DEVELOPMENT OF IPM PACKAGE(S) AGAINST TOMATO FRUIT BORER BY UTILIZING SOME INTEGRATED PEST MANAGEMENT TACTICS

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CERTIFICATE

This is to certify that the thesis entitled, **"DEVELOPMENT OF IPM PACKAGE(S) AGAINST TOMATO FRUIT BORER BY UTILIZING SOME INTEGRATED PEST MANAGEMENT TACTICS"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (MS) IN ENTOMOLOGY, embodies the result of a piece of bona fide research work carried out by MD. MIZANUR RAHMAN, Registration No. 05-01722 under my supervision and my 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, 2011
Dhaka, Bangladesh

(Professor Dr. Md. Mizanur Rahman)
Supervisor

DEDICATED TO

MY

BELOVED PARENTS

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ABSTRACT

The study was conducted at the Central Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh during 25 October, 2011 to 29 March, 2012 to study the effectiveness of some IPM packages against tomato fruit borer. The study was consists of seven treatments. These were as follows: T_1 = Neem oil @ 4ml/l of water at 7 days interval, T_2 = Neem seed kernel @ 300g/6l of water at 7 days interval, T_3 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval, T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval, T_5 = Dursban 20EC 3ml/l of water at 7 days interval, T_6 = Basathrin 10EC 2.5ml/l of water at 7 days interval and T_7 = Untreated Control. The study was laid out in Randomized Complete Block Design (RCBD) with three replications. The results of the study revealed that the highest number of fruits plant^{-1} were harvested from T_3 treated plot during flowering stage (54.00) and reproductive stage (63.15). While, the lowest number of fruit plot^{-1} at flowering (23.78) and at reproductive stage (39.77) was recorded from untreated control plot (T_7). Consequently, the highest healthy fruits yield (247.94kg) and total fruit yield (270.99kg) was also observed in T_3 treatment. On the other hand, the lowest percent of fruit borer infestation was found in the same treatment. The weight of total fruit, (2080 g) and healthy fruit, (1894 g) plot^{-1} was harvested in T_5 treated plot while, the lowest total fruit (1052.10 g) and healthy fruit (890.30 g) plot^{-1} was harvested from untreated control plot. The benefit cost ratio was the highest (1.377) in the plot of T_3 treatment.

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CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) belongs to family Solanaceae and genus *Solanum* is one of the most important vegetables after potato (*Solanum tuberosum* L.) and sweet potato (*Ipomoea batatus* L.) in Bangladesh. Moreover, it is top listed in canned vegetables (Chowdhury, 1979). Tomato is indigenous to the Peru and Equador region in South America and it probably evolved from *Lycopersicon esculentum* var. *cerasiforme*, the cherry form. However, it was domesticated and first cultivated in Central America by the early Indian civilizations of Mexico. The Spanish explorers introduced tomato into Spain and it was later taken to Morocco, Turkey and Italy (AIS, 2010).

In Bangladesh, tomato is grown during Rabi season. It is cultivated in almost all homestead gardens and also in the field due to its adaptability to wide range of soil and climate. It is one of the most highly praised vegetables consumed widely and it is a major source of vitamins A, B and C and minerals like calcium (Bose and Som, 1990). It is a nutritious and delicious vegetable used in salad, soups and processes into stable products like ketchup, sauce, pickles, paste, chutney and juice. Lycopene in tomato is a powerful antioxidant and reduces the risk of prostate cancer (Hossain *et al*. 2004). It is one of the most popular salad vegetables and is taken with great relish. It is widely employed in cannery and made into soups, pickles, ketchup, sauces, juices etc (Thompson and Kelly, 1983). Among the winter vegetable crops grown in Bangladesh, tomato ranks fourth in respect of production and third in respect of areas (Anonymous, 1999). The recent statistics shows that tomato was grown in 23886.639 ha of land and the total production was approximately 190 thousand tons in 2009-10 (BBS, 2012). The average yield of tomato was 32.20 ton per acre (BBS, 2011). The yield is quite low as compared to that of other top ten tomato producing countries.

A large number of tomato varieties grow in Bangladesh, most of them lost their potentiality due to genetic deterioration, diseases and insect infestations. In order to increase tomato production in Bangladesh, it is essential to identify cultivars capable of year-round production with higher yield and resistance to pests (Hannan *et al*., 2007). Among the insect pest of tomato, the tomato fruit borer is the serious pest. Due to severe infestation, fruit as well as seed maturation hampered greatly and the viability of the seeds are also reduced. When the tomato plant in fruiting stage, fruit borer larvae bore into the young fruit and feed on the internal tissue and make tunnel inside the fruit. As a result fruit, drop off. The larvae bore inside fruit and feed on inner tissues which become deformed in shape resulting low market value.

Though the pest is major in status, the management of fruit borer through non chemical tactics (cultural, mechanical, biological and host plant resistance etc.) undertaken by the researcher throughout the world is limited. So, the use of chemical insecticides is regarded to be the most useful measure to combat this pest. The only common method for controlling tomato fruit borer in Bangladesh is the application of chemical insecticides. The use of insecticides has become indispensable in increasing vegetable crop production because of its rapid effect, ease of application and availability. Generally the farmers of Bangladesh control this pest by the application of chemical insecticides. But, the application of chemical insecticides has got many limitation and undesirable side effects (Husain, 1993).

A huge quantity of pesticide is used in controlling tomato fruit borer and usually found that the vegetable growers apply 10-12 sprays in a season. Thus, the fruits, which are harvested at the short intervals, are likely to retain unavoidably high level of pesticide residues which may be highly hazardous causing serious problems including pest resistance, pest outbreak, pest resurgence and environmental pollution (Fishwick, 1988). As a result, these harmful insecticides dissolved into our water system and ultimately enter into the system of human, fishes and many other animals and cause severe damage to their health. Moreover, the farmers of Bangladesh are very poor and they have very limited access to buy insecticides and the spraying equipments (Husain 1984). Further, the excessive reliance on chemicals has led to the problem of resistance, resurgence, environmental pollution decimation of useful fauna & flora.

Neem oil is a plant originated (botanical) pesticide which is environment friendly and is well known for its diverse pest control properties. It works as an insect feeding deterrent, but in various forms it also serves as a repellent, growth regulator, oviposition (egg deposition) suppressant, sterilant (Subapriya and Nagini, 2005). Tomato pests are usually controlled by using chemicals and no serious efforts have been made to use non chemical methods. Published information shows that efforts have been made in many countries of the world to control tomato fruit worm by using natural enemies including *Chrysoperla carnea* and *Trichogramma.* Inayatullah (2007) studied the effect of *Trichogramma* alone and in combination with *Chrysoperla carnea* on the tomato fruit worm and reported significant reduction in fruit worm infestation and percent yield loss.

The concept of Integrated Pest Management (IPM) is becoming a practicable and acceptable approach over the world. The idea is to maintain the pest below economic threshold rather than eradicate it. This approach advocates an integration of all possible or at least some of the known natural means of control (cultural control, physical control, biological control, mechanical control etc.) with or without insecticides so that the best insect management in terms of economics & maintenance of pest population below threshold level. With the above view to minimize all these problems, this study was undertaken to develop an Integrated Pest Management package for combating tomato fruit borer. Hence, the present study was undertaken to fulfill the following objectives:

- To know the effectiveness of botanicals, synthetic insecticide and parasitoid on the infestation of tomato fruit borer.
- To develop an IPM package for sustainable, economic and environmental friendly control measure against tomato fruit borer.

CHAPTER II

REVIEW OF LITERATURE

The experiment was conducted for the development of an IPM package against the attack of tomato fruit borer (*Helicoverpa armigera*) in Tomato. Available literatures related to the present study are reviewed in this section. The review of literature in terms of "Development of an IPM package against the attack of tomato fruit borer (*Helicoverpa armigera*) by utilizing some botanicals and chemical insecticides in tomato" cited here with suitable headings-

2.1 General information of Tomato Fruit Borer

2.1.1 Nomenclature

Tomato fruit borer, *Helicoverpa armigera* (Hub.) is a polyphagous insect, belonging to the family Noctuidae of the order Lepidoptera. There are several genera under this family, and the genus *Helicoverpa* contains more number of species, including *Lelicoverpa armigera*, which is the serious pest of tomato (Mishra *et al.* 1996).

Synonym: *Helicoverpa armigera*, **Common name:** American boll worm

2.1.2 Origin and distribution

Tomato fruit borer is a versatile and widely distributed polyphagous insect. Besides Bangladesh, this pest occurs in Southern Europe, probably the whole of Africa, the middle East, India, Central and South East Asia to Japan, the Philippines, Indonesia, New Guinea, the eastern part of Australia, New Zealand and a number of pacific islands except desert and very humid region (Singh, 1972).

2.1.3 Host Range of tomato fruit borer

A wide range of host tomato fruit borer are cotton, tobacco, maize, sorghum, pennisetum, sunflower, various legumes, citrus, okra and other horticultural crops. Wild plants considered important include species of Euphorbiaceae, Amaranthaceae, Malvaceae, Solanaceae, Compositae, Portulaceceae and Convolvulaceae, but many other plant families are also reported to be the hosts of this insect pest (Jiirgen *et al.* 1977).

2.1.4 Life history of tomato fruit borer

2.1.4.1 Egg

Eggs are 0.4-0.5 mm in diameter, nearly spherical with flattened base, glistering yellowish- white in colour, changing to dark brown prior to hatching (Singh and Singh, 1975).

2.1.4.2 Larva

The fully grown larva is about 40 mm in length, general colour varies from almost black, brown or green to pale yellow or pink and is characterized by having a dark band along the back to each side of which there is a pale band. The larval period varies from 15.35 days (Singh and Singh, 1975)..

2.1.4.3 Pupa

The light brown pupa, living in the soil, is seldom seen unless special sampling techniques are used (Nachiappan and Subramanium, 1974).

2.1.4.4 Adult

Stout bodied moth has a wing span of 40 mm. General colour varies from dull yellow or olive grey to brown with little distinctive marking. The moths become sexually mature and mate about four days after emergence from the pupae having fed from the nectars of plants. The moth is only active at night and lays eggs singly on the plant. On hatching, the larva normally eats some or all of its egg shell before feeding on the plant. The larva passes through six instars and the larval period varies from 15-35 days (Ewing *et al.* 1947).

Damage by the pest was found to be independent of all these characters except ascorbic acid content, which was positively correlated with damage.

Gajendra *et al*. (1998) screened twenty four tomato cultivars against of tomato fruit borer, *H. armigera* during the spring in Madhya Pradesh. Cultivars Pusa early dwarf, Akra Vikas and Pusa Gourva with highly hairy peduncles were less susceptible to the pest damage than those with less hairs on the peduncles. Negative correlation between ascorbic acid content of the fruit and fruit damage by the pest was observed.

Sivaprakasam (1996) observed the leaf trichome (number/$mm^{2)}$, petioles, internodal stems and calyx on 9 tomato genotypes. Results suggested that the low fruit borer damage in Paiyur-1 and X-44 might be due to the presence of long calyx, trichomes, physically preventing feeding by *H. armigera* larvae, rather than to trichome number/mm^2. Paiyur-1 had lowest number of trichomes on all plants parts studied, but the largest calyx area per fruit (3.4 cm^2).

Rath and Nath (1995) conducted field screening of 112 tomato genotypes at Uttar Pradesh, India, during the Kharif season against *H. armigera*. Leaf trichome density, sepal length, number of branches, fruit diameter and P^H of ripe fruit showed a significant and positive impact on infestation level. The increased fruit number in a plant enhanced numbers of *H. armigera*. The percentages of plant infestation were negatively correlated with fruit pericarp, thickness and the percentages of fruit damage were negatively correlated with fruit per plant but positively correlated with trichome density.

Information on genetic variability, and genetic advance is derived from data on number of fruits/plant, fruit weight, fruit borer (*Heliothis armigera*) incidence, wilt (*Fusarium oxysporum f. sp Lyopersics*) incidence and yield of 16 tomato varieties grown at Ghumsar, Udayagiri was observed by Mishra and Mishra (1995). The cultivars BT 6-2, BT 10, BT 17, T 30 and T 32, exhibiting resistance to both wilt and fruit borer, could be utilized as donors in future multiple resistance breeding programmes.

Perring *et al.* (1988) observed that the interactions between the planting date of tomato and the population growth of *M. euphorbiae* and the occurrence of natural enemies in the field of California. The results showed that the aphid was influenced directly by planting date, and significantly higher aphid densities developed on young plants. Plant age also influenced the population growth of the aphid indirectly through the interaction between *M. persicae* and natural enemies.

2.2 General review of tomato fruit borer, *Heliothis armigera* (Hub.)

Usman *et al*. (2012) investigated the efficiency of *Trichogramma chilonis, T. chilonis* in combination with *Chrysoperla carnea* and neem extract against tomato fruit worm, *Helicoverpa armigera*, were carried out at the Research Farm of Agricultural University, Peshawar, Pakistan during summer 2009. Treatment having trichocard having 300 parasitized eggs in combination with *Chrysoperla* and neem extract is the most promising for effective management of *H. armigera* on tomato.

The study was carried out by Rahman *et al*. (2011) to determine the comparative efficacy of some chemical insecticides and botanicals against chilli fruit borer. In total cropping season the lowest percentage of fruit infestation by number (5.72%) was recorded from the treatment T_4 which was statistically similar (6.22%) with the treatment T_8 and the highest (24.90%) was recorded from untreated control treatment which was closely followed (17.39%) by the treatment T_5 and T_{11} (16.48%) and T_{10} (15.37%) respectively. Fruit infestation reduction over control by number estimated as the highest value (77.03%) was recorded from the treatment T_4, while the lowest (30.16%) was recorded from T_5 treatment. Highest weight of fruit yield (30.60 t/ha) was recorded from the treatment T_4 and the lowest yield (24.48 t/ha) of fruit was recorded from untreated control treatment. Among different treatments as whole botanicals (T_7-T_{11}) were more effective than those of the chemicals insecticides (T_1-T_6).

