# EFFICACY OF SOME NEWER INSECTICIDES AGAINST FRUIT BORER (*HELICOVERPA ARMIGERA*) IN TOMATO WITH SAFETY TO NATURAL ENEMIES


**BEJOY ROY**



**DEPARTMENT OF ENTOMOLOGY**

**SHER-E-BANGLA AGRICULTURAL UNIVERSITY**

**DHAKA - 1207**


**JUNE 2020**

# EFFICACY OF SOME NEWER INSECTICIDES AGAINST FRUIT BORER (*HELICOVERPA ARMIGERA*) IN TOMATO WITH SAFETY TO NATURAL ENEMIES

**BY**


**BEJOY ROY**

**Registration No.: 13-05364**


**A Thesis**

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

**MASTER OF SCIENCE**

**IN**

**ENTOMOLOGY**

**SEMESTER: JANUARY- JUNE, 2020**

**Approved by:**

**Prof. Dr. S. M. Mizanur Rahman**
**Department of Entomology**
**Supervisor**

**Prof. Dr. Md. Mizanur Rahman**
**Department of Entomology**
**Co-Supervisor**

**Prof. Dr. S. M. Mizanur Rahman**
**Chairman**
**Examination Committee**

# Department of Entomology

**Sher-e-Bangla Agricultural University**

**Sher-e-Bangla Nagar, Dhaka-1207**

**PABX: 99110351 & 9144270-79**


## *CERTIFICATE*

This is to certify that thesis entitled**, "EFFICACY OF SOME NEWER INSECTICIDES AGAINST FRUIT BORER (*HELICOVERPA ARMIGERA*) IN *TOMATO* WITH SAFETY TO NATURAL ENEMIES"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE** in **Entomology,** embodies the result of a piece of bona fide research work carried out by **BEJOY ROY, Registration No. 13-05364** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

**Dated: June, 2020**
**Place: Dhaka, Bangladesh**

**Prof. Dr. S. M. Mizanur Rahman**
**Supervisor**
**Department of Entomology**
Sher-e-Bangla Agricultural University
**Dhaka-1207**

DEDICATED TO

MY

BELOVED PARENTS

## *ACKNOWLEDGEMENT*

*All praises are due to the "Almighty Creator" Who kindly enabled the author to complete the research work and the thesis leading to Master of Science.*

*The author would like to express his heartiest respect, his deep sense of gratitude and sincere, profound appreciation to his supervisor, **Prof. Dr. S. M. Mizanur Rahman**, Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka for his sincere guidance, scholastic supervision, constructive criticism and constant inspiration throughout the course and in preparation of the manuscript of the thesis.*

*The author would like to express his heartiest respect and profound appreciation to his Co-supervisor, **Prof. Dr. Md. Mizanur Rahman**, Department of Entomology, SAU, Dhaka for his utmost cooperation and constructive suggestions to conduct the research work as well as preparation of the thesis.*

*The author expresses his sincere respect to all the teachers of Department of Entomology, SAU, Dhaka for providing the facilities to conduct the experiment and for their valuable advice and sympathetic consideration in connection with the study.*

*The author would like to thank all of friends especially and senior brother Md. Murad Hasan to help him in his research work.*

*The author expresses his profound gratitude and deepest appreciation to his parents, brothers, sisters, and relatives for their ever-ending prayer, encouragement, sacrifice and dedicated efforts to educate the author to this level.*

