoot infestation was in untreated control treatment at early growth stage of okra. The highest shoot infestation was observed with T_3 (7.67%) which was statistically similar with T_2 (7.08%) and T_4 (7.42%) followed by T_6 (6.08%) and T_1 (6.58%). Similar trend was observed at mid and late growth stages of okra. The lowest shoot infestation was found in T_5 both at mid and late growth stage (14.75% and 25.67%, respectively). Where the highest shoot infestation (36.83% and 51.33%, respectively) was in untreated control treatment. But in case of treated plots, the highest shoot infestation at mid and late growth stage (24.08% and 38.17%, respectively) was in T_3 (application of 5 Tricho card with *Trichogramma evanescense* followed by T_1 (18.00% and 33.50%, respectively), T_2 (20.00% and 35.33%, respectively).

Considering the mean infestation, the lowest shoot infestation was recorded in T_5 (15.20%) followed by T_6 (17.64%), T_1 (19.36%) and T_2 (20.80%). On the other hand, the highest shoot infestation (34.14%) was recorded in T_7 (untreated control) followed by T_3 (23.31%) and T_4 (22.21%). In case of shoot infestation reduction over control, the highest reduction (57.90%) was observed in T_5 followed by T_6 (51.08%), T_1 (46.56%) and T_2 (42.39%), whereas the lowest reduction shoot infestation over control was recorded in T_3 (35.49%) followed by T_4 (38.50%).

From the above findings it was revealed that the T_5 comprised with the application of 2 ml suspension of *Bacillus thuringiensis* Serovar *kurstaki* / litre water had performed as best treatment in terms of the highest reduction of shoots infestation over control.

The result obtained from the present study was similar with the findings of Rabindra *et al.* (2007) and Satpute *et al.* (2002).

Table 1: Effect of bio-control agents on the shoot infestation applied against okra shoot and fruit borer at different fruiting stages

Treatment	% Shoot infestation							
	Early fruiting stage	% reduction over control	Mid fruiting stage	% reduction over control	Late fruiting Stage	% reduction over control	Mean (%)	% reduction over control
T_1	6.58 c	53.80	18.00 e	51.13	33.50 e	34.74	19.36 d	46.56
T_2	7.08 b	50.29	20.00 d	45.70	35.33 d	31.17	20.80 d	42.39
T_3	7.67 b	46.20	24.08 b	34.62	38.17 b	25.65	23.31 b	35.49
T_4	7.42 b	47.95	22.33 c	39.37	36.88 c	28.17	22.21 c	38.50
T_5	5.17 e	63.74	14.75 g	59.95	25.67 g	50.00	15.20 f	57.90
T_6	6.08 d	57.31	16.75 f	54.52	30.08 f	41.40	17.64 e	51.08
T_7	14.25 a	--	36.83 a	--	51.33 a	--	34.14 a	--
$LSD_{0.05}$	0.654	--	1.002	--	1.224	--	1.015	--
CV (%)	5.43	--	6.38	--	8.57	--	7.38	--

In column the treatment means with same letters indicate the statistically similar at 5% level of significance

T_1= Application of *Trichogramma evanescense* @ 5 Tricho card / plot at 7 days interval
T_2= Application of *Trichogramma evanescense* @ 0.08 g / plot at 7 days interval
T_3= Application of *Bracon hebetor* @ 10 adults (Male: Female = 4: 6)/ plot at 7 days interval
T_4= Application of *Bracon hebetor* @ 15 adults (Male: Female = 6: 4)/ plot at 7 days interval
T_5= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension /liter water / plot at 7 days interval
T_6= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 1ml suspension /liter water / plot at 7 days interval
T_7= Untreated control

4.2 Effect of bio-control agents on the fruit infestation by number

Significant influence was observed by different treatments in terms of percent fruit infestation by number at different fruiting stages of okra as affected by okra shoot and fruit borer (Table 2). The lowest fruit infestation by number (12.44%) was recorded in T_5 where as the highest (42.66%) was in untreated control at early fruiting stage of okra. The results at early fruiting stage under treated plots, the highest fruit infestation by number was observed in T_3 (33.13%) followed by T_1 (18.63%), T_2 (21.63%), T_4 (29.02%) and T_6 (16.47%). Similar trend was observed at mid and late fruiting stages of okra. The lowest fruit infestation by number at mid and late fruiting stage (14.56% and 17.61%, respectively) was in T_5, while the highest (48.02% and 65.16% at mid and late fruiting stage respectively) was in untreated control. But in terms of treated plots, the highest fruit infestation by number at mid and late fruiting stage (36.47% and 41.86%, respectively) was in T_3 followed by T_1 (21.08% and 28.23%, respectively), T_2 (24.88% and 30.08%, respectively).