Money-Maker and Royesta were evaluated to screen out the suitable resistant/susceptible genotypes against the fruit borer in Pakistan (Sajjad *et al*., 2011). The results imparted that the percentage of fruit infestation and larval population per plant on tested genotypes of tomato varied significantly. Lower values of host plant susceptibility indices (HPSI) were recorded on resistant genotypes. Sahil, Pakit and Nova Mecb could be used as a source of resistance for developing tomato genotypes resistant to tomato fruit borer.

Bihari and Narayan (2010) conducted an experiment on the effects of tobacco leaf extract, tea extract, neem [*Azadirachta indica*] leaf extract (NLE), neem seed kernel extract (NSKE), jatropha [*Jatropha* sp.] leaf extract, jatropha kernel extract, karanj [*Pongamia pinnata*] leaf extract, karanj kernel extract, tulsi [*Ocimum tenuiflorum*] leaf extract (TLE), onion-garlic bulb extract (OGBE) and chilli fruit extract (CFE) on the performance of tomato and incidence of fruit borer (*Helicoverpa* sp.) were studied in Allahabad. NSKE, TLE and CFE recorded the highest number of flower clusters per plant (83.45, 80.85 and 80.10, respectively) and incidence of fruit set per plant (32.47, 32.10 and 32.00). The highest cost-benefit ratios were obtained with NLE, OGBE and CFE (1:51, 1:50 and 1:47).

Ali *et al*. (2009) conducted an experiment at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during October 2006 to March 2007 to explore the effective and eco-friendly management practice(s) among seven combinations of some cultural, mechanical, botanical and chemical practices along with one untreated control applied on the susceptible variety

BARI Tomato-2 against tomato fruit borer, *Helicoverpa armigera* (Hubner). Among the seven treatments, the botanical based treatment (T_6) comprising the spraying of neem oil @ 3 ml/l of water at 7 days interval along with plants supported with bamboo stick performed best in reducing 79.51% and 75.59% the fruit infestation over control by number and weight, respectively and contributed to maximum fruit yield (85.55 ton/ha), which increased 26.76% yield over control. Based on the economic analysis of the treatments, T_6 contributed the maximum benefit cost ratio which also produced maximum yield.

A field experiment was conduction by Hussain and Bilal (2007) during Kharif 2003-2004 to evaluate the efficacy of six insecticides at farmers field against *Helicoverpa armigera* infesting tomato. Among the treatments imidacloprid at 0.03% proved more effective followed by Deltamethrin and Fluvalinate. The spraying of these insecticides on tomato resulted in significantly higher reduction of larval population. The field data showed that Imidacloprid gave a significantly higher increase in yield (>78%) over control followed by Deltamethrin. Imidacloprid (0.03%) avoided 46% yield loss on tomato crop.

Tomato fruit borer has been found to cause a yield loss of up to 35% in tomato and up to 37.79% in Karnataka, India (Dhandapani *et al*., 2003). Sharma *et al.* (2003) reported that some 82 tomato germplasms were screened for their resistance to the tomato fruit borer. *H. armigera,* during 1996-97 at Ludhiana, Punjab, India. The total number of healthy and infested fruits was counted at every harvest and cumulative percent fruit damage was assessed. Fruit infestation varied from zero in Tomato Royal FM and WIR 4285 to 30.03% in L274.

Khanam *et al*. (2003) conducted an experiment on the screening of thirty tomato varieties/lines to tomato fruit borer, *Helicoverpa armigera* (Hub.) infestation in relation to their morphological characters and conducted in different laboratories of BAU and BINA, Mymensingh during Rabi season, November, 1999 to March 2000. The tomato fruit borer infestation varied significantly among the varieties/lines and also with the age of the tomato plants. Among the varieties/lines, V-29 and V-282 were found moderately resistant and susceptible, respectively. Plant height, stem diameter, total number of branches/plant, total number of leaves/plant, 2nd leaf area, total leaf chlorophyll, number of leaf hair and number of fruits/plant of V-29 line were 81.74 cm, 1.45 cm, 14, 453, 19.58 sq. cm, 1.13 mg/g, 12 and 48, respectively. Again the aforementioned characters for V-282 line were 80.74 cm, 1.18 cm, 9.396, 21.57 sq.cm, 1.24 mg/g, 17 and 30, respectively.

Karabhantanal and Kulkarni (2002) reported that the tritrophic interactions were assessed under net cage conditions among tomato cultivars L-15, PKM-1, Arka Vikas, Arka Sourabh, Arka Ashish on *Helicoverpa armigera* and egg hyperparasitoids (*Trichogramma chilonis* and *Trichogramma pretiosum*). Significantly lower oviposition by *H. armigera* was observed on local genotypes, L-15 and PKM-1, while the oviposition was higher on IIHR genotypes, Arka Sourabh, Arka Vikas and Arka Ashish. Irripective of *T. pretiosum* recorded higher hyperparasitism than *T. chilonis*. Further, it was observed that as the trichome density increased there was an increase in oviposition by *H. armigera* and a decrease in hyperparasitism by *Trichogramma* species.

Saha *et al*. (2001) reported that an investigation was conducted in Uttar Pradesh, India to determine the effect of intercropping. Tomato fruit borer (*Helicoverpa armigera*) heavily infested sole tomato plots compared to all intercrop treatments. The borer population was also found on sole lentil plots but was less than that on sole tomato plots. The fruit borer population was, more or less, similar in all intercropped plots even in the sole lentil plot. Their populations were higher on sole lentil but were less than tomato.

Rath and Nath (2001) reported that tomato genotypes were assessed for fruit damage by fruit borer *Helicoverpa armigera* in a field experiment conducted in Varanasi, Uttar Pradesh, India, during 1991 (112 genotypes) and 1992 (27 genotypes, along with wild type *Lycopersicon pimpinellifolium*). The genotypes were categorized according to percent fruit damage by the pest. Five genotypes, HT-64, Hybrid No.37, PTH-104, PTH-103, recorded the lowest level of per cent fruit damage (< 10) in both years. The wild genotype showed less than 10% fruit damage during 1992. H-86-82, ZLE-006, Parm-mitra and HS-173 recorded the highest fruit damage of more than 40% during 1991. During 1992, the highest fruit damage of more than 30% were recorded from Shrestha, Kalyanieunush, PTH-102, PTH 101, HS-173 and XLE-006.

Saha *et al.* (2000) reported that intercrops of tomato cv. Pusa Ruby were infested with different species of insect pests of tomato fruit borer, *Helicoverpa armigera*, showed significant differences in infestation levels in various intercrop situations in Varanasi, Uttar Pradesh, India, during Rabi season of 1996-97. However, there was a general downward trend in infestation level of different pests in intercrop combinations compared to their numbers in sole crops as preferred host. The intercrops were thus, found to be more suitable for natural suppression of pest populations.

Mehta *et al.* (2000) reported that studies on the management of tomato fruit borer, *Helicoverpa armigera* (Hubner) with nine insecticidal treatments were conducted for 3 seasons during 1995-1997 at Palampur (Himachal Pradesh), India. Over all effectiveness expressed as reduction in borer damaged tomato fruits and increase in fruit yield indicated the superiority of Deltamethrin alone or in combination all through the experimentation.

Satpathy *et al.* (1999) reported that in field trials in Varanasi, Uttar Pradesh, India, nuclear polyhedrosis virus applied with half the recommended dose of Endosulfan (350 g a.i./ha) gave effective control of *H. armigera* on tomato. Application of crude NPV at 300 LE was also effective when applied at 5-days interval. The results indicated that fruit damage was reduced in all treatments. Lowest infestations and highest yields of marketable fruits (7.388 t/ha) were recorded with the 0.44 kg Profenofos + Cypermethrin trectment.

Ganguli *et al.* (1998) reported that of a number of insecticidal treatments carried out against *Helicoverpa armigera* on tomato (variety Pusa Ruby) in Madhya Pradesh, India, during the Rabi season 1995-96, *Helicoverpa* nuclear polyhedrosis virus (250 larval equivalents) + Endosulfan at 0.07% was the most effective, resulted in 47.69% increase in yield and 32.52% avoidable losses.

Studies were conducted to assess the effects of intercropping various vegetables with tomatoes on the infestation of tomato fruit borer (TFB), *Helicoverpa armigera* in Karnataka, India, during the Kharif season of 1995(Patil *et al.* 1997). The greatest infestation of TFB (5.6%) was noticed in tomatoes intercropped with snap beans (*Phaseolus vulgaris*). The lowest infestation (3.4%) was observed in tomatoes intercropped with radishes (*Raphanus sativus*). The TFB infestation levels in tomatoes grown alone, tomatoes intercropped with coriander and onion was 4.5%, 4.2% and 4.7%, respectively. Total TFB infestation ranged from 17.0% in treatments where radishes were grown as an intercrop, to 28.2% in plots where snap beans were grown intercropped with tomatoes.

Marcano (1991) reported that the development of *Neoleucinodes elegantalis* was studied at temperatures of 14.7^0, 25.0^0, 30.2^0 and 34.5^0C and relative humilities of 79.5%, 65.7%, 75.4% and 40%, resp., using tomato as a food plant. At 14.7^0C there was no oviposition and times required for development of the larval, pupae and adult stages were 64.0, 41.5 and 9.4 days, respectively. At 20^0C there was no oviposition. The total time for development was 114.9, 50.9, 34.7 and 25.6 days at 14.7^0, 20.0^0, 25.0^0 and 30.2^0C,espectively.

Parihar and Singh (1986) reported that the larval population of *Heliothis armigera [Helicoverpa armigera]* on tomato and losses caused by this pest were studied in the Meerut district of Uttar Pradesh, India, In 1983-84 and 1984-85. The larval population was low until the first week of February in both years and increased rapidly thereafter, reaching a peak in the last week of March. In the last week of April, the population declined to 4 larvae/10 plants. Percent fruit infestation was low up to the end of February, while in the 2nd week of April 50.08 and 33.04% of fruits were infested in 1984 and 1985, respectively. By the 2nd week of May, 1.441% of fruits were infested in 1984 and 2.84% in 1985. It was recommended that control measures should be applied at the time of flowering, which is also the time of mass oviposition.

2.3 Status and nature of damage of tomato fruit borer (TFB)

Hussain and Bilal Ahmed (2006) conducted an experiment during two years where fruit damage due to TFB was highest (19.59%) in Noorbagh of district Srinagar and lowest (1.61%) in Awneera of district Pulwama. Whereas, on an overall mean basis district Anantnag recorded lowest (1.85%) and district Srinagar recorded highest (17.36%) fruit damage. However, hybrids were generally more damaged than local varieties. The effect of marigold which act as a trap crop along with various combinations of tomato showed that 3:1 combination recorded lowest fruit damage and larval population but trapped more larvae on trap crop. Thus, the yield was higher than other treatments. However, tomato equivalent yield was 2455714 kg/ha in 2003 and 28399.99 kg/ha in 2004.

Mehta *et al*. (2001) studied the management of tomato fruit borer, *Helicoverpa armigera* (Hubner) with nine insecticidal treatments and conducted for 3 seasons during 1995-1997 at

Palampur (Himachal Pradesh). Overall effectiveness was expressed as reduction in borer damaged tomato fruits and increase in fruit yield indicated the superiority of Deltamethrin alone or in combination all through the experimentation. Application of Deltamethrin resulted in lowest fruit damage (4.27%) followed by Cypermethrin (8.98%) and Acephate (9.16%). Among the biopesticides tested, Bt treated plots had lowest fruit infestation (10.68%) as compared to HaNPV (11.95%) and Azadirachtin (14.68%). A mixture of Deltamethrin+Bt application revealed a fruit damage of 5.58 percent while untreated control had 24.2 percent fruit damage. The mean fruit yield was highest in Deltamethrin-+-Bt. treated plots followed by Deltamethrin, Acephate and Cypermethrin.

Tomato fruit borer, *Heliothis armigera* (Hub.) is one of the serious pests attacking tomato. This pest some times cause damage to the extent of about 50-60 percent fruits (Singh and Singh, 1977). The larvae of this pest bore into the fruit and feed inside. As a result the fruits become unfit for human consumption. Sometimes the damage by this pest is followed by fungal infection which causes rotting of the fruits (Husain *et al.* 1998).

Patel and Koshiya (1997) worked on seasonal abundance of *Heliothis armigera* during Kharif season, the pest started its activity in groundnut from first week of July. There after, the pest moves to cotton crop from last week of July and started to build up its population during the month of August to mid-September. Simultaneously the pest infestation was also noticed in sunflower and pearl millet during this period but the population was very low in sunflower. However, in pearl millet, it was at peak during September. In Rabi season, post activity was observed in chickpea during November to February. However, its population was at peak during December. In summer season, the pest started its activity on groundnut in February and was active up to June.

The seasonal history of tomato fruit borer, *Heliothis armigera* varies considerably due to different climatic conditions throughout the year. A Study revealed that the population of *Heliothis armigera* began to increase from the mid-January and peaked during the last weed of February. The population of this pest was positively correlated with average temperature, mean relative humidity and total rainfall. Parihar and Singh (1986) in India showed that, the larval population of *Heliothis armigera* on tomato was low until the first week of February and increased rapidly there after, reaching to 4 larvae/ 10 plants, percent fruit infestation was low up to the end of February, while in the second week of April 50.08% and 33.04% of fruits were infested in 1984 and 1985, respectively.

2.4 Management of tomato fruit borer

In the present study (Arora *et al.*, 2012) an indigenous biopesticide formulation (BPF) comprising easily accessible botanicals along with cow urine, was evaluated for its effectiveness against insect pests of tomato crop under field condition. BPF gave promising results in controlling tomato fruit borers and afforded substantial yield of the produce. The BPF treatment could control 70–80% of fruit borers compared to check plots, resulting in enhanced fruit yield of 35 tonnes/ha as compared to 15 tonnes/ha

The study was conducted on the insecticide-resistance-management of the tomato fruit-borer, *Helicoverpa armigera* (Hübner), employing a bio-intensive integrated management strategy on the tomato crop in Pakistan (Sajjad (2011). The study comprised of 1) host plant resistance, 2) role of weather factors in the population fluctuations, 3) contribution of physio-morphic and chemical plant-characters, in the population fluctuation of the pest, 4) bio-intensive IPM of the pest. The study was conducted to integrate various control methods, viz., biological control (release of *Chrysoperla carnea* and *Bracon hebetor*,), botanical control (spray of neem-seed kernel extract, Neemosol), chemical control (Spinosad, Tracer 240 SC) and bacterial control (*Bacillus thuringiensis*) alone and all of their possible interactions for the management of *Helicoverpa armigera,* on the tomato crop, during 2008. An Integration of B. *thuringiensis* + Tracer + *B. hebetor* + Neemosol and *C. carnea*, resulted in a maximum yield, lowest larval population of *H. armigera* and minimum infestation of marketable tomato fruits.