***June, 2020***

***SAU, Dhaka*** ***The Author***

# ABSTRACT

Tomato fruit borer is one of the most harmful insect in our country. This is mostly control by the chemical insecticides, which are available in the market. But the present investigation was undertaken for the evaluation of some management practices against tomato fruit borer. The experiment included 5 treatments $T_1$: flubendiamide (Belt 24 WG), $T_2$: spinosad (Success 2.5 SC), $T_3$: emamectin benzoate (Proclaim 5G), $T_4$: Farmer's practice (Cypermethrin 10 EC); $T_5$: Control (no pesticides). Sprayings was done at 7 days interval. The field experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on number of healthy and infested fruits/plant, weight of healthy and infested fruits/plant, weight of single fruit/plant, diameter of single fruit/plant, yield per plot and healthy and infested yield per hectare were recorded and at last economic analysis was done. The treatment of flubendiamide (Belt 24WG) was the highest (30.23) number of healthy fruits/plants the control $T_5$ gives the least (8.93) fruits/plant. Control treatment shows the highest level of infestation which was significantly different from all other treatments. The lowest (1.23) number of infested fruits/plant was found at early stage in Farmer's practice (Cypermethrin 10 EC) and highest (4.83) for control treatment. $T_5$ shows the highest level of infestation. At early fruiting stage, the lowest infestation percentage (3.11%) was recorded from flubendiamide (Belt 24 WG) treatment which was significantly different from all other treatments. On the other hand, the highest (26.19%) infestation percentage was recorded from control treatment. The highest (165.11g) fruit weight was observed for flubendiamide (Belt 24 WG) and the lowest (63.9g) for control treatment. The highest (13.8mm) fruit diameter was observed for flubendiamide (Belt 24 WG) and the lowest (5.9mm) for control treatment. The highest (10.86 t/ha.) yield was observed for the treatment flubendiamide (Belt 24 WG) and the lowest (7.79 t/ha.) yield was observed for control treatment. Considering the control of tomato fruit borer, the highest benefit cost ratio was 1.79 recorded from emamectin benzoate (Proclaim 5G). The benefit cost ratio was due to application of the different management practices against tomato fruit borer was $T_3 > T_4 > T_2 > T_1 > T_5$. Number of recorded natural enemies was relatively low in pesticide treated plots in compare with untreated control.

# LIST OF CONTENTS

## LIST OF CONTENTS (Cont'd)

## LIST OF CONTENTS (Cont'd)

## LIST OF TABLES

**LIST OF FIGURES**

## LIST OF PLATES

# LIST OF APPENDICES

## LIST OF ABBREVIATION AND ACRONYMS

| | | |
|---|---|---|
| AEZ | = | Agro-Ecological Zone |
| BARI | = | Bangladesh Agricultural Research Institute |
| BBS | = | Bangladesh Bureau of Statistics |
| FAO | = | Food and Agriculture Organization |
| N | = | Nitrogen |
| B | = | Boron |
| *et al.* | = | And others |
| TSP | = | Triple Super Phosphate |
| MoP | = | Muriate of Potash |
| RCBD | = | Randomized Complete Block Design |
| DAT | = | Days after Transplanting |
| $ha^{-1}$ | = | Per hectare |
| g | = | gram |
| kg | = | Kilogram |
| SAU | = | Sher-e-Bangla Agricultural University |
| SRDI | = | Soil Resources Development Institute |
| wt | = | Weight |
| LSD | = | Least Significant Difference |
| $^{0}C$ | = | Degree Celsius |
| NS | = | Not significant |
| Max | = | Maximum |
| Min | = | Minimum |
| % | = | Percent |
| NPK | = | Nitrogen, Phosphorus and Potassium |
| CV% | = | Percentage of Coefficient of Variance |

# CHAPTER I

# INTRODUCTION

Tomato (*Solanum lycopersicum L.*), one of the most popular and widely grown vegetables in the world, ranking second in importance next to potato and mostly grown in home gardens and by the market gardeners. It can be used both in fresh or processed form and is a good source of vitamins A, B and C which also helps in healing of wounds due to antibiotic properties. It is a nutritious and delicious vegetables used in salad, soups and processes into stable products like ketchup, sauce, pickles, chutney and juice. Lycopene in tomato is a powerful antioxidant and reduces the risk of prostate cancer. It is widely employed in cannery and made into soups, pickles, ketchup, sauces, juices, etc. (Thompson and Kelly, 1983).