Considering the mean infestation, the lowest fruit infestation by number (14.87%) was recorded in T_5 followed by T_6 (18.98%), T_1 (22.65%) and T_2 (25.53%). On the other hand, the highest fruit infestation (51.95%) was recorded in T_7 (untreated control) followed by T_3 (37.15%) and T_4 (32.11%). In case of fruit infestation reduction over control, the highest reduction (55.28%) was observed in T_5 followed by T_6 (50.29%), T_1 (44.37%) and T_2 (41.70%), whereas the lowest reduction fruit infestation over control was recorded in T_3 (24.73%) followed by T_4 (29.40%).

From the above findings it was revealed that the T_5 comprised with the application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2 ml suspension / litre water had performed as the best treatment in terms of the highest reduction of fruit infestation over control.

The results obtained from the present study was similar with the findings of Swaroop *et al.* (2005).

Table 2: Effect of bio-control agents on the fruit infestation by number applied against okra shoot and fruit borer at different fruiting stages

Treatment	% Fruit infestation by number							
	Early fruiting stage	% reduction over control	Mid fruiting stage	% reduction over control	Late fruiting stage	% reduction over control	Mean (%)	% reduction over control
T_1	18.63 e	36.22	21.08 e	52.09	28.23 e	44.80	22.65 e	44.37
T_2	21.63 d	34.41	24.88 d	46.56	30.08 d	44.13	25.53 d	41.70
T_3	33.13 b	14.29	36.47 b	25.22	41.86 b	34.68	37.15 b	24.73
T_4	29.02 c	18.31	32.27 c	32.37	35.04 c	37.51	32.11 c	29.40
T_5	12.44 g	44.47	14.56 g	64.73	17.61 g	56.65	14.87 g	55.28
T_6	16.47 f	39.64	17.64 f	58.43	22.82 f	52.80	18.98 f	50.29
T_7	42.66 a	--	48.02 a	--	65.16 a	--	51.95 a	--
$LSD_{0.05}$	1.284	--	1.542	--	1.664	--	2.114	--
CV (%)	6.54	--	7.49	--	9.38	--	8.39	--

In column the treatment means with same letters indicate the statistically similar at 5% level of significance

T_1= Application of *Trichogramma evanescense* @ 5 Tricho card / plot at 7 days interval
T_2= Application of *Trichogramma evanescense* @ 0.08 g / plot at 7 days interval
T_3= Application of *Bracon hebetor* @ 10 adults (Male: Female = 4: 6)/ plot at 7 days interval
T_4= Application of *Bracon hebetor* @ 15 adults (Male: Female = 6: 4)/ plot at 7 days interval
T_5= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension /liter water / plot at 7 days interval
T_6= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 1ml suspension /liter water / plot at 7 days interval
T_7= Untreated control

4.3 Effect of bio-control agents on the fruit infestation by weight

Different treatments had significant influence on percent fruit infestation by weight at different fruiting stages of okra as affected by okra shoot and fruit borer (Table 3). As shown in Table 3, the lowest fruit infestation by weight (11.97 %) was recorded in T_5 where as the highest (40.83 %) fruit infestation recorded in with untreated control treatment at early fruiting stage of okra. The results at early fruiting stage under treated plots, the highest fruit infestation by weight was observed in T_3 (31.74%) followed by T_1 (17.83%), T_2 (20.89%), T_4 (27.90%) and T_6 (15.90%). Similar trend was observed at mid and late fruiting stages of okra. The lowest fruit infestation by weight at mid and late fruiting stage (14.00% and 16.96%, respectively) fruit was recorded in T_5 while the highest

(45.97% and 62.38% at mid and late fruiting stage respectively) fruit infestation was recorded in untreated control. But in terms of treated plots, the highest fruit infestation by weight at mid and late fruiting stage (35.01% and 40.11% respectively) was recorded in T_3. Considering the mean infestation, the lowest fruit infestation by weight (14.31%) was recorded in T_5 followed by T_6 (18.29%), T_1 (21.63%) and T_2 (24.66%) on the other hand, the highest fruit infestation (49.73%) was recorded in T_7 (untreated control) followed by T_3 (35.62%) and T_4 (30.91%). In case of fruit infestation reduction over control, the highest reduction (48.97%) was observed in T_5 followed by T_6 (44.63%), T_1 (38.70%) and T_2 (36.05%), whereas the lowest reduction fruit infestation over control was recorded in T_3 (19.74%) followed by T_4 (23.67%).

From the above findings it was revealed that the T_5 comprised with the application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2 ml suspension / litre water had performed as the best treatment in terms of the highest reduction of fruit infestation over control.

The results obtained from the present study were similar with the findings of Swaroop *et al.* (2005).