Satish *et al*. (2009) carried out to evaluate biological activity of organic manures against tomato fruit borer, *Helicoverpa armigera* (Hub.) and botanicals and biopesticides against egg parasitoid, *Trichogramma chilonis* Ishii and biochemical effects of *Pseudomonas florescens* on tomato under pot culture conditions. The feeding and infestation of the larvae of *H. armigera* were significantly low in farm yard manure (FYM)+*Azospirillum*+Silicate solubilising bacteria (SSB)+*Phosphobacteria*+Neem cake applied plants followed by FYM + *Azospirillum* + SSB + *Phosphobacteria* + Mahua cake applied plants. *Trichogramma* parasitization on *H. armigera* eggs was adversely affected by Neem oil 3% on treated plants followed by neem seed kernel extract (NSKE 5%)+spinosad 75 g a.i./ha. Under laboratory condition among the microbial pesticide tested Spinosad (75 g a.i./ha), *Ha*NPV+Spinosad+*Bt* (1.5×10^{12} POBs/ha+75 g a.i./ha+15000 IU/mg (2 lit/ha)), Spinosad+*Bt* (75 g a.i./ha+15000 IU/mg-2 lit/ha) showed higher insecticidal toxicity (100 per cent mortality on 72 h) to all instars of *H. armigera* larvae. Biochemical parameters like Phenol content, Peroxidase and phenyl alanine ammonialyase (PAL) activity recorded higher levels in *Pseudomonas florescens* seed treatment @ 30 g/kg of seed and its foliar spray @ 1 g/litre in treated tomato plants.

Ashok and Shivaraju (2009) studied among the new insecticide molecules evaluated against tomato fruit borer, *Helicoverpa armigera* (Hubner) revealed that beta Cyfluthrin 9% + Imidacloprid 21% - 300OD @ 18 + 42 g a.i./ha and 15.75+ 36.75g a.i./ha were very effective in suppressing the larval population to 75.95 and 70.17 percent, respectively compared to Monocrotophos 36 SL @ 450 g a.i./ ha (68.67), beta Cyfluthrin 2.5 SC @ 18 g a.i./ha (68.64), Lambda cyhalothrin 5 EC + Thiamethoxam 25 WG @ 15.625+31.25 g a.i./ha (68.53), Imidacloprid 200 SL @ 42 g a.i./ha (62.86), Triazophos 40 EC @ 400 g a.i./ha (58.23) and Endosulfan 35 EC 2 437.5 g a.i./ha (40.86) after third spray. The per cent reduction in fruit damage was maximum in Monocrotophos 36 SL @ 450 g a.i./ha (68.83) followed by Lambda cyhalothrin 5 EC + Thiamethoxam 25 WG (65.60), beta Cyfluthrin 9% + Imidacloprid 21% - 300 OD @ 18 + 42 g a.i./ha (64.60) and lowest in Triazophos 40 EC @ 400 g a.i./ha (36.70). Further, beta Cyfluthrin 9% + Imidacloprid 21% - 300 OD @ 18 +

42 g a.i./ha recorded significantly higher yield (274.74 q/ha) followed by Lambda Cyhalothrin 5 EC + Thiamethoxam 25 WG (264.48 q/ha) and Monocrotophos 36 SL @ 450 g a.i./ha (253.81q/ha).

Recognizing the potential of the *Trichogramma* species as a biological control agents, entomologist in the early 1900 began to mass rear *Trichogramma* for insect control. Today *Trichogramma* species are the most widely used insect natural enemy in the world because their mass rearing is easy on one hand and they attack many important crop insect pests on other hand (Ayvaz *et al*., 2008).

Ravi *et al*. (2008) studies on the effectiveness of different sequential application of microbials *viz.*, NPV of *Helicoverpa armigera* (Hübner) (*Ha*NPV @ 1.5x1012 OB/ha), *Bacillus thuringiensis* var. *kurstaki* Berliner (Delfin® 25 WG @1 kg/ha), Spinosad 45 SC @ 75 g a.i./ha) and Neem (Neemazol 1.2 EC @ 1000ml/ha) against *H. armigera* in comparison with sequential application of synthetic insecticides and untreated control on tomato F1 hybrid Ruchi. Results of the field experiments showed that different sequential application of microbials and Neemazol were equally effective as that of sequential application of synthetic chemical insecticides *viz.*, Endosulfan 35 EC (@ 350 g a.i./ha), Quinolphos 25 EC (@ 250 g a.i./ha) and Indoxacarb 14.5 SC (@ 75 g a.i./ha) in reducing *H. armigera* larval population and fruit damage. Relatively higher number of predatory mirids (*Macrolophus* spp.) and spiders (*Argiope* spp and *Thomisus* spp.) were recorded in microbials and neem applied plots compared to the chemical insecticides treated plot. Thus the microbials and neem could be the best alternatives for the sustainable management of *H. armigera* on tomato with less impact on the naturally occurring predatory arthropods.

Srinivasan *et al*. (2005) reported that the *Solanum viarum*, a wild solanaceous plant, was heavily infested by tomato fruit borer (TFB), *Helicoverpa armigera*. *S. viarum* was consistently preferred by TFB over its natural host, tomato. Hence, it was aimed to exploit the presence of feeding stimulants in *S. viarum*. Pure rice flour diet was prepared with an aqueous leaf extract of *S. viarum*, steam distillate (SD) of *S. viarum*, hexane fraction of SD of *S. viarum*, water fraction of SD of *S. viarum* and aqueous leaf extract of tomato. The purpose for halving the SD into a hexane fraction and water fraction was to determine whether the feeding stimulants, if any, are hydrophilic or lipophilic. In our experiments, there was very little larval feeding on the pure rice flour diet (check) and 60% died within a week.

Ogbulu *et al*. (2005) reported that the avalanche of synthetic insecticides and their misuse, studies on the use of neem plant parts namely, neem leaves (NL), neem barks (NB), neem roots (NR), neem leaf, bark and root combination (NLBR) and neem seed kernel power (NSKP) extracts were evaluated for oviposition deterrence on pepper and tomato fruits against *Atherigona orientalis* (Schiner). A 2% solution of each of the neem plant part extracts when applied individually was effective against the pest on both pepper and tomato fruits. A combination of neem leaf, bark and root was more effective than the individual neem plant parts. A 2% Neem seed kernel powder was significantly more effective than other neem plant parts and also significantly offered the highest relative protection (RP) to pepper and tomato fruits. Percentage RP followed this order: NSKP>NLBR>NR>NB>NL.

In Bangladesh, it was reported that Cypermethrin, Deltamethrin, Fenvalerate and Quinalphos @ 1.5 ml/l of water gave the better result (Alam, 2004). In addition to the fruit borer, leaf miner, *Liriomyza trifolii* (Burgess) and red spider mite, *Tetranychus urticae*

(Koch) are the other important pests of tomato. Soil application of neem cake at 20 days after planting (DAP), sprays of neem seed powder (NSP) extract or neem soap or pongamia soap are recommended for the management of these pests (Krishna Moorthy et al., 2003).

Sundarajan (2002) screened methanol extracts of selected plants namely *A nisomeles malabarica, Ocimum camum* [*O. americana*], *O. basilicum, Euphorbia hirta, E. heterophylla, Vitex negundo, Tagetes indica* and *Parthenium hysterophorus* for their insecticidal activity against the fourth instar larvae of *H. armigera* by applying dipping method of the leaf extracts at various concentrations (0.25, 0.50, 1.00, 1.50 and 2.00%) on young tomato leaves. The larval mortality of more than 50% has been recorded for all the plant extracts in 2 percent test concentration (48 h) except *E. heterophylla* which recorded 47.3% mortality in 2% concentration. Among the plant extracts tested *V. negundo* was found to show higher rate of mortality (82.50%) at 2% concentration.

Mechanical control comprising removal of infested fruits is a safe and cheap control technique. It was found that the larvae of this insect can be controlled successfully by this methods following every alternate day during marble size tomato to before ripen period. Report revealed that about 75% control is possible only by this method. But it could be possible to get better result by mechanical method + spraying of botanical pesticides (Nazim *et al*., 2002).

Kulat *et al.* (2001) conducted an experiment on extracts of some indigenous plant materials, which are claimed important as pest control like seed kernels of neem, *Azadiracta indica, Pongamia glabra [P. pinnata],* leaves of tobacco *Nicotiana tabacam* and indiara, a neem based herbal product, against *H. armigera* on chickpea cv. I.C.C.V. 5 for its management in Rabi seasons of 1993-96 at College of Agriculture, Nagpur, Maharashtra, India. The results revealed that the crop treated with the leaf extract on *N. tabacum* and seed extract of *P. glabra* (5%) and indiara (1%) and neem seed kernel extract (5%) exhibited low level of population built up compared to control.

Sundeep *et al*. (2000) conducted an experiment on the economics of controlling *H. armigera* f through suitable cultivars (Punjab Kesri, Punjab Chhuhara, Punjab Tropic and Hybrid Naveen) and cultural practices in tomato for two years (199394) at Punjab Agricultural University, Ludhiana, Pubjab, India. The cumulative fruit damage and fruit yield were invariably lower in the late transplanted crop. The fruit damage was significantly lower in early maturing and small fruited cultivars Punjab Kesri followed by hybrid Naveen. The fruit yields were however, significantly higher in longer duration and medium fruited hybrid Naveen followed by the variety Punjab Kesri. The returns were highest in early transplanted Naveen followed by late transplanted Naveen and early transplanted Punjab Kesri.

Sundarajan and Kumuthakalavalli (2000) tested Petroleum ether extracts of the leaves of *Gnidia glauca* Gilg., *Leucas aspera* Link., and *Toddalia asiatica* Lam. against sixth instar larvae of *H. armigera* (Hubner) at 0.2, 0.4, 0.6, 0.8 and 1.0% by applying to bhendi (okra) slices. After 24 hr, percentage mortality, EC 50 and EC 90 were calculated. Total mortality was recorded in the treamtent with 0.8% of the extract of *G. glauca*. Of the three leaf extracts used, *G. glauca* showed an EC 50 of 0.31%.

Ju *et al*. (2000) tested six desert plants chosen to study their toxicity and effects on the growth and metamorphosis of the insect pest, *Helicoverpa armigera*. An artificial diet containing 5% aqueous extracts of *Cynanchum auriculatum* or *Peganum harmala* var. multisecta showed strong toxicity to the larvae and same dosage also significantly affected metamorphosis of the insect. An artificial diet containing 1% aqueous extracts of *C.*

auriculatum or 5% aquous extracts of *P. harmala* resulted in mortality of 85% and 55%, respectively and a zero emergence rate.

Walunj *et al*. (1999) conducted field trials at Ahemadnager, Maharashtra, India to asses the efficacy if Profenofos at 0.5kg/ha Profenofos + Cypermethrin at 0.33-0.44kg, Lufenuron at 0.33kg, Dichlirvos at 0.76 and Cypermethrin at 0.05kg for control of *H. armigera* in tomatoes cv. Namdhari Hybrid 815. Products were applied 5 times at 15 day intervals. The results indicated that fruit damage was reduced in all treatments. Lowest infestations and highest yields of marketable fruits (7.388t/ha) were recorded with the 0.44kg Profenofos + Cypermethrin treatment.

Pinto *et al* (1997) reported in Sicily that when the population exceeds the economic threshold, control can be effected using systemic products such as phosphoric esters (acephate, methomyl, dimethoate) or synthetic Pyrethroids (Alphamethrin [Alphacypermethrin], Deltmethrin); the latter must be used once only so as not to favour the build-up of mites. Agronomic methods of defense may also by used, such as weeding to kill the pupae, deep ploughing of adjacent uncultivated areas during the period of oviposition, and elimination of weeds on which the females oviposit.

Botanical pesticides are becoming popular day by day. Now a day these are using many insects against fruit borer. It was found that Lepidopteran insect is possible to control by botanical substances. Weekly spray application of the extract of neem seed kernel has been found to be effective against *Helicoverpa armigera* (Karim, 1994).

Patel *et al*. (1991) conducted an experiment for the estimation of avoidable yield loss due to fruit bore, *Helicoverpa armogera* in tomato (cv Roma) planted at three dates (first week each of April, May and June),during 1993 and 1994, in Kullu valley, Himachal Pradesh, India. showed that in crop transplanted in the first week of April cause yield loss to the extent of 105.29,76.02 and 57.02% could be avoided by giving three sprays with Acephate (0.05%) Fenvalerate (0.01%) and Endosulfan (0.05%), respectively. In crop transplanted in the first week of May resulted yield loss of 32.64, 28.04 and 18.50% could be avoided as a result of sprays of respective insecticides. Whereas in June-transplanted crop, 2 sprays each of Acephate, Fenvalerate and Endosulfan helped in avoiding 25.03, 13.91 and 11.76% yield loss, respectively. Irrespective of dates of transplanting, the average yield loss to the extent of 49.27 and 26.59% could be avoided by sprays of Acephate, Fenvalerate and Endisulfan. The average net return per tupee invested worked out to be Rs 14 for ace hate, Rs 13.18 for Fenvalerate and Rs 7.80 for Endosulfan sprays.

The synthetic organic pesticides introduced from the second World War time were soon recognized as wonder pest control chemicals and their increasing uses in the post-war world have significantly contribute in the well being of the mankind. Acute and chronic toxic effects of pesticides in animals are the results of interference with well established bio-chemical process (Hassle, 1990).

Dilbagh *et al*. (1990) conducted field trials in Punjab, India and revealed that Fenvalerate, Permethrin and Cypermethrin applied at 50ga.i./ha, or Decamethrin [detamethrin] applied at 20g a.i./ha gave equal or better control of the noctuid *Flelicoverpa armigera* than Carbaryl or Endosulfan applied at 1000 and 700g a.i./ha, respectively. Yields were higher when synthetic Pyrethroids were used.