Considering the scenario of Bangladesh, tomato is grown during *Rabi* season. Among the winter vegetable crops grown in Bangladesh, tomato ranks fourth in respect of production and third in respect of areas (BBS, 2018). The recent statistics shows that tomato was grown in 68366 acres of land and the total production was approximately 388725 M. tons in 2016-2017 (BBS, 2018).

The production of tomato of Bangladesh is not enough in comparison to other tomato growing countries of the world (Aditya *et al.*, 1997). The number of tomato varieties grows in Bangladesh, lost their potentiality due to genetic deterioration, disease and insect infestation. In order to increase tomato production in Bangladesh, it is essential to identify cultivars capacity for year-round production with higher yield and resistance to pests (Hussain *et. al.,* 2007). Different limiting factors are responsible for the low yield of tomato in Bangladesh. Among them the attack of insect pest is one of the important factors for low yield of tomato and damage all parts of the plant including leaves, stems, flowers and fruits.

Tomato commonly attacked by a number of pests and 13 major insect pests of tomato which include mainly, lepidopteron, coleopteran and hemipterans are listed to attack it at various growth stages of the crop. The important insect pests of tomato are fruit borer, *Helicoverpa armigera* Hubner: whitefly, *Bemisia tabaci* Gen; jassids, *Amrasca devastans* Ishida; leaf miner, *Liriomyza trifolii* Blanchard and hadda beetle, *Epilachana dodecastigma* Widemann, *Helicoverpa armigera* (Hubner), one of the most serious agricultural insect pests worldwide alone causes huge losses due to its high reproductive potential. Larvae of fruit worm are polyphagous and feed exclusively on foliage, flower buds and flowers, while the later instars of these insects bore into fruit decreasing its market value. Due to wider host range, multiple generations, migratory behavior, high fecundity and existing insecticide resistance this insect has become a difficult pest to tackle (Hussain *et al*., 2001). Among them tomato fruit borer, *Helicoverpa armigera* is one of the serious pests. It has been reported to cause extent of damage to about 50-60 percent fruits. Due to severe infestation, fruit as well as seed maturation hampered greatly and the viability of the seeds are reduced. The use of insecticides has become indispensable in increasing vegetable crop production because of its rapid effect, ease of application and availability.

The management practices against tomato fruit borer (*Helicoverpa armigera*) in tomato have been done elsewhere but a few of them is related to this present study. Though the pest is major in status, the management of fruit borer through non chemical tactics like 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 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 application of chemical insecticides. But, the application of chemical insecticides has got many limitations and undesirable side effects (Husain, 1993).

The farmers of Bangladesh are very poor and have very low availability to buy insecticides and the spraying equipment (Husain, 1984). This study is about the efficacy of some modern insecticides as well as those insecticides would be less harmful for natural enemies. For this purpose, some newer insecticide will be applied and result will be demonstrated. Flubendiamide is initially quickly degraded in soil by indirect photolysis however further microbial degradation occurs at a slower rate and it is eco-friendly as well. Belt 24 WG contains flubendiamide which is the first representative of a new chemical insecticide classes-the diamides. In contrast to other insecticide classes targeting the insect nervous system, flubendiamide acts at receptors in insect muscles causing an immediate cessation of feeding and thus avoids crop damage. It is well suited for the control of a broad range of Lepidoptera pests (Husain, 1984). The unique mode of action makes the compound well suited as a tool in insect resistance management programmes. Other prominent newer insecticides are spinosad (Success 2.5 SC) and emamectin benzoate (Proclaim 5 SG). The efficacy of these insecticides was assessed in this study.

Considering the above facts and points, the present research program has been designed with the following objectives:

1. To evaluate the field infestation levels of target insect pests *viz*. tomato fruit borer (*Helicoverpa armigera*)
2. To demonstrate the efficacy of newer insecticides against tomato fruit borer
3. To assess the impacts of those insecticides on natural enemies.