Table 3: Effect of bio-control agents on the fruit infestation by weight applied against okra shoot and fruit borer at different fruiting stages

Treatment	% Fruit infestation by weight							
	Early fruiting stage	% reduction over control	Mid fruiting stage	% reduction over control	Late fruiting stage	% reduction over control	Mean (%)	% reduction over control
T_1	17.83 e	29.59	20.07 e	47.44	27.00 e	39.08	21.63 e	38.70
T_2	20.89 d	28.06	24.00 d	41.45	29.09 d	38.63	24.66 d	36.05
T_3	31.74 b	8.67	35.01 b	20.17	40.11 b	30.38	35.62 b	19.74
T_4	27.90 c	11.73	31.05 c	26.92	33.77 c	32.37	30.91 c	23.67
T_5	11.97 g	36.73	14.00 g	59.83	16.96 g	50.34	14.31 g	48.97
T_6	15.90 f	32.65	16.99 f	53.76	21.98 f	47.48	18.29 f	44.63
T_7	40.83 a	--	45.97 a	--	62.38 a	--	49.73 a	--
$LSD_{0.05}$	1.244	--	1.347	--	1.286	--	1.285	--
CV (%)	4.25	--	6.17	--	7.34	--	9.27	--

In column the treatment means with same letters indicate the statistically similar at 5% level of significance

T_1= Application of *Trichogramma evanescense* @ 5 Tricho card / plot at 7 days interval
T_2= Application of *Trichogramma evanescense* @ 0.08 g / plot at 7 days interval
T_3= Application of *Bracon hebetor* @ 10 adults (Male: Female = 4: 6)/ plot at 7 days interval
T_4= Application of *Bracon hebetor* @ 15 adults (Male: Female = 6: 4)/ plot at 7 days interval
T_5= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension /liter water / plot at 7 days interval
T_6= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 1ml suspension /liter water / plot at 7 days interval
T_7= Untreated control

4.4 Fruit yield

4.4.1 Healthy fruit yield

Healthy fruit yield was significantly influenced by different bio-control agents at different fruiting stages of okra as affected by okra shoot and fruit borer (Table 4). Results showed that the highest healthy fruit yield (912 kg/ha, 2886 kg/ha and 1586 kg/ha at early, mid and late fruiting stage, respectively) of okra was recorded in T_5, where the lowest (284 kg/ha, 1375 kg/ha and 395 kg/ha at early, mid and late fruiting stage respectively) was recorded in untreated control. Among the treated plots, the lowest healthy fruit yield (385 kg/ha, 1734 kg/ha and 681 kg/ha at early, mid and late fruiting stage respectively) was observed by T_3.

The results obtained from another treatment, T_6 (698 kg/ha, 2644 kg/ha and 1221 kg/ha at early, mid and late fruiting stage respectively) showed higher healthy fruit but significantly different from others. T_1 (636 kg/ha, 2450 kg/ha and 1079 kg/ha at early, mid and late fruiting stage respectively) and T_2 (534 kg/ha, 2169 kg/ha and 980 kg/ha at early, mid and late fruiting stage respectively) also showed intermediate healthy fruit yield compared to other treatments.

Thus it is seen from Table 4 that T_5 gave the significantly highest increase of healthy fruit yield at early (221.13%), mid (109.90%) and late fruiting stage (301.52%) over control. Treatment, T_6 (145.77%, 92.29%, and 209.11% at early, mid and late fruiting stage respectively) also showed higher increase of healthy fruit yield over control where the lowest increase of healthy fruit yield fruit over control at early, mid and late fruiting stages were 35.56%, 26.11% and 72.41% respectively in T_3.

Table 4: Effect of bio-control agents on healthy fruit yield applied against okra shoot and fruit borer at different fruiting stages

Treatment	Healthy fruit yield (kg/ha)							
	Early fruiting stage	% increase over control	Mid fruiting stage	% increase over control	Late fruiting stage	% increase over control	Mean (%)	% increase over control
T_1	636 c	123.94	2450 c	78.18	1079 c	173.16	1388.33 c	125.09
T_2	534 d	88.03	2169 d	57.75	980 d	148.10	1227.67 d	97.96
T_3	385 f	35.56	1734 f	26.11	681 f	72.41	933.33 f	44.693
T_4	447 e	57.39	1899 e	38.11	869 e	120.00	1071.67 e	71.833
T_5	912 a	221.13	2886 a	109.90	1586 a	301.52	1794.67 a	210.85
T_6	698 b	145.77	2644 b	92.29	1221 b	209.11	1521.00 b	149.06
T_7	284 g	--	1375 g	--	395 g	--	684.67 g	--
$LSD_{0.05}$	4.365	--	6.129	--	5.254	--	5.368	--
CV (%)	9.58	--	10.49	--	8.76	--	10.57	--