Ogunwolu (1989 studied the effects of damage caused by *H. armigera* on yields of tomato transplanted at different times in Nigeria in 1985-86 by treatment with some insecticides against this pest. Fruit damage was highly but negatively correlated with the number, weight and yield increased by spraying, showing that serious damage was caused by *H.*

armigera. Cypermethrin suppressed fruit damage by 70.4 and 52.2% in 1985 and 1986 and increased yield by 115.0 and 67.6% respectively.

2.5 Integrated pest management (IPM)

Sajjad (2011) conducted an experiment to integrate various control methods, viz., biological control (release of *Chrysoperla carnea* and *Bracon hebetor*, each @ 1 card/5-m2), botanical control (spray of neem-seed kernel extract, Neemosol @ 1480 ml/ha), chemical control (Spinosad, Tracer 240 SC @ 197.6 ml/ha) and entomopathogenic fungal control (*Bacillus thuringiensis* @ 2 kg/ha) alone and in all of their possible interactions for the management of *Helicoverpa armigera*, on the tomato crop, during 2008. These control methods were applied three times on the tomato crop (CV Sahil), after the appearance of the pest. An Integration of *B. thuringiensis* + tracer + *B. hebetor* + neemosol and *C. carnea*, resulted in a maximum yield (305.92 q/ha), lowest larval population of *H. armigera* and minimum infestation of marketable tomato fruits caused by the pest, as such it, proved to be the best.

Ghosh *et al*. (2010) reported that the tomato fruit borer, *Helicoverpa armigera* Hub. is a polyphagous pest attacking cotton, tomato, okra, chilli, cabbage, pigeon pea, gram etc. throughout the world as well as in India. Due to its high fecundity, polyphagous nature, quick adaptation against insecticides, control of this pest with any single potent toxicant for a long time is quiet difficult and rather impossible. So the newer chemicals need to be evaluated for controlling this pest. Field experiment was undertaken for two cropping seasons during September - December, 2006 and September - December, 2007 to find out the efficacy of Spinosad 45% SC against tomato fruit borer (*H. armigera* Hub.) along with Quinalphos 25% EC, Lambda Cyhalothrin 5% EC and Cypermethrin 10 EC at ‘Gayespur’ village (Nadia, West-Bengal, India). It was found that Spinosad was effective against *H. armigera* on tomato at 73 to 84 gm a.i./ha than Quinalphos, Lambda Cyhalothrin and Cypermethrin. Spinosad at 73 to 84 g a.i./ha were very safe for three important predators recorded in tomato field that is, *Menochilus sexmaculaus.*, *Syrphus corollae* and *Chrysoperla carnea.* Spinosad is such a new chemical which is derived from fermentation broth of soil Actinomycetes, *Saccharopolyspora spinosa*, containing a naturally occurring mixture of spinosyn A and spinosyn D. It is safe to nymphs and adults of the natural enemies.

Sathish and Raguraman (2007) carried out experiment to evaluate the biological activity of organic amendments against the fruit borer, *Helicoverpa armigera.* Safety of botanicals and biopesticides against egg parasitoid, *Trichogramma chilonis* Ishii and biochemical effects of *Pseudomonas florescens* on tomato under pot culture conditions were tested. The feeding and infestation of the larvae of *H. armigera* were significantly low in FYM + *Azospirillum* + SSB + *Phosphobacteria* + Neem cake and followed by FYM + *Azospirillum* + SSB + *Phosphobacteria* + mahua cake applied plants. *Trichogramma* parasitization on *H. armigera* eggs was adversely affected by Neem oil 3% on treated plants followed by NSKE + Spinosad. Under laboratory condition among the microbial pesticide tested Spinosad (75 g a.i./ha), *HaNPV* + Spinosad + *Bt* (1.5 xl012 POBs/ha +75 g a.i./ha +15000 IU/mg (2 lit/ha), Spinosad + *Bt* (75 g a.i./ha +15000 IU/mg (2 lit/ha) showed superiority in exhibiting higher insecticidal toxicity (100 per cent mortality on 72 h) to all instars of *H. armigera* larvae. Biochemical parameters like phenol content, Peroxidase and Phenyl alanine ammonialyase (PAL) activity recorded higher levels in *Pseudomonas florescens* seed treatment @ 30 g/kg of seed and foliar spray @ 1 g/litre treated tomato plants. These biochemical components were negatively correlated to *H. armigera* infestation in tomato.

The adoption of IPM technology in tomato using African marigold as a trap crop, root dipping of seedlings in Imidacloprid, soil application of neem/pongamia cake, spraying of botanicals like pongamia soap and biopesticide like Ha NPV has been found effective in both insect as well as disease management. The IPM technology has been found economically viable as the yield on IPM farms has been found higher by about 46 per cent, cost of cultivation has been less by about 21 per cent and the net returns have been higher by 119 per cent. The technology can be considered environment-friendly as it uses more of eco-friendly inputs and less of chemicals. The constraints like non-availability of botanicals and bio-pesticides should be addressed on priority basis to make the technology sustainable and more popular (Gajanana *et al*., 2006).

Karabhantanal *et al*. (2005) carried out investigation during 2001 and 2002 in Kharif season in Karnataka, India to evaluate different Integrated pest management (IPM) module against tomato fruit borer, *Helicoverpa armigera*. The result revealed that the IPM module consisting of trap crop (15 row of tomato; 1 row marigold) + *Trichoghamma pretiosum* (45000%/ha) –NSKE (5%)-Ha NPV (250LE/ha)- Endosulfan 35 EC (1250ml/ha) was significantly superior over the rest of the modules tested in restricting the larvae population (100% after the fourth spray). As a result of which, the lowest fruit damage (11.87%), highest marketable fruit yield (224.56q/ha) and additional net profit (22935/ha was observed) in this module, but was comparable with the recommended package of practice and IPM module consisting of nomuraea rilevi (2.0 x1011 conidia/ha) NSLE (5%) HaNPV (250le/ha)-Endosulfan 35EC (1250ml/ha).

Brar *et al*. (2003) carried out a study to determine the effectiveness of *Trichogeamma pretiosum* (5 releases weekly at 50000 per ha), *H. armigera* nuclear polyhedrosis virus (Ha NPV; 2, 3 or sprays at 7, 10 or 15-day intervals at 1.5 x1012 polyhedral occlusion bodied per ha) and /or Endosulfan (3 sprays at 15 day intervals at 700g/ha) for the management of tomato fruit borer (*H. armigera*) in Punjab, India, during 19992002. In all study year, egg parasitism was high (3.32-61.00%) in plots where *T. pretiosum* was released. The mean egg parasitism was highest in the plot treated with *T. pretiosum* alone (49.33). The mean egg parasitism was 7.45 and 14.85% in the Endoslfan-treated and control plots, respectively. Fruit damage was highest during 1999-2000. Among all treatments, treatment with *T pretionum* + HaNPV + Endosulfan resulted in the lowest fruit damage (13.07%) and the highest mean yield (243.86 q/ha). The control treatment had the highest borer incidence and fruit damage. and the lowest yield (163.31 q/ha) among all treatment. The yields in Endosulfan alone was 209.31q/ha, which was significantly superior to HaNPV sprays (184.15q/ha). It is concluded that the treatment combination *T. pretiosum*+ HaNPV+ Endosulfan was most effective for *H. armigera* control.

Pokharkar *et al*. (1999) conducted an study during the spring seasons of 1992 and 1993 in Hisar, Haryana, India to evaluate the effectiveness it nuclear polyhedrosis virus alone and in combination with Endosulfan in the integrated control of *Hekicoverpa armigera* on tomato *(Lycopersicon esculentum*).Three sprays of Endosulfan 0.07% at 10 day-intervals starting from 50% flowering of the crop proved to be effective. Application of *Helicoverpa armigera* nuclear virus at 700 LE (larval equivalent)/ha gave better protection to tomatoes from *H. armigera* resulting in a 98.25-100% reduction in the larval population, 6.89% mean fruit damage, 57.49kg/plot mean marketable yield, and it was as effective as the *H. armigera* nuclear polyhedeosis virus at the 500 LE/ha dose. Sequential application with the first spray of Endosulfan 0.07% followed by 2 sprays of *Helicoverpa armigera* nuclear polyhedrosis virus at 250 LE/ha greatly reduced the larval population and was comparable with 3 application of Endosulfan 0.07% applied alone.

Ganguly and Dubey (1998) evaluated a number of insecticidal treatments against *Helicoverpa* on tomato (variety Pusa Rube) in Madhya Pradesh, India, during the Rabi season of 1995-1996, *Helicoverpa* nuclear polyhedrosis virus (250 larval equivalents) + Endosulfan at 0.07% was the most effective, resulting in a 47.96% increase in yield and 32.52% avoidable losses.

Pandey *et al*. (1997) conducted a series of experiments in 1993-96 in the western hills, Nepal, to understand the pest dynamics and to develop integrated pest management (IPM) technologies against tomato fruit borer *Helicoverpa armigera*. Monitoring of *H. armegera* for several seasons across the agro- ecological zones indicated that March-April is the peak activity period of the moth. The period coincides with the showering/fruiting seasons of tomato and the pest causes severe yield losses. Tomato CV Roma and local landraces collected from kholakhet, par bat were found to be less preferred for egg laying by this pest. The naturally occurring egg parasitoid was low in middle range of hills. Within the river basins, activity of the parasitoid was low early in the season. There is scope for augmentative release of laboratory reared parasitoids for the management if this pest. Nuclear polyhedrosis viruses, although reported to be useful against *H. armigera* elsewhere, was not very promising under these conditions.

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted to study on the effectiveness of some management practices against tomato fruit borer. This chapter provides a brief description of plant materials, experimental site, soil type, weather condition, land preparation, fertilizer application, experimental design layout, collection of data, method of intercultural operations, fruit harvesting and statistical analysis etc. under the following headings:

3.1 Description of the experimental site

3.1.1 Duration and location

The experiment was conducted at the Central Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during Rabi season from 25 october, 2010 to 29 march, 2012. Geographically the experimental field is located at $24^0$09′ N latitude and $90^0$26′ E longitude at an elevation of 8 m above the sea level (Khan, 1997) belonging to the Agro-ecological Zone “AEZ-28” of Madhupur Tract (UNDP, 1988; FAO, 1988).

3.1.2 Soil

The soil of the research field is medium high land with adequate irrigation facilities and low organic matter content. The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage facilities during the experimental period.

3.1.3 Climate

The experimental area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during the months of April to September (Kharif Season) and scanty rainfall during the rest period of the year (Biswas, 1987). The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February (SRDI, 1991). The detailed meteorological data in respect of air temperature, relative humidity, total rainfall and soil temperature collected from the Meteorological Department of Bangladesh, Agargoan, Dhaka-1207 during the period of study and presented in Appendix II.

3.2 Experimental treatments

A. Variety: The healthy seeds of BARI tomato–4 were used in the experiment. Tomato seeds are collected from Khamar Bari, Farmgate Dhaka.

B. Treatments: Seven treatments were considered in this study and the treatments (T) were:

T_1 = Neem oil @ 4ml/l of water at 7 days interval.

T_2 = Neem seed kernel @ 300g/6l of water at 7 days interval.

T_3 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval.

T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval.

T_5 = Dursban 20EC 3ml/l of water at 7 days interval.

T_6 = Basathrin 10EC 2.5ml/l of water at 7 days interval.

T_7 = Untreated Control.

3.3 Experimental design and layout

The experiment consisted of 7 treatments and was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental plot was first divided into three blocks. Each block consisted of 7 plots. Thus, the total numbers of plot were 21. Different combinations of treatments were assigned to each block as per design of the experiment. The size of a unit plot was 3m×2m. A distance of 0.5 m between the plots and 1.0 m between the blocks were maintained.

3.4 Seed treatment

Seeds were treated with Vitavex-200 @ 0.25% before sowing to prevent seeds from the attack of soil borne disease. Furadan @ 1.2 kg ha^{-1} was also used against wireworm and mole cricket.

3.5 Seedbed preparation

Seedbed was prepared on 25 October, 2011 for raising seedlings of tomato and the size of the seedbed was 3m×1m. For making seedbed, the soil was well ploughed and converted into loose friable and dried masses to obtained good tilth. Weeds, stubbles and dead roots were removed from the seedbed. Cow dung was applied to the prepared seedbed at the rate of 10 t ha^{-1}.

3.6 Land preparation

The experimental area was first opened on 20 November, 2011 by a disc plough and exposed to direct sunshine to kill soil borne pathogens and soil inhabitant insects. It was prepared by several ploughing and cross ploughing with a power tiller followed by laddering to bring about a good tilth. The land was leveled, corners were shaped and the clods were broken into pieces. The weeds, crop residues and stables were removed from the field. Total organic manures were applied according to their treatment and finally leveled. The soil of the plot was treated by Seven 50 wp @ 5kg/ha to protect the young plants from the attack of mole cricket, ants and cutworm.

3.7 Raising of seedlings

Light watering and weeding were done several times. Chemical fertilizers were not applied for raising of seedlings. Seedlings were not attacked by any kind of insect pest or disease. Healthy and 30 days old seedlings were transplanted into the experimental field on 5 December, 2011.

3.8 Fertilizer application

Recommended manures and fertilizers were applied as described by Rashid, 2003 :

Cowdung	: 10 t ha^{-1}
Urea	: 500 kg ha^{-1}
TSP	: 400 kg ha^{-1}
MP	: 20 kg ha^{-1}

All well decomposed cowdung, TSP and 50% urea and MP were applied at the time of final land preparation. Further application of the rest of urea and MP were applied after 10 days of planting.

3.9 Cultural practices

After transplanting, a light irrigation was done. Subsequent irrigation was applied as and when needed. Proper drainage system was also developed for draining out excess water. After 15 days of transplanting a single healthy seedling per pit was allowed to grow discarding the others, propping of each plant by bamboo stick was provided and maintained at 1.0 m height from ground level for additional support and to allow normal creeping. Weeding and mulching in the plot were done, whenever necessary.