# CHAPTER II
# REVIEW OF LITERATURE

Tomato is an important vegetable crop in Bangladesh, but the crop cultivation faces various problems including the pest management. Fruit borer is the most important insect pest of tomato in Bangladesh. Literatures related to the present study on the efficacy of some newer insecticides against tomato fruit borer (*Helicoverpa armigera* Hubner) have been done elsewhere but the number are very limited. An attempt has been taken in this chapter to review the pertinent literatures. The information is given below under the following sub-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 several numbers of species, including *Helicoverpa armigera*, which is the serious pest of tomato (Mishra and Mishra, 1996).

### 2.1.2 Origin and distribution

Tomato fruit borer is a versatile and widely distributed polyphagous insect. Beside 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 for desert and humid region (Singh, 1972).

### 2.1.3 Host range of tomato fruit borer

A wide range of host crop plants occurs including cotton, tobacco, maize, sorghum, pcnnisetum, sunflower, various legumes, citrus, okra and other horticultural crops. Wide plants considered important include species of Euphorbiaceae, Amaranthaceae, Malvaceae, Solanaceae, Compositae, Portutacaceae, Convolvulaceae but other plant families are reported to be the host (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 color, changing to dark brown prior to hatching (Singh and Singh, 1977).

#### 2.1.4.2 Larva

The fully-grown larva is about 40 mm in length, general color varies from almost black, brown and 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, 1977).

#### 2.1.4.3 Pupa

The light brown pupa is about 22 mm in length, 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 color 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. 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 tomato cultivars against tomato fruit borer, *H. armigera* during the spring in Madhya Pardesh. 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 damage by the pest was observed.

Sivaprakasam (1996) observed the leaf trichome, petioles, internodal stems and calyx on 9 tomato genotypes. Results suggested that the low fruit borer damage in Paiyar-1 and X-44 might be due to the presence of long calyx, trichome, physically preventing feeding by *H. armigera* larvae, rather than to trichome number/mm2, paiyur-1 had lowest number of trichomes on all plants parts studied, but the largest calyx area per fruits (3.4 cm2).

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 pH 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 trachoma density.

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

Perring *et al.* (1988) observed that the interactions between the planting data 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 significant 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 Management of tomato fruit borer

#### 2.2.1 Cultural control

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.

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 ate very harvest and cumulative percent fruit damage was assessed. Fruit infestation varied from zero in Tomato Royal FM and WIR 4285 to 30.03% in L 274.

Khanam *et al.* (2003) conducted an experiment on the screening of their tomato varieties 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 and also with the age of the tomato plants. Among the varieties V 29 and V 282 were found moderately resistant and susceptible.

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. Significantly lower oviposition by H. armigera was observed on local genotypes, L 15 and PKM 1 while the oviposition was highest on IIHR genotypes Arka Sourabh, arka Vikas and Arka Ashish. Irrespective 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.

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 categories according to percent fruit damage by the pest. Five genotypes HT 64, Hybride 37, PTH 104, PTH 103 recorded the lowest level of percent fruit damage (< 10) in the both years.

Sundeep *et al.* (2000) conducted an experiment on the economics of controlling *H. armigera* through suitable cultivars (Punjab Kesri, Punjab Chhuhara, Punjab Tropic and Hybrid Naveen) and cultural practices in tomato for two years (1993-94) at Punjab Agricultural University, Ludhiana, Punjab, 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.

Patil *et al.* (1997) studied 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. No insecticides were used during the course of the experiment. 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. The greatest reduction in marketable yields of tomatoes was observed in tomatoes intercropped with snap beans followed by tomatoes intercropped with onions. The greatest marketable yields were observed in tomatoes intercropped with radishes. 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.

### 2.2.2 Mechanical control

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 this method 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).

### 2.2.3 Insecticidal control

Singh *et al.* (2017) evaluated nine newer and biorational insecticides against fruit borer, *Helicoverpa armigera* infesting tomato. And found that chlorantraniliprole 18.5 SC (0.02%), abamectin 5 SG (0.01%) and spinosad 2.5 SC (0.01%) ranked in middle order of their efficacy.