In column the treatment means with same letters indicate the statistically similar at 5% level of significance

T_1= Application of *Trichogramma evanescense* @ 5 Tricho card / plot at 7 days interval

T_2= Application of *Trichogramma evanescense* @ 0.08 g / plot at 7 days interval

T_3= Application of *Bracon hebetor* @ 10 adults (Male: Female = 4: 6)/ plot at 7 days interval

T_4= Application of *Bracon hebetor* @ 15 adults (Male: Female = 6: 4)/ plot at 7 days interval

T_5= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension /liter water / plot at 7 days interval

T_6= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 1ml suspension /liter water / plot at 7 days interval

T_7= Untreated control

4.4.2 Infested fruit yield

Infested fruit yield was significantly influenced by different bio-control agents at different fruiting stages of okra as affected by okra shoot and fruit borer (Table 5). Results showed that the lowest infested fruit yield (124 kg/ha, 470 kg/ha and 324 kg/ha at early, mid and late fruiting stage respectively) was obtained by T_5 where the highest infested fruit yield (196 kg/ha, 1170 kg/ha and 655 kg/ha at early, mid and late fruiting stage respectively) of okra was with untreated control treatment. Among the treated plots, the highest infested fruit yield (179 kg/ha, 934 kg/ha and 456 kg/ha at early, mid and late fruiting stage respectively) was observed by T_3. The results obtained from another treatment; T_6 (132 kg/ha, 541 kg/ha and 344 kg/ha at early, mid and late fruiting stage respectively) also showed lower infested fruit yield but significantly different from others. Treatment, T_1 (138 kg/ha, 615 kg/ha and 399 kg/ha at early, mid and late fruiting stage respectively) and T_2 (141 kg/ha, 685 kg/ha and 402 kg/ha at early, mid and late fruiting stage respectively) showed intermediate level of infested fruit yield compared to other treatments.

In terms of percent reduction over control, T_5 gave the significantly highest reduction of infested fruit yield at early (36.73%), mid (59.83%) and late fruiting stage (50.53%) over control, where the lowest reduction of infested fruit yield (8.67%, 20.17% and 30.38% at early, mid and late fruiting stages, respectively) over control was observed in T_3. Treatment, T_6 (32.65%, 53.76%, and 47.48% at early, mid and late fruiting stage respectively) also showed higher percent reduction of infested fruit yield over control but significantly different from all other treatments.

A similar finding was observed by Sasikala *et al.* (1999) which was conformity with the present study.

Table 5: Effect of bio-control agents on infested fruit yield applied against okra shoot and fruit borer at different fruiting stages

Treatment	Infested fruit yield (kg/ha)					
	Early fruiting stage	% reduction over control	Mid fruiting stage	% reduction over control	Late fruiting stage	% reduction over control
T_1	138 e	29.59	615 e	47.44	399 d	39.08
T_2	141 d	28.06	685 d	41.45	402 d	38.63
T_3	179 b	08.67	934 b	20.17	456 b	30.38
T_4	173 c	11.73	855 c	26.92	443 c	32.37
T_5	124 g	36.73	470 g	59.83	324 f	50.53
T_6	132 f	32.65	541 f	53.76	344 e	47.48
T_7	196 a	--	1170 a	--	655 a	--
$LSD_{0.05}$	3.986	--	5.192	--	4.864	--
CV (%)	7.45	--	10.87	--	8.34	--

In column the treatment means with same letters indicate the statistically similar at 5% level of significance

T_1= Application of *Trichogramma evanescense* @ 5 Tricho card / plot at 7 days interval
T_2= Application of *Trichogramma evanescense* @ 0.08 g / plot at 7 days interval
T_3= Application of *Bracon hebetor* @ 10 adults (Male: Female = 4: 6)/ plot at 7 days interval
T_4= Application of *Bracon hebetor* @ 15 adults (Male: Female = 6: 4)/ plot at 7 days interval
T_5= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension /liter water / plot at 7 days interval
T_6= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 1ml suspension /liter water / plot at 7 days interval
T_7= Untreated control

4.4.3 Total fruit yield

Total fruit yield was significantly influenced by different bio-control agents at different fruiting stages of okra as affected by okra shoot and fruit borer (Table 6). Results showed that the highest total fruit yield (1036 kg/ha, 3356 kg/ha and 1910 kg/ha at early, mid and late fruiting stage respectively) was obtained by T_5 where the lowest total fruit yield (480 kg/ha, 2545 kg/ha and 1050 kg/ha at early, mid and late fruiting stage respectively) of okra was with untreated control treatment. Among the treated plots, the lowest total fruit yield (564 kg/ha, 2668 kg/ha and 1137 kg/ha at early, mid and late fruiting stage respectively) was observed by T_3.