3.10 Data collection and calculation

Fruits were harvested separately from each tomato plant of whole plot. Data collection was started from vegetative stage up to fruit harvest. Ten plants were randomly selected and tagged from each plot prior to harvest for collection of data on plant characters, fruit infestation, fruit yield etc.

3.11 A brief outline of the procedure of data recording

a) Number of fruits plant^{-1}

Fruits of selected plants of each replication were counted and then the average number of fruits for each plant was determined.

b) Number of infested fruits plant^{-1}

Fruit borer infested fruits of selected plant were counted at flowering and reproductive stage.

c) Number of total fruits plot^{-1}

The number of fresh and fruit borer infested fruits of every replicated plots were recorded five times during harvest and then the mean number was considered

d) Number of healthy fruits plot^{-1}

The number of fresh or healthy fruits of every replicated plot was recorded five times at each 05 harvest and then the mean number was considered

e) Number of infested fruits plot^{-1}

The number of fruit borer infested fruits of every replicated plot was recorded five times at each 05 harvest and then the mean number was considered

f) Fruits infestation (%)

The number of fresh and fruit borer infested fruits of every replicated plot was counted five times at each 05 harvest. The percent of fruit infestation were calculated by the following formula:

$$\text{Fruit infestation (\%)}: \frac{\text{Number of infested fruits}}{\text{Number of total fruits}} \times 100$$

g) Weight of total fruits plot^{-1}

The fresh and fruit borer infested fruits of every replicated plot was weighted(g) at five times at each 05 harvest and then mean weight was considered.

h) Weight of healthy fruits plot^{-1}

The fresh or healthy fruits of every replicated plot were weighted(g) at five times at each 05 harvest and then mean weight was considered.

i) Weight of infested fruits plot^{-1}

The fruit borer infested fruits of every replicated plot was weighted(g) five times at each 05 harvest and then mean weight was considered.

j) Weight of infested fruits (%)

The fresh and fruit borer infested fruits of every replicated plots weighted(g) five times at each 05 harvest and then mean weight was considered. The percentage of infested fruits weight was calculated by the following formula:

$$\text{Weight of infested fruits (\%)}: \frac{\text{Weight of infested fruits}}{\text{Weight of total fruits}} \times 100$$

3.14 Statistical analysis

The data obtained from various parameters were statistically analyzed in MSTAT-C computer program (Russel, 1986). The mean values for all the parameters were calculated and the analysis of variance for the characters was done and means were separated by Duncan's Multiple Range Test (DMRT) at 5 % levels of probability (Gomez and Gomez, 1984) among treatments.

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted at the central farm of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during 25 October, 2011 to 29 March, 2012 to study on the development of IPM packages against the tomato fruit borer. The result of the present study regarding the healthy fruits, fruit yield %, infestation and economic analysis were presented, discussed and interpreted under the following headings:

4.1 Effect of different treatments on the tomato fruit borer in respect of fruit number and fruit yield after harvest

4.1.1 Fruit by number at first harvest (13 March, 2012)

Significant variation due to treatment was observed in the infestation by tomato fruit borer, number of fruits plot^{-1}, number of healthy fruits plot^{-1}, number of infested fruits and fruits infestation number (%) at first harvest (13 March, 2012) (Appendix VII and Table 1).

The maximum number of fruits plot^{-1} (48.23) was observed in T_3 (comprising *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) which was significantly different from all other treatments where control treatment produce the minimum number of fruits plot^{-1} (28.96).

Accordingly the treatments T_3 also produce the maximum number of healthy fruits (43.36) but the lowest number of healthy fruits (24.69) were harvested from control (T_7) treatment which was statistically identical to that of T_2 (25.46). The rest of the treatment gave intermediate level of activity and produced optimum number of healthy fruits plot^{-1}.

Table.1 Effect of different treatments on the tomato fruit borer expressed by number of fruits, fruits infestation and their infestation percent at first harvest (13 March, 2012)

Treatment	Number of total fruits plot^{-1}	Number of healthy fruits plot^{-1}	Number of infested fruits plot^{-1}	Infestation (%)
T_1	36.08 c	30.78 c	5.30 sa	14.70 a
T_2	29.04 e	25.46 d	3.58 bc	12.33 b
T_3	48.23 a	43.36 a	4.87 ab	10.07 c
T_4	30.87 de	27.69 cd	3.18 c	10.22 c
T_5	45.23 b	39.74 b	5.50 a	12.16 b
T_6	33.80 cd	29.69 c	4.11 b	12.13 b
T_7	28.96 e	24.69 d	4.27 b	14.74 a
$LSD_{0.05}$	**3.56**	**3.32**	**0.92**	**2.19**
Level of significance	**	**	**	**
CV (%)	**5.53**	**5.90**	**11.29**	**9.87**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Neem oil @ 4ml/l of water at 7 days interval

T_2 = Neem seed kernel @ 300g/6l or 0.167kg/l of water at 7 days interval

T_3 = *T. evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval

T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval

T_5 = Dursban 20EC 3ml/l of water at 7 days interval.

T_6 = Basathrin 10EC2.5ml/l of water at 7 days interval.

T_7 = Untreated Control.

Among the treatments, the maximum infested fruit was recorded in the treatment T_5 (5.50) which were not differed significantly with that of T_1 (5.30). However, treatment T_4 produces the minimum number of infested fruits (3.18) at first harvest. The fruit infestation was lower (10.07%) in T_3 treated plot which was statistically identical to that of T_4 (10.22). The Untreated Control (T_7) had the maximum fruit infestation (14.74%) which was significantly identical to that of T_1 (14.70). While treatment, T_2 (12.33) and treatment T_6 (12.136) treated plot showed intermediate level of infestation and was statistically identical (Table 1).

4.1.2 Characteristics of fruits yield by weight at first harvest (13 March, 2012)

Significant difference was found among treatments for controlling tomato fruit borer. Total weight of fruits, weight of healthy and infested fruits and % fruits weight infestation at first harvest are presented in Appendix VIII and Table 2.

Weight of total fruits was the highest (2564.70 g) in the treatment T_3 (*Trichogramma evanescense* @ 0.25gm/6m^2 at 7 days interval + Neem oil @ 4ml/L of water at 7 days interval) which was significantly different with all other treatments while untreated control (1570.00 g) and treatment T_2 (1571.60 g) gave similar results.

Weight of healthy fruits had also higher (2437.00 g) in the treatment T_3 treated plot which was significantly differed from other treatments. The lowest weight of healthy fruits (1358.00 g) was found in control (T_7) treatment which was not significantly different that of T_2 (1377.00 g) and T_6 (1438.00 g) treated plot.

Among the treatments, weight of infested fruits was higher (265.00 g) in T_1 treated plot which was not differed significantly from that of T_5 (250.20 g) and they are closely followed by the treatment T_6 (215.00 g) and T_7 (212.00 g) where T_7 and T_6 were statistically similar. However, treatment T_4 treated plot produces the lower weight of infested fruits (116.90 g) at first harvest which was also statistically identical to that of T_3 (127.70) treated plot.

Table 2. Effect of different treatments on tomato fruit borer measured by the weight of healthy and infested fruits at weight and infested fruits at first harvest (13 March, 2012)

Treatment	Weight of total fruits $plot^{-1}$ (g)	Weight of healthy fruits $plot^{-1}$ (g)	Weight of infested fruits $plot^{-1}$ (g)	Infestation (%)
T_1	2281.00 b	2016.00 b	265.00 a	11.58 ab
T_2	1571.60 e	1377.00 d	194.60 b	12.38 a
T_3	2564.70 a	2437.00 a	127.70 c	5.18 d
T_4	1765.00 cd	1648.00 c	116.90 c	6.62 d
T_5	1865.00 c	1615.00 c	250.20 a	13.40 a
T_6	1653.00 de	1438.00 d	215.00 ab	12.94 a
T_7	1570.00 e	1358.00 d	212.00 ab	13.50 a
$LSD_{0.05}$	**164.5**	**202.3**	**46.59**	**2.37**
Level of significance	**	**	**	**
CV (%)	**4.91**	**6.73**	**13.38**	**12.67**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Neem oil @ 4ml/l of water at 7 days interval

T_2 = Neem seed kernel @ 300g/6l or 0.167kg/l of water at 7 days interval

T_3 = *T. evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval

T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval

T_5 = Dursban 20EC 3ml/l of water at 7 days interval.

T_6 = Basathrin 10EC 2.5ml/l of water at 7 days interval.

T_7 = Untreated Control.

The fruit weight infestation was lower (5.18%) in T_3 treated plot which was closely followed by T_4 (6.62%). Control treatment (T_7) had the higher infested fruit weight (13.50%) which was not differing significantly from that of T_2 (12.38%), T_6 (12.94%) and T_5 (13.40%). Treatment T_1 (11.58%) comprising Neem oil @ 4ml/l of water at 7 days interval level of infested fruit growth showed the intermediate results (Table 2).

From the first harvest observation, it was found that the treatment T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) recorded the higher yield of tomato in terms of fruits production and lower infestation level compared to other treatments. The treatment T_3 was more effective to controlling the tomato fruit borer and produced the maximum number of total and healthy fruit.

4.1.3 Characteristics of fruit by number at second harvest (17 March, 2012)

Number of total fruits plot^{-1}, number of healthy fruits plot^{-1}, number of infested fruits plot^{-1} and % fruits infestation differed significantly among the treatments applied against tomato fruit borer at second harvest (17 March, 2012) (Appendix IX and Table 3).

Among the treatments applied against fruit borer, treatment T_3 (comprising *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) recorded the maximum total fruits plot^{-1} (61.36) which was significantly different from other treatments where control treatment produce the minimum number of total fruits plot^{-1} (41.23) which was statistically similar to that of T_4 (41.79). However, treatments T_3 also produce the maximum number of healthy fruits (56.12) which was closely followed by T_5 (48.60) and the lowest number of healthy fruits (33.40) was found in control (T_7) treatment. Number of healthy fruits of treatments T_1 (45.41) and T_6 (46.48) were statistically similar. The maximum number of infested fruits (7.83) of T_7 (control treatment) treated plot which was statistically similar to that of T_1 (neem oil @ 4ml/l of water at 7 days interval) (7.81) and it was also statistically similar to that of T_5 (Darsban 3ml/l of water at 7 days interval) (6.89). Similarly, the treatment T_4 produces the minimum number of infested fruits (4.55) at second harvest and it was statistically similar to that of T_3 (5.24).

Table 3. Effect of different treatments on the tomato fruit borer measured by number of fruits, fruits infestation and their infestation percent at second harvest (17 March, 2012)

Treatment	Number of total fruits plot^{-1}	Number of healthy fruits plot^{-1}	Number of infested fruits plot^{-1}	Infestation (%)
T_1	53.22 bc	45.41 c	7.81 a	14.68 b
T_2	48.24 c	42.14 d	6.10 b	12.57 bc
T_3	61.36 a	56.12 a	5.24 c	8.54 d
T_4	41.79 d	37.24 e	4.55 c	10.89 c
T_5	55.48 b	48.60 b	6.89 ab	12.40 bc
T_6	53.17 bc	46.48 bc	6.69 b	12.57 bc
T_7	41.23 d	33.40 f	7.83 a	18.99.11 a
$LSD_{0.05}$	**5.08**	**2.99**	**1.16**	**2.07**
Level of significance	**	**	**	**
CV (%)	**5.68**	**3.81**	**10.60**	**9.90**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Neem oil @ 4ml/l of water at 7 days interval

T_2 = Neem seed kernel @ 300g/6l or 0.167kg/l of water at 7 days interval

T_3 = *T. evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval

T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval

T_5 = Dursban 20EC 3ml/l of water at 7 days interval.

T_6 = Basathrin 10EC 2.5ml/l of water at 7 days interval.

T_7 = Untreated Control.

Fruit infestation also was higher (18.99%) in control treatment and it was followed by T_1 (14.68) treated plot and they differed significantly with other treatments. Both the T_2 and T_6 treated plot had the same fruit level of borer infestation (12.57) which was statistically identical to that of T_5 (12.40). In contrast, treatment T_3 treated plot had the lower level of fruit borer infestation (8.54%) and this was followed by T_4 (10.89) at second harvest (Table 3).

4.1.4 Characteristics of fruits yield by weight at second harvest (17 March, 2012)

Weight of total fruits plot^{-1}, weight of healthy fruits plot^{-1}, weight of infested fruits plot^{-1} and (%) weight of infested fruits showed significant difference among the treatments applied against tomato fruit borer at second harvest (17 March, 2012) (Appendix X and Table 4).

Among the treatments, weight of total fruits had higher (3681.30 g) in the treatment T_3 (*Trichogramma evanescense* @ 0.25gm/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) which was significantly different from that of other treatments. Control treatment had the lower total weight of fruits (2346.50 g) which was statistically similar to that of T_2 (2393.00 g). Other treatments gave the intermediate level of total weight of fruit.

Weight of healthy fruits had also significantly higher (3348.00 g) in T_3 treated plot which was significantly differed from that of other treatments. The lowest weight of healthy fruits (2014.00 g) was found in T_2 treated plot which was statistically similar to that of control or T_7 (2015.00 g) and it was followed by T_4 (2268.00 g) treated plot. The other treatments T_5 (2740.00 g), T_6 (2640.00 g) and T_1 (2576.00 g) applied plots recorded statistically similar weight of healthy fruits.

Weight of infested fruits was higher (511.70 g) in T_5 treated plot which was statistically similar to that with T_6 (474.70 g). On the other hand, the lowest weight of infested fruit (312.70 g) was recorded in the treatment T_4 treated plot which was statistically similar to that of T_7 (331.50 g), T_3 (333.30 g), T_1 (366.40 g) and T_2 (379.10 g).

The infested fruit weight was lower (9.05%) in T_3 treated plot. Among the treatment, T_1 (12.41%) and T_4 (12.12%) treated plot gave the intermediate level of infested fruit weight and they were statistically identical. Among the other treatment, treatment T_2 had higher infested fruit weight (15.82%) which was statistically similar to that of all other all treatments viz. T_5 (15.74%), T_6 (15.24%) and control or T_7 (14.13%).