Chowdhury *et al*., (2017) conducted experiment on comparative efficacy of certain bio-pesticides against tomato fruit borer, *Helicoverpa armigera* (Hub.) and reported incremental per cent reduction of different treatments as per sequence spinosad (74.97%), followed by quinalphos (66.31%) *Ha*NPV (59.74%) > *Beauveria bassiana* (57.58%) > *Verticillium lecanii* (47.10%) > *Metarhizium anisopliae* (44.46%) found. to be the most economically viable treatment.

The results of present investigation of Babar *et al*., (2016) shows among the bio-insecticides spinetoram 12% SC (Radiant) and spinosad 240 SC (Tracer) proved to be most effective by exhibiting average maximum percentage mortality of the pest up to seven days after treatment whereas among the chemical insecticides proved to be most effective followed by chlorantraniliprole.

Patel *et al*., (2016) evaluated bio-efficacy of different insecticides and result revealed that chlorantraniliprole 35 WG @ 30 g a.i./ha reduced larval population of *H. armigera* as well as recorded lowest per cent of fruit damage compared to standard checks. Fruit yield was recorded significantly higher in plots treated with chlorantraniliprole 35 WG @ 30 (270.71 q/ha) followed by chlorantraniliprole 18.5 SC @ 30 g a.i./ha (267.36 q/ha).

Devi *et al*., (2014) reported that spinosad 45SC was consistently superior to other tested insecticides against *H. armigera*.

Katroju *et al*., (2014) in their studies found spinosad 45SC and Bifenthrin 10%EC to be most effective in controlling the population of *Helicoverpa armigera* larvae in tomato fields. In our studies among the chemical insecticides used Lufenuron 5%EC (lufenuron) proved to be most effective insecticides after 03, 05 and 07 days however among the chemical insecticides Challenger 36%SC (chlorofenapyr) exhibited an effective control of the pest only up to 05 days after treatment.

A field experiment was conduction by Hussain and Bilal (2007) during Kharif 2003-2004 to evaluate the efficacy of six insecticides at farmer’s 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 less on tomato crop.

In Bangladesh, it was reported that cypermethrin, deltamethrin, fenvalerate and quinalphos @ 1.5 ml/L of water gave the better result (Alam, 2004).

Mehta *et al.* (2000) carried out an experiment on the management of tomato fruit borer, *Helicoverpa armigera* (Hubner) with nine insecticidal treatments for 3 seasons during 1995-1997 at Palampur (Himachal Praddesh, India). Overall 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.

Walunj *et al.* (1999) conducted field trails at Ahemadnagar, Maharashtra, India to assess the efficacy of profenofos at 0.5kg/ha, profenofos + cypermethrin at 0.33-0.44kg, lufenuron at 0.33 kg, dichlorvos at 0.76 kg and cypermethrin at 0.05 kg for control of *Helicoverpa armigera* in tomatoes cv. Namdhari Hybrid 815. Products awere applied 5 times at 15 days 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 0.44 kg profenofos + cypermethrin treatment.

Pinto *et al.* (1997) reported in Sicily that when the population exceeds the economic threshold, control can be affected using systemic products such as phosphoric esters (acephate, methomyl, dimethoate) or synthetic pyrethroids (alphamethrin, alpha-cypermethrin, deltamethrin); the latter must be used once only so as not to favor the build-up of mites. Agronomic methods of defense may also be used, such as weeding to kill the pupae, deep ploughing of adjacent uncultivated areas during the period of ovipositon and elimination of weeds in which females oviposit.

Patel *et al.* (1991) conducted field studies in Gujrat, India to determine an effective and economical insecticide formulation to control the noctuid *Helicoverpa armigera* on tomatoes, endosulfan (0.07%) spray gave the highest cost-benefit ratio (1: 5.26) followed by endosulfan (2%) dust (1: 4.9) reults are also given monocrotophos, quinalphos and malathion.

Dilbagh *et al.* (1990) conducted field trials in Punjab, India and revealed that fenvalerate, permethrin and cypermethrin applied at 50g a.i./ha, or decamethrin 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.