Similar finding was observed by Sasikala *et al.* (1999) and Rabindra *et al.* (2007) which has conformity with the present study.

Table 6: Effect of bio-control agents on total fruit weight applied against okra shoot and fruit borer at different fruiting stages

Treatment	Fruit yield (kg/ha)							
	Early fruiting stage	% increase over control	Mid fruiting stage	% increase over control	Late fruiting stage	% increase over control	Total fruit yield/ha (kg)	% increase over control
T_1	774 c	61.25	3065 c	20.43	1478 c	40.76	5317 c	30.48
T_2	675 d	40.63	2854 d	12.14	1382 d	31.62	4911 d	20.52
T_3	564 f	17.50	2668 f	4.83	1137 f	8.29	4369 f	7.21
T_4	620 e	29.17	2754 e	8.21	1312 e	24.95	4686 e	14.99
T_5	1036 a	115.83	3356 a	31.87	1910 a	81.90	6310 a	54.85
T_6	830 b	72.92	3185 b	25.15	1565 b	49.05	5580 b	36.93
T_7	480 g	--	2545 g	--	1050 g	--	4075 g	--
$LSD_{0.05}$	5.289	--	8.546	--	6.354	--	10.146	--
CV (%)	8.56	--	9.68	--	7.584	--	9.845	--

In column the treatment means with same letters indicate the statistically similar at 5% level of significance

T_1= Application of *Trichogramma evanescense* @ 5 Tricho card / plot at 7 days interval
T_2= Application of *Trichogramma evanescense* @ 0.08 g / plot at 7 days interval
T_3= Application of *Bracon hebetor* @ 10 adults (Male: Female = 4: 6)/ plot at 7 days interval
T_4= Application of *Bracon hebetor* @ 15 adults (Male: Female = 6: 4)/ plot at 7 days interval
T_5= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension /liter water / plot at 7 days interval
T_6= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 1ml suspension /liter water / plot at 7 days interval
T_7= Untreated control

4.5 Effect of bio-control agents on infestation intensity of fruits

The effects of different treatments on the infestation intensity per fruit expressed in terms of percent fruits having infestation intensity corresponding to any of 4 scales such as scale 1 (low infestation intensity; 1-2 bores/fruit), scale 2 (moderate infestation intensity; 3-4 bores/fruit), Scale 3 (high infestation intensity; 5-6 bores/fruit) and scale 4 (very high infestation intensity; ≥7 bores/fruit) are presented in Table 7.

It was seen from the Table 7 that among the infested fruits those belonging to scale 4 was only 9.89% in T_5, 11.79% in T_1, 12.17% in T_6, 13.38% in T_2 and 14.10% in T_4 as against 19.79% in control where significantly difference was observed among them.

While those belonging to scale 3 was 23.16% in T_1, 22.97% in T_2, 23.25% in T_3 and 23.50% in T_4 having no significant difference among them where T_5 (22.62%), T_6 (22.05%) and control treatment (26.35%) had significant difference among them and was also significantly different from all other treatments.

The infested fruits belonging to scale 2 followed considerably higher value in all the cases such as 26.50% in T_5 having no significant difference in T_1 (26.52%), T_2 (26.38%) and T_6 (26.25%) where T_3 (23.71%), T_4 (24.78%) and control (25.66%) having significant difference.

But in terms of scale 1, the highest value was achieved by T_5 (41.23%) where the lowest was by control treatment (28.20%). The most significant finding is that considerably a very high proportion of infested fruits (41.23%) belonged to scale 1 in T_5 having significant difference with 28.20% in control. On the other hand, T_1 (38.53%), T_2 (37.27%), T_3 (36.10%), T_4 (37.63%) and T_6 (39.27%) having significantly higher bores (1-2 bores) per fruit over control.

Thus it may be inferred from the above analysis that the proportion of infested fruits in the infested category under different treatments would vary greatly in terms of infestation intensity i.e., in terms of number of bores per fruit. So, although an insecticide treatment might be effective in protecting the crop significantly against infestation in terms of reducing the number of bores per fruit, its effect would not be reflected exactly if the fruits were considered infested irrespective of the number of bores per fruit. For example, referring back to the effects of the treatments on fruit infestation as shown in Table 2, in T_5, 12.44%, 14.56% and 17.61% fruits by number at early, mid and late fruiting stage respectively were found infested of which a very big proportion i.e., 41.23% belonged to Scale 1 (only 1-2 bores/fruit) while a very small proportion, i.e., only 9.89% belonged to Scale 4 (>7 bores per fruit) as against 42.66%, 48.02% and 65.16% infested fruits (at early, mid and late fruiting stage respectively) in control of which a small proportion i.e., only 28.20% belonged to Scale 1 (1-2 bores per fruit) while a large proportion i.e., 19.796% belonged to Scale 4 (>7 bores per fruit).