Table 4. Effect of different treatments on the tomato fruit borer measured by the total, healthy and infested weight of fruits and % infested fruits weight at first harvest (17 March, 2012)

Treatment	Weight of total fruits plot^{-1} (g)	Weight of healthy fruits plot^{-1} (g)	Weight of infested fruits plot^{-1} (g)	Infestation (%)
T_1	2942.00 c	2576.00 b	366.40 b	12.41 b
T_2	2393.00 e	2014.00 d	379.10 b	15.82 a
T_3	3681.30 a	3348.00 a	333.30 b	9.05 c
T_4	2581.00 d	2268.00 c	312.70 b	12.12 b
T_5	3252.00 b	2740.00 b	511.70 a	15.74 a
T_6	3115.00 bc	2640.00 b	474.70 a	15.24 a
T_7	2346.50 e	2015.00 d	331.50 b	14.13 a
$LSD_{0.05}$	**193.00**	**199.9**	**76.73**	**2.61**
Level of significance	**	**	**	**
CV (%)	**3.74**	**4.47**	**11.14**	**10.90**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Neem oil @ 4ml/l of water at 7 days interval

T_2 = Neem seed kernel @ 300g/6l or 0.167kg/l of water at 7 days interval

T_3 = *T. evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval

T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval

T_5 = Dursban 20EC 3ml/l of water at 7 days interval.

T_6 = Basathrin 10EC 2.5ml/l of water at 7 days interval.

T_7 = Untreated Control.

From the investigation of second harvest, it was clear that the treatment T3 (Trichogramma evanescense @ 0.25gm/6m2 at 7 days interval + Neem oil @ 4ml/L of water at 7 days interval) provided the greater production of tomato in terms of maximum number and weight of fruits and lower infestation compared to other treatments. The treatment T3 was more effective against tomato fruit borer which enhance more fruit production of tomato.

Similar trend were also observed by Rahman *et al*. (2011) where they determine the comparative efficacy of some chemical insecticides and botanicals against chili fruit borer. The experiment comprised with twelve treatments and among them first six (T_1-T_6) were the application of insecticide and others (T_7-T_{11}) were botanicals. Treatments were T_1: Sumicidin @ 6.0 ml/2 litre of water at 7 days interval; T_2: Malathion @ 6.0 ml/2 litre of water at 7 days interval; T_3: Ripcord @ 3.0 ml/2 litre of water at 7 days interval; T_4: Marshal @ 6.0 ml/2 litre of water at 7 days interval; T_5: Diazinon @ 6.0 ml/2 litre of water at 7 days interval; T_6: Suntaf @ 2.5 ml/2 litre of water at 7 days interval; T_7: Allamanda leaf extract @ 0.5 kg/2 litre of water at 7 days interval; T_8: Neem leaf extract @ 0.5 kg/2 litre of water at 7 days interval; T_9: Garlic clove + extract @ 0.5 kg/2 litre of water at 7 days interval; T_{10}: Ginger rhizome extract @ 0.5 kg/2 litre of water at 7 days interval; T_{11}: Onion bulb extract @ 0.5 kg/2 litre of water at 7 days interval; T_{12}: Untreated control. In total cropping season the lowest percentage of fruit infestation by number (5.72%) was recorded from the treatment T_4 treated plot which was statistically similar (6.22%) with the treatment T_8 and the highest (24.90%) was recorded from untreated control and which was closely followed (17.39%) by the treatment $T_{5,}$ T_{11} (16.48%) and T_{10} (15.37%). Fruit infestation reduction over control by number estimated as the highest value (77.03%) and was recorded from the treatment T_4, while the lowest (30.16%) was recorded from T_5 treatment. Fruit infestation reduction over control by weight was estimated and the highest value was (63.35%), recorded from the treatment T_4, while the lowest (22.84%) reduction of fruit infestation over control was from the treatment T_5. Highest weight of fruit yield (30.60 t/ha) was recorded from the treatment $T_{4.}$

4.1.5 No. of fruit by at third harvest (21 March, 2012)

A significant variation was observed on number of total fruits plot^{-1}, number of healthy fruits plot^{-1}, number of infested fruits plot^{-1} and the % fruits infestation due to the effect of treatments applied against tomato fruit borer at third harvest (21 March, 2012) (Appendix XI and Table 5).

Among the treatments applied against of fruit borer, T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) had the maximum number of total fruits plot^{-1} (44.20) which was statistically identical to that of T_1 (40.50) and T_4 (40.26). The minimum number of total fruits (23.42) was found in control plot and it was also statistically similar to that of T_5 (24.05) and T_2 (27.05). Treatment T_6 provided the intermediate level of total fruits plot^{-1} (35.77).

Treatments T_3 also produce the maximum number of healthy fruits (40.15) compared to other treatment applied against tomato fruit borer and this was followed by the second highest (35.59) in T_5 and third highest (35.20) in T_1 treated plot. The untreated control plot had the minimum number of healthy fruits (19.70) and it was statistically similar to that of T_5 (20.51) and T_2 (23.14) treated plot.

Infested fruit was the maximum (5.63) in treatment T_6 and which was followed by the treatment T_1 (5.30) and T_4 (4.67) treated plot. On the other hand, the T_5 treated plot produces the minimum number of infested fruits (3.54) at third harvest and it was statistically similar to that of untreated control (3.72) and T_2 (3.91) treated plot. Other treatment gave the intermediate of fruit borer infestation.

Fruit borer infestation was the highest (15.88%) in control plot which was statistically identical to that of T_6 (15.73%) and these were followed by T_5 (14.72), T_2 (14.43) and T_1

(13.03) treated plot. However, treatment T_3 gave the lower fruit borer infestation (9.14%) which was followed by T_4 (11.59%) at third harvest (Table 5).

Table 5. Effect of different treatments on the tomato fruit borer in terms of number of fruits, fruits infestation and their percent infestation at third harvest (21 March, 2012)

Treatment	Number of total fruits plot^{-1}	Number of healthy fruits plot^{-1}	Number of infested fruits plot^{-1}	Infestation (%)
T_1	40.50 a	35.20 b	5.30 ab	13.03 ab
T_2	27.05 c	23.14 d	3.91 c	14.43 ab
T_3	44.20 a	40.15 a	4.05 bc	9.14 c
T_4	40.26 a	35.59 b	4.67 abc	11.59 bc
T_5	24.05 c	20.51 d	3.54 c	14.72 ab
T_6	35.77 b	30.14 c	5.63 a	15.73 a
T_7	23.42 c	19.70 d	3.72 c	15.88 a
$LSD_{0.05}$	**3.95**	**3.30**	**1.27**	**3.61**
Level of significance	**	**	**	**
CV (%)	**6.62**	**6.26**	**16.50**	**15.27**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Neem oil @ 4ml/l of water at 7 days interval

T_2 = Neem seed kernel @ 300g/6l or 0.167kg/l of water at 7 days interval

T_3 = *T. evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval

T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval

T_5 = Dursban 20EC 3ml/l of water at 7 days interval.

T_6 = Basathrin 10EC 2.5ml/l of water at 7 days interval.

T_7 = Untreated Control.

4.1.6 Fruits yield by weight at third harvest (21 March, 2012)

Weight of total fruits plot^{-1}, weight of healthy fruits plot^{-1}, weight of infested fruits plot^{-1} and the % weight of infested fruits showed significant variation due to the effect of different treatments applied to suppress tomato fruit borer recorded at third harvest (21 March, 2012) (Appendix XII and Table 6).

Table 6. Effect of different treatments on the tomato fruit borer in terms of fruits weight and % infested fruits weight at third harvest (21 March, 2012)

Treatment	Weight of total fruits $plot^{-1}$ (g)	Weight of healthy fruits $plot^{-1}$ (g)	Weight of infested fruits $plot^{-1}$ (g)	Infestation (%)
T_1	1661.00 c	1426.00 c	234.50 b	14.07 b
T_2	1225.00 e	1081.00 e	144.10 d	11.84 c
T_3	2534.00 a	2315.00 a	219.90 bc	8.68 d
T_4	1316.00 e	1192.00 de	123.70 d	9.370 d
T_5	1945.0 b	1651.00 b	293.90 a	15.22 a
T_6	1467.00 d	1303.00 cd	164.10 c	11.19 c
T_7	928.65 f	776.90 f	151.75 c	16.34 a
$LSD_{0.05}$	**150.0**	**163.3**	**19.99**	**1.46**
Level of significance	**	**	**	**
CV (%)	**5.25**	**6.60**	**5.24**	**6.51**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Neem oil @ 4ml/l of water at 7 days interval

T_2 = Neem seed kernel @ 300g/6l or 0.167kg/l of water at 7 days interval

T_3 = *T. evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval

T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval

T_5 = Dursban 20EC 3ml/l of water at 7 days interval.

T_6 = Basathrin 10EC 2.5ml/l of water at 7 days interval.

T_7 = Untreated Control.

Among the treatments, total fruits weight had higher (2534.00 g) in treatment T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) which was significantly different from all other treatments. Untreated control plot provided the lower total weight of fruits (928.65 g) which was also statistically differed with other treatments.

Treatment T_3 treated plot provided the higher weight of healthy fruits (2315.00 g) and the lowest weight of healthy fruits (776.90 g) was recorded in control plot (T_7) at third harvest. All the treatments applied against tomato fruit borer differed significantly from each others (table 6).

Among the treatment, T_5 treated plot produces the highest weight of infested fruits (293.90 g) which was followed by T_1 (234.50 g) treated plot. However, the lowest weight of infested fruit (123.70 g) was obtained in the treatment T_4 treated plot which was statistically similar to that of T_2 (144.10 g). Among other treatments, T_6 treated plot and untreated control (T_7) plot area statistically similar (164.10 and 151.75 g, respectively).

The infested fruit weight was lower (8.68%) in the T_3 treated plot which was followed by the T_4 (9.37%) treated ones. The untreated control (T_7) plot had the lowest weight of infested fruit (16.34%) which was statistically similar to that of T_5 (15.22%) treated plot. Among the other treatment, T_2 and T_6 had the intermediate level of weight of infested fruit and they are statistically similar (11.84 and 11.19%, respectively).

From the investigation at third harvest, it was clear that the greater performance was obtained to enhance the number and weight of fruits and ensure lower infestation when treatment T_3 was applied thus this treatment was more effective against tomato fruit borer ensure enhanced fruit production of tomato.

4.1.7 Number of fruit at fourth harvest (25 March, 2012)

Significant difference was found among the treatments applied against tomato fruit borer in terms of number of total fruits plot^{-1}, number of healthy fruits plot^{-1}, number of infested fruits plot^{-1} and % fruits infestation at fourth harvest (25 March, 2012) (Appendix XIII and Table 7).

Among the treatments, the maximum number of total fruits plot^{-1} (39.01) was obtained from the treatment T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) which was statistically similar to that of T_5 (38.26) at fourth harvest. This was followed by that of T_4 (25.49), T_2 (27.05), T_1 (23.21) and T_6 (23.49) treated plot. On the other hand, in untreated control had the minimum number of total fruits plot^{-1} (22.80). Among the other two treatments T_1 (23.21) and T_6 (23.49) treated plot produced number of fruit per plot which showed statistically similar.

Table 7. Effect of different treatments applied to suppress the tomato fruit borer in terms of number of fruits, fruits infestation and percent infestation at fourth harvest (25 March, 2012)

Treatment	Number of total fruits plot^{-1}	Number of healthy fruits plot^{-1}	Number of infested fruits plot^{-1}	Infestation (%)
T_1	23.21 bc	20.90 bcd	2.31 d	9.891 d
T_2	27.04 b	23.96 b	3.08 b	11.25 c
T_3	39.01 a	35.95 a	3.06 b	7.791 e
T_4	25.49 b	23.48 bc	2.01 d	7.800 e
T_5	38.26 a	33.75 a	4.51 a	11.75 c
T_6	23.49 bc	20.16 cd	3.33 b	14.11 a
T_7	22.80 c	18.26 d	4.51 a	13.05 b
$LSD_{0.05}$	**4.13**	**3.36**	**0.67**	**0.663**
Level of significance	**	**	**	**
CV (%)	**8.24**	**7.50**	**12.43**	**3.45**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Neem oil @ 4ml/l of water at 7 days interval

T_2 = Neem seed kernel @ 300g/6l or 0.167kg/l of water at 7 days interval

T_3 = *T. evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval

T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval

T_5 = Dursban 20EC 3ml/l of water at 7 days interval.

T_6 = Basathrin 10EC 2.5ml/l of water at 7 days interval.

T_7 = Untreated Control.

Treatment T_3 treated plot provided the maximum number of healthy fruits (35.95) which was followed by T_5 (33.75) but they was statistically identical. On the other hand, control plot had the minimum number of healthy fruits (18.26) similar to that of T_6 (20.16) and T_1 (20.90) treated plot.

The number of borer infested fruit was the maximum (4.51) in both the T_5 and control plot (T_7). The number of borer infested fruit of T_6 (3.33), T_2 (3.08), T_3 (3.06) treated plot are statistically comparable. Again this parameter of T_1 (2.31) and T_4 (2.01) treated plots were statistically similar.

Percent borer infested fruit was higher (14.11%) in T_6 treated plot which was significantly higher than all other treatments. Treatment T_3 treated plot gave the lower number of borer infested fruit (7.79%) which was statistically similar to that of T_4 (7.80%) at 4th harvest (Table 7).

4.1.8 Fruits yield by weight at fourth harvest (25 March, 2012)

Weight of total fruits plot^{-1}, weight of healthy fruits plot^{-1}, weight of infested fruits plot^{-1} and the % weight of infested fruits showed significant variation among the tested treatments applied against tomato fruit borer at fourth harvest (25 March, 2012) (Appendix XIV and Table 8).

The highest weight of total fruits plot^{-1} (2080 g) was recorded in the T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) treated plot which was statistically similar to that of T_4 (2076.40 g). Untreated control plot provided the lowest total weight of fruits (1052.10 g) which was followed by the T6 (1179.00) treated plot.

Treatment T_3 also had the higher weight of healthy fruits (1894.00 g) and it was statistically similar to that T_4 of (1850.00 g). Similarly, the lowest weight of healthy fruits (890.30 g) was found in control plot and it was followed by that of T_6 (1024.00 g) and they are statistically identical.