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 contributed 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 (Hussall, 1990).

Ogunwolu (1989) studied the effects of damage caused by *Helicoverpa 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 of harvested fruits. Fruit damage was significantly reduced and yield increased by spraying, showing that serious damage was caused by *H. armigera*. Cypermethrin suppressed fruit damaged by 70.4 and 55.2% in 1985 and 1986 and increased yield by 115.0 and 67.6% respectively.

In India, it was also found that tomato plants (line CV S-22) were sprayed with various insecticides 4 times at 2-weel intervals from the onset of flowering. Cypermethrin (30g a.i./ha), Deltamethrin (10g a.i./ha) and permethrin (100g a.i./ha) gave good control of *H. armigera* (Divakar and Pawar, 1987).

Of several insecticides compared against *H. armigera*, quinalphos at 0.05% was the most effective (Tewari, 1985).

### 2.2.5 Integrated pest management (IPM)

Karabhantanal *et al.* (2005) carried out an investigation during 2001 and 2002 during kharif season in Karnataka, India, to evaluate different Integrated pest management (IPM) modules against tomato fruit borer, *Helicoverpa armigera*. The results revealed that the IPM module consisting of trap crop (15 row of tomato: 1 row of 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 larval population (100% after the fourth spray). As a result of which the lowest damage (11.87%), highest marketable fruit yield (224.56q/ha) and additional profit (Rs. 22915/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) NSKE (5%) HaNPV (250 LE/ha) – endosulfan 35EC (1250ml/ha).

Brar *et al.* (2003) carried out a study to determine the efficacy of *Trichogramma pretiosum* (5 releases weekly @ 5000 per ha), *H. armigera* nuclear polyhedrosis virus (Ha NPV; 2, 3 or 5 sprays at 7,19 or 15-day intervals at 1.5 × 1012 polyhedral occlusion bodies per ha) and/or endosulfan (3 sprays at 15 day intervals at 700 g/ha) for the management of tomato fruit borer (*H. armigera*) in Punjab, India, during 1999-2002. In all study years, egg parasitism was high (36.32-61.00%) in plots where *T. pretiosum* was released. The mean egg parasitism was 7.45 and 14.85% in the Endosulfan-treated and control plots respectively. Fruit damage was highest during 1999-2000. Among all treatments, treatment with *T. pretiosum* + Ha NPV + endosulfan resulted in the lowest fruit damage (13.07%) and the h9ighest mean yield (243.86 q/ha). The control treatment had the borer incidence and fruit damage, and the lowest yield (163.31 q/ha) among all treatments. The yield in endosulfan alone was 209.31 q/ha, which was significantly superior to three Ha NPV sprays (184.15q/ha). It is concluded that the treatment combination *T. pretiosum* + Ha NPV + endosulfan was most effective for *H. armigera* control.

Sundararajan (2002) carried out toxicological studies to evaluate the effect of leaf methanolic extracts of 5 indigenous plant materials namely, *Abutilon indicum, Achyranthes aspera, Ailanthus excels, Alstonia venenata and Azima tetracantha* against *Helicoverpa armigera*. Twenty healthy larvae collected from a tomato field were released into plastic containers containing tomato leaves treated with each of the plant extracts. The larval mortality was reordered 48 h after the release. Larval mortality on tomato leaves treated with *Azima tetracantha*, *Achyranthes aspera*, *Abutilon indicum*, *Ailanthus excels* and *Alsotnia venenata* averaged 51, 58, 62, 67 and 73% respectively.