From the above findings it was revealed that for all treatments applied against of okra shoot and fruit borer, the highest percent fruit infestation by number was belonged to in scale 1 comprised with 1-2 bores/fruit followed by scale 2, scale 3 and scale 4 but reverse untreated control where the highest percent fruit infestation was belonged in scale 4 followed by scale 3, scale 2 and scale 1.

Table 7: Effect of bio-control agents on the infestation intensity of okra fruits caused by okra shoot and fruit borer

Treatment	% Fruit infestation by number at different scales of infestation intensity			
	Scale 1 (1-2 bores/fruit)	Scale 2 (3-4 bores/fruit)	Scale 3 (5-6 bores/fruit)	Scale 4 (>7 bores/fruit)
T_1	38.53 b	26.52 a	23.16 b	11.79 e

T_2	37.27 c	26.38 a	22.97 b	13.38 cd
T_3	36.10 d	23.71 d	23.25 b	16.95 b
T_4	37.63 c	24.78 c	23.50 b	14.10 c
T_5	41.23 a	26.25 a	22.62 bc	09.89 g
T_6	39.27 b	26.50 a	22.05 c	12.17 d
T_7	19.79 a	25.66 b	26.35 a	28.20 e
$LSD_{0.05}$	1.142	0.568	0.886	1.042
CV (%)	7.85	6.18	6.58	5.69

In column the treatment means with same letters indicate the statistically similar at 5% level of significance

T_1= Application of *Trichogramma evanescense* @ 5 Tricho card / plot at 7 days interval
T_2= Application of *Trichogramma evanescense* @ 0.08 g / plot at 7 days interval
T_3= Application of *Bracon hebetor* @ 10 adults (Male: Female = 4: 6)/ plot at 7 days interval
T_4= Application of *Bracon hebetor* @ 15 adults (Male: Female = 6: 4)/ plot at 7 days interval
T_5= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension /liter water / plot at 7 days interval
T_6= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 1ml suspension /liter water / plot at 7 days interval
T_7= Untreated control

4.6 Effect of bio-control agents on yield contributing characters

4.6.1 Length of fruits

Table 8 showed that length of healthy fruits/plants was greatly influenced by different eco-friendly management technique under the present study. Results revealed that the highest length of healthy fruit/plant (12.36 cm) was achieved by the treatment of T_5 (Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension/liter of water/ plot at 7 days interval) which was statistically similar with T_6 (12.35 cm) but significantly different from all other treatments. The lowest length of healthy fruit/plant (8.61 cm) was found to untreated control treatment (T_7), which was not significantly same or similar with other treatments.

Results were also shown in Table 9 that length of infested fruits/plot were varied significantly by different treatment. Results indicated that the highest length of infested fruit/plant (9.11 cm) was observed by the treatment of T_5 (Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension/liter of water/ plot at 7 days interval) which was significantly different from all other treatments. The lowest length of infested fruit/plant (6.81 cm) was found to untreated control treatment (T_7) which was significantly same with all other treatments except T_5 and T_6.

In terms of percent increase over control, the highest increase of healthy and infested fruit length (43.50% and 33.71%, respectively) over control was obtained by $T_{5,}$ where the lowest healthy and infested fruit length (15.64% and 5.78%, respectively) over control was obtained by T_3.

4.6.2 Girth of healthy fruits/plant

The results obtained incase of girth of healthy fruits/plants was influenced by different eco-friendly management system under the present study. Results showed that the girth of healthy fruits/plant (3.23 cm) was achieved by the treatment of T_5 (Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension/liter of water/ plot at 7 days interval) which was statistically identical with T_6 (3.15 cm) but significantly different from all other treatments. The lowest girth of healthy fruits/plant (2.63 cm) was found to untreated control treatment (T_7), which was significantly different from other treatments.

Representing data in Table 9 also showed that girth of infested fruits was influenced significantly by different treatments. Results showed that the highest girth of infested fruits/plot (3.03 cm) was achieved by the treatment of T_5 (Application of *Bacillus thuringiensis* Serovar *kurstaki* @2ml suspension/liter of water/ plot at 7 days interval), which was closely followed by T_6 but significantly different from all other treatments. The lowest girth of infested fruit/plot (2.68 cm) was found to untreated control treatment (T_7) which was not significantly different from T_1, T_2, T_3 and T_4.

In terms of percent increase over control, the highest increase of healthy and infested girth of fruit (23.07% and 12.95%, respectively) over control was obtained by $T_{5,}$ where the lowest healthy and infested girth of fruit (0.99% and 1.75%, respectively) over control was obtained by T_3.