Table 8. Effect of different treatments applied against the tomato fruit borer on the characters of fruits weight and % weight of infested fruit at fourth harvest (25 March, 2012)

Treatment	Weight of total fruits plot^{-1} (g)	Weight of healthy fruits plot^{-1} (g)	Weight of infested fruits plot^{-1} (g)	Infestation (%)
T_1	1798.00 b	1564.00 b	234.90 a	13.08 b
T_2	1514.00 c	1275.00 c	238.90 a	15.70 a
T_3	2080.00 a	1894.00 a	185.60 b	8.745 d
T_4	2076.40 a	1850.00 a	226.40 a	10.86 c
T_5	1322.00 cd	1172.00 cd	149.60 c	11.34 c
T_6	1179.00 de	1024.00 de	155.50 c	12.96 bc
T_7	1052.10 e	890.30 e	161.80 c	15.38 a
$LSD_{0.05}$	**201.3**	**175.5**	**19.89**	**0.653**
Level of significance	**	**	**	**
CV (%)	**7.14**	**7.07**	**5.90**	**3.02**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Neem oil @ 4ml/l of water at 7 days interval

T_2 = Neem seed kernel @ 300g/6l or 0.167kg/l of water at 7 days interval

T_3 = *T. evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval

T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval

T_5 = Dursban 20EC 3ml/l of water at 7 days interval.

T_6 = Basathrin 10EC 2.5ml/l of water at 7 days interval.

T_7 = Untreated Control.

Among the botanical and mechanical treatment against tomato fruit borer, treatment T2 recorded the highest weight of infested fruits (238.90 g) which was statistically similar to T1 (234.90) and T4 (226.40 g) treated plot. Weight of infested fruit harvested from T5 (149.60), T6 (155.50) and T7 (161.80) treated plot was lower but statistically similar. Medium level of infested fruit weight plot-1 was revealed in T3 (185.60g) treated plot. The percent fruit infestation was significantly lowest (8.75%) in T3 which was statistically different from all other treatments. The percent weight of infested fruits was the highest (15.38%) in control plot (T7) which was statistically identical with that of T2 (15.70%) treated plot.

These results revealed that the greater effectiveness was obtained in the treatment T_3 which was effective to suppress the tomato fruit borer which would enhance the production of tomato with minimum fruit infestation.

4.1.9 Number of fruit at fifth harvest (29 March, 2012)

Significant difference was observed on number of total fruits plot^{-1}, number of healthy fruits plot^{-1}, number of infested fruits plot^{-1} and the percent fruits infestation recorded in different treatment applied against tomato fruit borer at fifth harvest (29 March, 2012) are presented in Appendix XV and Table 9.

The maximum number of total fruits plot^{-1} (78.16) was recorded in T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) treated plot which was followed by the second highest (56.28) in T_4 treated plot at fifth or final harvest. The T_2 treated plot produced 48.45 number of the total fruits plot$^{-1.}$ Among the other treatments, T_5 (42.67) and T_6 (43.42) treated plot showed statistically similar number. On the other hand, untreated control plot provided the minimum number of total fruits plot^{-1} (35.08) and it was statistically similar to that of T_1 (36.88) treated plot. Treatments T_3 also had the maximum number of healthy fruits (72.36) compare to other treatments. The second highest results on the number of healthy fruits plot^{-1} (50.47) was harvested from T_4 treated plot which was differing significantly among the other treatments. Similarly, rest of the treatment produce the number of healthy fruits with the rank order of T_2 (42.99) > T_6 (40.15) > T_5 (38.47) > T_1 (32.15) > T_7 (30.36) whereas the untreated control plot produced the minimum number of healthy fruits.

Table 9. Effect of different treatments applied against the tomato fruit borer on the number of fruits, fruits infestation and percent fruit infestation at fifth harvest (29 March, 2012)

Treatment	Number of total fruits plot^{-1}	Number of healthy fruits plot^{-1}	Number of infested fruits plot^{-1}	Infestation (%)
T_1	36.88 e	32.15 e	4.73 c	12.82 a
T_2	48.45 c	42.99 c	5.45 b	11.20 b
T_3	78.16 a	72.36 a	5.83 a	7.46 d
T_4	56.28 b	50.47 b	5.81 a	10.20 c
T_5	42.67 d	38.47 d	4.20 d	9.82 c
T_6	43.42 d	40.15 cd	3.27 e	7.51 d
T_7	35.08 e	30.36 e	4.72 c	13.38 a
$LSD_{0.05}$	**4.59**	**3.98**	**0.398**	**0.867**
Level of significance	**	**	**	**
CV (%)	**5.29**	**5.10**	**4.59**	**4.71**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Neem oil @ 4ml/l of water at 7 days interval

T_2 = Neem seed kernel @ 300g/6l or 0.167kg/l of water at 7 days interval

T_3 = *T. evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval

T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval

T_5 = Dursban 20EC 3ml/l of water at 7 days interval.

T_6 = Basathrin 10EC 2.5ml/l of water at 7 days interval.

T_7 = Untreated Control.

The number of fruit borer infested fruit was the maximum (5.83) in T_3 treated plot which was statistically similar to that of T_4 (5.81) followed by the third highest in (5.45) T_2 treated plot. However, treatment T_1 (4.73) and T_7 (4.72) (control) were statistically similar results in respect of fruit borer infested fruits at final harvest. On the other hand, the minimum number of healthy fruits (3.27) was found in T_6 treated plot.

Percent fruit borer infestation was higher (13.38%) in T_7 untreated control plot which was statistically identical to that of T_1 (12.82%) which were followed by T_2 (11.20%). Percent fruit borer infestation in T_4 (10.20%) and T_5 (9.82%) treated plot were statistically similar at final harvest. Among the other treatments, the lower fruit borer infestation (7.46%) was obtained in T_3 treated plot which was statistically similar (7.51%) to that of T_6 at final harvest.

4.1.10 Fruits weight at fifth harvest (29 March, 2012)

Weight of total fruits plot^{-1}, weight of healthy fruits plot^{-1}, weight of infested fruits plot^{-1} and percent infested fruit weight showed significant variation among different treatments against tomato fruit borer at final or fifth harvest (29 March, 2012) (Appendix XVI and Table 10).

The highest weight of the total fruits plot^{-1} (3044 g) was observed in T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) at final harvest. Treatment T_4 (2183 g) and T_6 (1725 g) was the second and third in respect of weight of total fruit plot^{-1} at final harvest. The weight of total fruit plot^{-1} in the treatments were statistically similar viz., 1482.0 g in T_1, 1453.00 g in T_5, 1427.10 g in T_2 and 1421.30 g in T_7 (control). These results revealed the following ranking order in respect of total fruits weight plot^{-1} $T_3>T_4>T_6>T_1>T_5>T_2>T_7$.

Treatment T_3 also produced the higher weight of healthy fruits (2803.00 g) where the second (1857.00 g) and third (1580.00 g) highest levels were recorded from T_4 and T_6, treated plot. Weight of healthy fruit plot^{-1}were statistically similar in T_5 (1333.00 g) T_2 (1250.00 g), T_1 (1246.00 g) and control T_7 plot (1190.00 g). So, the lowest weight of healthy fruits was recorded from untreated control plot.

Table 10. Effect of different treatments applied against the tomato fruit borer on the fruits weight and percent infested fruits weight at fifth harvest (29 March, 2012)

Treatment	Weight of total fruits plot^{-1} (g)	Weight of healthy fruits plot^{-1} (g)	Weight of infested fruits plot^{-1} (g)	Infestation (%)
T_1	1482.00 d	1246.00 d	236.10 c	15.77 ab
T_2	1427.10 d	1250.00 d	177.10 d	12.41 c
T_3	3044.00 a	2803.00 a	241.00 b	7.92 d
T_4	2183.00 b	1857.00 b	326.00 a	14.87 b
T_5	1453.00 d	1333.00 d	120.10 f	8.19 d
T_6	1725.00 c	1580.00 c	145.70 e	8.44 d
T_7	1421.30 d	1190.00 d	231.30 c	16.27 a
$LSD_{0.05}$	**201.7**	**147.9**	**20.17**	**1.33**
Level of significance	**	*	**	**
CV (%)	**6.28**	**5.26**	**5.03**	**6.05**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Neem oil @ 4ml/l of water at 7 days interval

T_2 = Neem seed kernel @ 300g/6l or 0.167kg/l of water at 7 days interval

T_3 = *T. evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval

T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval

T_5 = Dursban 20EC 3ml/l of water at 7 days interval.

T_6 = Basathrin 10EC 2.5ml/l of water at 7 days interval.

T_7 = Untreated Control.

Among the treatments, the weight of infested fruits was significantly the highest (326.00 g) in the T_4 treated plot which was followed by the second highest (241.00 g) in T_3. The lowest weight of infested fruits was 120.10 g in T_5.

The percent infested fruit weight was the lowest (7.92%) in T_3 treated plot which was statistically identical to that of T_5 (8.19%) and T_6 (8.44%) at final harvest. The percent infested fruit weight was the lowest (16.27%) in untreated control plot T_7 which was closely followed by the T_1 (15.77%) treated plot (Table 10).

4.2 Effect of different treatment against tomato fruit borer in respect of fruit yield and BCR.

The analysis was done in order to find out the profitable treatment based on cost and benefit of various components. Non-materials and overhead cost were recorded for all the treatments of unit plot and calculated on ha^{-1} basis (marketable yield). The price of tomato fruits at the local market rate was considered. The result of economic analysis of tomato cultivation showed that the highest net benefit of Tk. 9924833 ha^{-1} was obtained in T_3 treatment and the second highest net benefit was found Tk. 50073.33 ha^{-1} in T_4 treatment.

Among the different treatment, treatment T_3 (*T. evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) gave the maximum net return Tk. 99248.33 where BCR was 1.377 and minimum net return Tk. 1768.22 from untreated control with BCR of 1.038 (Table 11).

Table 11. Benefit cost ratio (BCR) of tomato due to different treatments against the tomato fruit borer

Treatment	Marketable yield (t ha^{-1})	Gross return (Tk. ha^{-1})	Total cost for production (Tk. ha^{-1})	Net Return (Tk. ha^{-1})	Benefit cost ratio (BCR)
T_1	14.743	250636.67	208333.33	42303.33	1.203
T_2	12.270	208590.00	190000.00	18590.00	1.098
T_3	21.328	362581.67	263333.33	99248.33	1.377
T_4	14.220	241740.00	191666.67	50073.33	1.261
T_5	14.185	241145.00	203333.33	37811.67	1.186
T_6	13.308	226241.67	205000.00	21241.67	1.104
T_7	10.384	176522.33	170000.00	6522.33	1.038

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 10 plants per treatment

In a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability

T_1 = Neem oil @ 4ml/l of water at 7 days interval

T_2 = Neem seed kernel @ 300g/6l or 0.167kg/l of water at 7 days interval

T_3 = *T. evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval

T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days

T_5 = Dursban 20EC 3ml/l of water at 7 days interval.

T_6 = Basathrin 10EC 2.5ml/l of water at 7 days interval.

T_7 = Untreated Control.

Note. **Sale of tomato** @ Tk. 17.00 kg^{-1} @ Tk. 17000 t^{-1}
Total income: Marketable yield (t ha^{-1}) × Tk @ 17000.00
BCR: Gross return ÷ Total cost of production

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted at the central farm of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during 25 October, 2011 to 29 March, 2012 to study on the effectiveness of some management practices against tomato fruit borer. The experiment consisted of 7 treatments *viz.* T_1 = Neem oil @ 4ml/l of water at 7 days interval, T_2 = Neem seed kernel @ 300g/6l of water at 7 days interval, T_3 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval, T_4 = *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days, T_5 = Dursban 20EC 3ml/l of water at 7 days interval, T_6 = Basathrin 10EC 2.5 ml/l of water at 7 days interval and T_7 = Untreated Control.

Among the recording data at first harvest, the number of total fruits significantly was the maximum (48.23) was found in the treatment T_3 where healthy and infested fruits were 43.36 and 4.87, respectively and their infestation was lower (10.07%). However, the minimum number of total fruits (28.96) and healthy fruits (24.69) were found in control where higher infestation was occur (14.74%). Weight of total and healthy fruits were also recorded the higher (2564.70 and 2437.00 g, respectively) in T_3 compare to other treatments where fruits infestation was lower (5.18%). On the other hand, the lower weight of total fruits (1570.00 g) and healthy fruits (1358.00 g) were noticed in control where infested fruit weight was 212.0 g and the infestation was higher (13.50%). Similar results were also observed at second, third, fourth and fifth harvest.

Among the treatments applied against fruit borer, treatment T_3 (comprising *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) recorded the maximum total fruits plot^{-1} (61.36) which was significantly different from other treatments where control treatment produce the minimum number of total fruits plot^{-1} (41.23) which was statistically similar to that of T_4 (41.79). However, treatments T_3 also produce the maximum number of healthy fruits (56.12) which was closely followed by T_5 (48.60) and the lowest number of healthy fruits (33.40) was found in control (T_7) treatment. Number of healthy fruits of treatments T_1 (45.41) and T_6 (46.48) were statistically similar. The maximum number of infested fruits (7.83) of T_7 (control treatment) treated plot which was statistically similar to that of T_1 (neem oil @ 4ml/l of water at 7 days interval) (7.81) and it was also statistically similar to that of T_5 (Darsban 20EC 3ml/l of water at 7 days interval) (6.89). Similarly, the treatment T_4 produces the minimum number of infested fruits (4.55) at second harvest and it was statistically similar to that of T_3 (5.24). Among the treatments, weight of total fruits had higher (3681.30 g) in the treatment T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) which was significantly different from that of other treatments. Control treatment had the lower total weight of fruits (2346.50 g) which was statistically similar to that of T_2 (2393.00 g). Other treatments gave the intermediate level of total weight of fruit. The infested fruit weight was lower (9.05%) in T_3 treated plot. Among the treatment, T_1 (12.41%) and T_4 (12.12%) treated plot gave the intermediate level of infested fruit weight and they were statistically identical. Among the other treatment, treatment T_2 had higher infested fruit weight (15.82%) which was statistically similar to that of all other all treatments viz. T_5 (15.74%), T_6 (15.24%) and control or T_7 (14.13%).