Table 8: Effect of different bio-control agents on yield contributing characters of okra during the management of okra shoot and fruit borer

Treatment	Yield contributing parameters							
	Fruit length (cm)				Girth of fruit (cm)			
	Healthy	% increase over control	Infested	% reduction over control	Healthy	% increase over control	Infested	% reduction over control
T_1	10.97 b	27.37	7.43 c	9.01	2.85 b	8.49	2.77 b	3.25
T_2	10.75 b	24.81	7.27 c	6.66	2.84 b	8.12	2.75 b	2.72
T_3	9.96 b	15.64	7.21 c	5.78	2.65 b	0.99	2.73 b	1.75
T_4	10.44 b	21.21	7.24 c	6.27	2.87 b	9.36	2.77 b	3.47
T_5	12.36 a	43.50	9.11 a	33.71	3.23 a	23.07	3.03 a	12.95

T_6	12.35 a	43.39	8.32 b	22.12	3.15 a	20.02	2.85 ab	6.23
T_7	8.61 c	--	6.81 c	--	2.63 b	--	2.68 b	--
$LSD_{0.05}$	1.267	--	0.568	--	0.276	--	0.1866	--
CV (%)	6.61	--	5.17	--	5.38	--	3.69	--

In column the treatment means with same letters indicate the statistically similar at 5% level of significance

T_1= Application of *Trichogramma evanescense* @ 5 Tricho card / plot at 7 days interval
T_2= Application of *Trichogramma evanescense* @ 0.08 g / plot at 7 days interval
T_3= Application of *Bracon hebetor* @ 10 adults (Male: Female = 4: 6)/ plot at 7 days interval
T_4= Application of *Bracon hebetor* @ 15 adults (Male: Female = 6: 4)/ plot at 7 days interval
T_5= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension /liter water / plot at 7 days interval
T_6= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 1ml suspension /liter water / plot at 7 days interval
T_7= Untreated control

4.7 Economic analysis of the management practices

Economic analysis of management practices based on different bio-control agents for the eco-friendly management of okra shoot and fruit borer are presented in Table 9. In this study untreated control (T_7) did not require any pest management cost. It is to be noted here that the expenses incurred referred to those only on pest control. Thus it is revealed that the adjusted net return was the highest (Tk. 64374.00) in T_5 followed by Tk. 45517.00 in T_6, Tk. 38387.00 in T_1, 26169.00 in T_2, 18225.00 in T_4 and Tk. 9026.00 in T_3.
Similarly, it is revealed that the BCR was the highest (11.41) in case of T_5 which was higher than all other treatments having BCR from T_1 (9.69), T_6 (8.82), T_2 (5.19), T_1 (4.34) and T_2 (2.15).

Table 9. Management practices based on bio-control agents applied against okra shoot and fruit borer

Treatment	Cost of pest management	Yield (kg/ha)		Gross return (Tk.)	Net Return (Tk.)	Adjusted net return (Tk.)	BCR
		Healthy fruits	Infested fruits				
T_1	3960	4165	1152	117949	113989	38387	9.69
T_2	5040	3683	1228	106811	101771	26169	5.19
T_3	4200	2800	1569	88828	84628	9026	2.15
T_4	4200	3215	1471	98027	93827	18225	4.34
T_5	5640	5384	918	145616	139976	64374	11.41
T_6	5160	4563	1017	126279	121119	45517	8.82
T_7	--	2054	2021	75602	75602	--	--

Treatment	Cost of insecticide management		Total
T_1	Application of 5 Tricho card (*Trichogramma evanescense*) @ Tk.	=	3960

	330/ha for single application		
T_2	Application of 0.08 g (*Trichogramma evanescense*) @ Tk. 420/ha for single application	=	5040
T_3	Application of 10 adults *Bracon hebetor* (Male : Female = 4 : 6) @ Tk. 350/ha for single application	=	4200
T_4	Application of 15 adults *Bracon hebetor* (Male : Female = 6 : 4) @ Tk350/ha for single application	=	4200
T_5	Application of *Bacillus thuringiensis* Serovar *Kurstaki* 2ml suspension/liter of water @ Tk. 430/ha for single application	=	5640
T_6	Application of *Bacillus thuringiensis* Serovar *Kurstaki* 1ml suspension/liter of water @ Tk. 470/ha for single application	=	5160
T_7	Untreated control	=	0

Market price of okra: Tk 25.00 for healthy and Tk. 12.00 for infested fruit

CHAPTER V

SUMMARY AND CONCLUSION

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka to evaluate the 'eco-friendly management of okra shoot and fruit borer through bio-control agent'. The experiment was comprised with seven treatments including untreated control. It was set up in Randomized Complete Block Design with three replications. The treatments of the experiment were T_1= Application of *Trichogramma evanescense* @ 5 Tricho card/ plot at 7 days interval, T_2= Application of *Trichogramma evanescense* @ 0.08 g / plot at 7 days interval, T_3= Application of *Bracon habetor* @ 10 adults (Male : Female = 4 : 6)/ plot at 7 days interval, T_4= Application of *Bracon habetor* @ 15 adults (Male : Female = 6 : 4)/ plot at 7 days interval, T_5= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension /liter water / plot at 7 days interval, T_6= Application of *Bacillus thuringiensis* Serovar *kurstaki* @ 1ml suspension /liter water / plot at 7 days interval, T_7= Untreated control .Data were collected on shoot infestation, fruit infestation by number and weight, yield and yield contributing parameters and also on infestation intensity.