Among the treatments applied against of fruit borer, T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) had the maximum number of total fruits plot^{-1} (44.20) which was statistically identical to that of

T_1 (40.50) and T_4 (40.26). The minimum number of total fruits (23.42) was found in control plot and it was also statistically similar to that of T_5 (24.05) and T_2 (27.05). Treatment T_6 provided the intermediate level of total fruits plot^{-1} (35.77).

Treatments T_3 also produce the maximum number of healthy fruits (40.15) compared to other treatment applied against tomato fruit borer and this was followed by the second highest (35.59) in T_5 and third highest (35.20) in T_1 treated plot. The untreated control plot had the minimum number of healthy fruits (19.70) and it was statistically similar to that of T_5 (20.51) and T_2 (23.14) treated plot. The infested fruit weight was lower (8.68%) in the T_3 treated plot which was followed by the T_4 (9.37%) treated ones. The untreated control (T_7) plot had the lowest weight of infested fruit (16.34%) which was statistically similar to that of T_5 (15.22%) treated plot. Among the other treatment, T_2 and T_6 had the intermediate level of weight of infested fruit and they are statistically similar (11.84 and 11.19%, respectively).

Among the treatments, the maximum number of total fruits plot^{-1} (39.01) was obtained from the treatment T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) which was statistically similar to that of T_5 (38.26) at fourth harvest. This was followed by that of T_4 (25.49), T_2 (27.05), T_1 (23.21) and T_6 (23.49) treated plot. On the other hand, in untreated control had the minimum number of total fruits plot^{-1} (22.80). Among the other two treatments T_1 (23.21) and T_6 (23.49) treated plot produced number of fruit per plot which showed statistically similar. The highest weight of total fruits plot^{-1} (2080 g) was recorded in the T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) treated plot which was statistically similar to that of T_4 (2076.40 g). Untreated control plot provided the lowest total weight of fruits (1052.10 g) which was followed by the T_6 (1179.00) treated plot. Treatment T_3 also had the higher weight of healthy fruits (1894.00 g) and it was statistically similar to that T_4 of (1850.00 g). Similarly, the lowest weight of healthy fruits (890.30 g) was found in control plot and it was followed by that of T_6 (1024.00 g) and they are statistically identical.

The maximum number of total fruits plot^{-1} (78.16) was recorded in T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) treated plot which was followed by the second highest (56.28) in T_4 treated plot at fifth or final harvest. The T_2 treated plot produced 48.45 number of the total fruits plot$^{-1.}$ Among the other treatments, T_5 (42.67) and T_6 (43.42) treated plot showed statistically similar number. On the other hand, untreated control plot provided the minimum number of total fruits plot^{-1} (35.08) and it was statistically similar to that of T_1 (36.88) treated plot.

Treatments T_3 also had the maximum number of healthy fruits (72.36) compare to other treatments. The second highest results on the number of healthy fruits plot^{-1} (50.47) was harvested from T_4 treated plot which was differing significantly among the other treatments. Similarly, rest of the treatment produce the number of healthy fruits with the rank order of T_2 (42.99) > T_6 (40.15) > T_5 (38.47) > T_1 (32.15) > T_7 (30.36) whereas the untreated control plot produced the minimum number of healthy fruits. The highest weight of the total fruits plot^{-1} (3044 g) was observed in T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) at final harvest. Treatment T_4 (2183 g) and T_6 (1725 g) was the second and third in respect of weight of total fruit plot^{-1} at final harvest. The weight of total fruit plot^{-1} in the treatments were statistically similar viz., 1482.0 g in T_1, 1453.00 g in T_5, 1427.10 g in T_2 and 1421.30 g in T_7 (control). These results revealed the following ranking order in respect of total fruits weight plot^{-1} T_3>T_4>T_6>T_1>T_5>T_2>T_7.

Treatment T_3 also produced the higher weight of healthy fruits (2803.00 g) where the second (1857.00 g) and third (1580.00 g) highest levels were recorded from T_4 and T_6, treated plot. Weight of healthy fruit plot^{-1}were statistically similar in T_5 (1333.00 g) T_2 (1250.00 g), T_1 (1246.00 g) and control T_7 plot (1190.00 g). So, the lowest weight of healthy fruits was recorded from untreated control plot.

During the total harvest period (first to fifth harvest), number of total fruits (270.99), healthy fruits (247.94), were maximum recorded in T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) while the number of total infested fruits was 23.05. Similarly, from this treatment the lowest fruit infestation (8.60%) also recorded during the entire harvest period. Among the fruit yield characters, the weight of total fruits and healthy fruits was also recorded the highest (13.91 and 12.80 kg plot^{-1}, respectively) where lower infestation (7.92%) was come up. In contrast, control treatment recorded the lowest production of total fruits (7.32 kg plot^{-1}) and healthy fruits (6.23 kg plot^{-1}) as well as highest infestation (15.12%) were noticed in this treatment.

Therefore, it could be concluded that the treatment T_3 (*Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval) was more efficient to control the fruit borer as well as better growth and higher yield of tomato among the all controlling treatments of tomato fruit borer. So, considering the above observation *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval may be possible to use as disease management while we can reduce our cost and save the environment as well as any hazardous effect on human, animal, fish etc.

Recommendation

Considering the above observation of the present study further investigation in the following areas may be suggested.

1. Evaluation of different treatment T3 comprising *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval + Neem oil @ 4ml/l of water at 7 days interval applied against tomato fruit borer revealed that the treatment ensure reduced rate of fruit infestation with increased yield. The treatment T_4 having *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval might be chosen as the second life defense. Treatment T_2 and T_4 have significant effect in suppressing this pest. So, it might be recommended to use the neem seed kernel with *Trichogramma evanescense* @ 0.25g/6m^2 at 7 days interval to combat the pest.
2. Further study may be needed for ensuring the integrated pest management practices in relation to growth and yield performance in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.
3. More mechanical and botanical treatments against tomato fruit borer may be needed to include for future study as sole or different combination to avoid total rely on insecticides.

CHAPTER VI

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APPENDICES

Appendix I. The morphological, physical and chemical properties of the experimental land

A. Morphological properties of the soil

Constituents	**Characteristics**
Location	Field Laboratory, Department of Agronomy, SAU, Dhaka
Soil Tract	Madhupur
Land type	high land, fertile, well drained
General soil type	Slightly acidic in reaction with low organic matter content
Agro-ecological one	“AEZ-28” of Madhupur Tract
Topography	Fairly level
Soil colour	Dark grey
Drainage	Moderate

B. Physical properties of the soil

Constituents	**Results**
Particle size analysis	
Sand (%) (0.0-0.02 mm)	21.75
Silt (1%) (0.02-0.002 mm)	66.60
Clay (%) (<0.002 mm)	11.65
Soil textural class	Silty loam
Colour	Dark grey
Consistency	Grounder

Result obtained from the mechanical analysis of the initial soil sample done in the Soil Resources Development Institute (SRDI), Dhaka.

C. Chemical composition of the initial soil (0-15 cm depth)

Constituents	**Results**
Soil pH	5.8
Organic matter (%)	1.30
Total nitrogen (%)	0.101
Available phosphorus (ppm)	27
Exchangeable potassium (me/100 g soil)	0.12

Methods of analysis

Texture	**Hydrometer methods**
pH	Ptentiometric method
Organic carbon	Walkely-Black method
Total N	Modified kjeldhal method
Soluble P	Olsen method ($NAHCO^3$)
Exchangeable K	Flame photometer method (Ammonium)

Result obtained from the mechanical analysis of the initial soil sample done in the Soil Resources Development Institute (SRDI), Dhaka.

Appendix II. Monthly air temperature, rainfall, relative humidity and sunshine hours during the growing season (October 2011 to March 2012)

Date/Week	*Air temperature (^{O}C)		Relative humidity (%)	Rainfall (mm) (Total)
	Maximum	Minimum		
October, 2010	26.11	18.05	77	19
November, 2010	25.82	16.04	78	00
December, 2010	22.40	13.50	74	00
January, 2011	24.50	12.40	68	00
February, 2011	27.10	16.70	67	30
March, 2011	31.40	19.60	54	11

* Monthly average and ** Monthly total
Source: Bangladesh Meteorological Dept. (Climate and Weather Division), Agargoan, Dhaka- 1207

Appendix III. Mean square on number of fruits, fruits infestation and their infestation percent under different treatment against the tomato fruit borer at first harvest (13 March, 2012)

Source of variation	Degrees of freedom	Mean square of			
		Number of total fruits $plot^{-1}$	Number of healthy fruits $plot^{-1}$	Number of infested fruits $plot^{-1}$	Infestation (%)
Replication	2	1.264	1.472	0.416	3.108
Treatment	6	216.786**	154.779 **	6.004 **	7.161 **
Error	12	4.007	3.482	0.267	1.520

**= significant at 1% level of probability

Appendix IV. Mean square on the characters of fruits weight and infested their infestation percent under different treatment against the tomato fruit borer at first harvest (13 March, 2012)

Source of variation	Degrees of freedom	Mean square of			
		Weight of total fruits $plot^{-1}$ (g)	Weight of healthy fruits $plot^{-1}$ (g)	Weight of infested fruits $plot^{-1}$ (g)	Infestation (%)
Replication	2	1901.95	12925.58	792.28	3.70
Treatment	6	540718.44**	492434.92**	8674.34**	22.05**
Error	12	8553.58	12925.58	685.90	1.78

**= significant at 1% level of probability

Appendix V. Mean square on number of fruits, fruits infestation and their infestation percent under different treatment against the tomato fruit borer at second harvest (17 March, 2012)

Source of variation	Degrees of freedom	Mean square of			
		Number of total fruits plot^{-1}	Number of healthy fruits plot^{-1}	Number of infested fruits plot^{-1}	Infestation (%)
Replication	2	6.49	3.86	2.805	9.116
Treatment	6	279.16**	168.70**	18.337**	38.121 **
Error	12	8.16	2.83	0.422	1.360

**= significant at 1% level of probability

Appendix VI. Mean square on the characters of fruits weight and infested their infestation percent under different treatment against the tomato fruit borer at first harvest (17 March , 2012)

Source of variation	Degrees of freedom	Mean square of			
		Weight of total fruits plot^{-1} (g)	Weight of healthy fruits plot^{-1} (g)	Weight of infested fruits plot^{-1} (g)	Infestation (%)
Replication	2	17191.339	14628.571	3468.489	3.409
Treatment	6	744384.426**	663061.629**	17755.347**	16.486 **
Error	12	11769.858	12628.571	1860.337	2.158

**= significant at 1% level of probability

Appendix VII. Mean square on number of fruits, fruits infestation and their infestation percent under different treatment against the tomato fruit borer at third harvest (21 March, 2012)

Source of variation	Degrees of freedom	Mean square of			
		Number of total fruits plot^{-1}	Number of healthy fruits plot^{-1}	Number of infested fruits plot^{-1}	Infestation (%)
Replication	2	5.439	2.015	0.362	2.093
Treatment	6	227.745 **	199.993 **	2.344 **	15.279 **
Error	12	4.934	3.344	0.513	4.115

**= significant at 1% level of probability

Appendix VIII. Mean square on the characters of fruits weight and infested their infestation percent under different treatment against the tomato fruit borer at third harvest (21 March, 2012)

Source of variation	Degrees of freedom	Mean square of			
		Weight of total fruits plot^{-1} (g)	Weight of healthy fruits plot^{-1} (g)	Weight of infested fruits plot^{-1} (g)	Infestation (%)
Replication	2	6251.27	7806.23	146.28	0.670
Treatment	6	1127406.67**	720995.02**	46719.27**	20.268 **
Error	12	7112.81	8430.11	126.28	0.673

**= significant at 1% level of probability

Appendix IX. Mean square on number of fruits, fruits infestation and their infestation percent under different treatment against the tomato fruit borer at fourth harvest (25 March, 2012)

Source of variation	Degrees of freedom	Mean square of			
		Number of total fruits plot^{-1}	Number of healthy fruits plot^{-1}	Number of infested fruits plot^{-1}	Infestation (%)
Replication	2	7.437	3.50	0.173	0.207
Treatment	6	162.779**	142.608 **	1.961 **	18.002 **
Error	12	5.402	3.571	0.140	0.139

**= significant at 1% level of probability

Appendix X. Mean square on the characters of fruits weight and infested their infestation percent under different treatment against the tomato fruit borer at fourth harvest (25 March, 2012)

Source of variation	Degrees of freedom	Mean square of			
		Weight of total fruits plot^{-1} (g)	Weight of healthy fruits plot^{-1} (g)	Weight of infested fruits plot^{-1} (g)	Infestation (%)
Replication	2	34258.54	15558.35	175.00	0.205
Treatment	6	607504.10**	521248.00**	6758.09**	14.150 **
Error	12	12803.86	9729.28	125.00	0.135

**= significant at 1% level of probability

Appendix XI. Mean square on number of fruits, fruits infestation and their infestation percent under different treatment against the tomato fruit borer at fifth harvest (29 March, 2012)

Source of variation	Degrees of freedom	Mean square of			
		Number of total fruits $plot^{-1}$	Number of healthy fruits $plot^{-1}$	Number of infested fruits $plot^{-1}$	Infestation (%)
Replication	2	15.870	9.558	0.070	0.571
Treatment	6	660.357 **	609.441**	2.666**	16.190 **
Error	12	6.654	5.008	0.050	0.238

**= significant at 1% level of probability

Appendix XII. Mean square on the characters of fruits weight and infested their infestation percent under different treatment against the tomato fruit borer at fifth harvest (29 March, 2012)

Source of variation	Degrees of freedom	Mean square of			
		Weight of total fruits $plot^{-1}$ (g)	Weight of healthy fruits $plot^{-1}$ (g)	Weight of infested fruits $plot^{-1}$ (g)	Infestation (%)
Replication	2	22857.143	6914.288	128.571	0.691
Treatment	6	1048713.580**	778456.603 **	28827.027**	29.644 **
Error	12	12857.143	6914.288	128.571	0.558

**= significant at 1% level of probability