In case of shoot infestation, due to management of okra shoot and fruit borer by bio-control agents the lowest shoot infestation (15.20%) was recorded in T_5 followed by T_6 (17.64%), T_1 (19.36%) and T_2 (20.80%). On the other hand, the highest shoot infestation (34.14%) was recorded in T_7 (untreated control) followed by T_3 (23.31%) and T_4 (22.21%). In case of shoot infestation reduction over control, the highest reduction (57.90%) was observed in T_5 followed by T_6 (51.08%), T_1 (46.56%) and T_2 (42.39%), whereas the lowest reduction shoot infestation over control was recorded in T_3 (35.49%) followed by T_4 (38.50%).

In case of fruit infestation the lowest fruit infestation by number (14.87%) was recorded in T_5 followed by T_6 (18.98%), T_1 (22.65%) and T_2 (25.53%). On the other hand, the highest fruit infestation (51.95%) was recorded in T_7 (untreated control) followed by T_3 (37.15%) and T_4 (32.11%). In case of fruit infestation reduction over control, the highest reduction (55.28%) was observed in T_5 followed by T_6 (50.29%), T_1 (44.37%) and T_2 (41.70%), whereas the lowest reduction fruit infestation over control was recorded in T_3 (24.73%) followed by T_4 (29.40%).

In case of fruit infestation the lowest fruit infestation by weight (14.31%) was recorded in T_5 followed by T_6 (18.29%), T_1 (21.63%) and T_2 (24.66%) on the other hand, the highest fruit infestation (49.73%) was recorded in T_7 (untreated control) followed by T_3 (35.62%) and T_4 (30.91%). In case of fruit infestation reduction over control, the highest reduction (48.97%) was observed in T_5 followed by T_6 (44.63%), T_1 (38.70%) and T_2 (36.05%), whereas the lowest reduction fruit infestation over control was recorded in T_3 (19.74%) followed by T_4 (23.67%).

From above mentioned findings and summary of the results the study can be concluded below:

- The treatment comprised with the application of *Bacillus thuringiensis* Serovar *kurstaki* @ 2ml suspension /liter water / plot at 7 days interval (T_5) gave the best result in reducing the shoot infestation (57.90%) fruit infestation by number and weight (55.28% and 48.97%, respectively)
- The maximum yield (6310 kg/ha) as well as increasing the yield contributing characters such as length (43.50%) and girth (23.07%) of fruits and yield (54.85%) of okra was produced in T_5.
- The highest percent increase of healthy and reduction of infested fruits length (43.50% and 33.71%, respectively) over control was obtained by T_5.
- The highest percent increase of healthy and reduction of infested girth of fruit (23.07% and 12.95%, respectively) over control was obtained by T_5.
- Similarly, it was revealed that the highest BCR (11.41) was achieved by T_5 which was higher than all other treatments having BCR from T_1 (9.69), T_6 (8.82), T_2 (5.19), T_1 (4.34) and T_2 (2.15).

CHAPTER VI

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Appendices

Appendix I. Monthly average air temperature, relative humidity and total rainfall of the experimental site during the period from March 2009 to July 2009

Month	RH (%)	Max. Temp. (ºC)	Min. Temp. (ºC)	Rain fall (mm)
March	44.95	33.80	20.28	0
April	61.40	33.74	23.81	185
May	64.27	32.5	24.95	180
June	66.24	28.28	25.34	184
July	81	31.4	25.8	542

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix II: Characteristics of experimental soil was analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	***Characteristics***
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur 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
Cropping pattern	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B.
hysical and chemical properties of the initial soil

Characteristics	*Value*
Partical size analysis	
% 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: Soil Resource Development Institute (SRDI)

Appendix III: Doses of manures and fertilizer and their methods of application used for this experiment (Haque, 1993)

Manure/Fertilizer	Dose per ha (kg)	Basal dose (kg/ha)	Top dressing(kg/ha)	
			First*	Second**
Cow dung	5000	Entire amount	-	-
Urea	150	-	75	75
TSP	120	Entire amount	-	-
MP	110	Entire amount	-	-

*25 days after sowing, **45 days after sowing