Pokharkar *et al.* (1999) conducted an experiment during the spring season of 1992 and 1993 in Hisar, Haryna, India, to study the effectiveness of nuclear polyhedrosis virus alone and in combination with endosulfan in the integrated control of *Helicoverpa armigera* on tomato (*Lycopersicon esculentum*). Three sprays of endosulfan 0.07% at 10-days-intervals starting from 50% flowering of the crop proved to be effective. Application of *Helicoverpa armigera* nuclear polyhydrosis virus at 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, 57.49 kg/plot (4 m × 5 m) mean total yield and 53.64kg/plot mean marketable yield, and it was as effective as the *Helicoverpa armigera* nuclear polyhedrosis virus at the 500 LE/ha dose. Sequential application with the first spray of Endosufan 0.07% followed by 2 sprays of *Helicoverpa armigera* nuclear polyhedrosis virus at 250 LE/ha greatly reduced the larval population and was comparaable with 3 applications of endosulfan 0.07% applied alone.

Satpathy *et al.* (1999) conducted a field trails 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.

Ganguly and Dubey (1998) evaluated a number of insecticidal treatments against *Helicoverpa armigera* on tomato (variety Pusa Ruby) in Madhya Pradesh, India, during the Rabi season 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 32.53% available losses.

Sivaprakasam (1996) conducted field studies in Tamil Nadu, India, during July–December 1992 and revealed that nuclear polyhedrosis virus + endosulfan (260g) and endosulfan (520g) sprays gave an effective level of control of *Helicoverpa armigera* infesting the PKM 1 variety of tomato.

Gopal and Senguttuvan (1997) conducted field trials in India to determine the efficacy of insecticides (endosulfan and diflubenzurun), neem products and nuclear polyhedrosis virus (NPV) alone or in combination for the control of fruit borer, *Helicoverpa armigera,* on tomatoes. Neem seed kernel extracts (NSKE) 3% + Eendosulfan 0.035% + NPV at 250 larval equivalents (LE) ha-1 applied 3 times at 45, 55 and 65 days after planning gave the highest larval mortality, reduced fruit damage, and the highest fruit yield, followed by neem oil 3% + endosulfan 0.035% +NPV at 250 LE ha-1 and endosulfan 0.07% gave the highest cost benefit ratio, followed by NSKE 3% + NPV at 250 LE ha-1and NSKE 3% + endosulfan 0.035% + NPV at 250 LE ha-1.

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. armigera* 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 flowering/fruiting season of tomato and the pest causes severe yield losses. Tomato cv. Roma and local landraces collected from Kholakhet, Parbat, were found to be less preferred for egg laying by this pest. The naturally occurring egg parasitoid *Trichogramma chilonis* was more abundant in the river basins than in the low-middle range 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 of this pest. Nuclear polyhedrosis viruses, although reported to be useful against *H. armigera* elsewhere, was not very promising under these conditions.

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

Abbas *et al*. (2015) studied the effect of nine insecticides on *H. armigera*. The result showed that the average maximum mortality, *i.e*. 89.36 and 85.09 per cent of the pest, was observed with chlorantraniliprole + thiamethoxam and spinetoram respectively. It also worked well even after 7 and 10 days. Similarly, chlorantraniliprole, flubendiamide and indoxacarb resulted better on the basis of damaged fruits and per cent loss of yield as compared to rest of the treatments.

However, Ambule *et al*. (2015) studied the relative efficacy of nine newer insecticides against tomato fruit borer and found that chlorantraniliprole 18.5 SC per cent recorded minimum larval population (0.58 larva/ plant) and 10.62 per cent fruit damage on weight basis than the remaining treatments which was identical with and spinosad 0.0068 per cent (0.68 larva/plant and 11.34% fruit damage).

Hussain and Bilal (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 24557.14 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 1995-1997 at Palampur, Himachal Pradesh, India. Overall effectiveness was expressed as reduction in borer damaged tomato fruits and increase in fruit yield indicated the superiority of Deltamethrin resulted in lowest fruit damage (4.27%) followed by Cypermethrin (8.98%) and Acephate (9.16%). Among the bio pesticides 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%while untreated control had 24.2%

fruit damage. The mean fruit yield was highest in Deltamethrin+Bt treated plots followed by Deltamethrin, Acephate and Cypermethrin.

Tomato fruit borer, *Helicoverpa armigera* (Hubner) is one of the serious pests attacking tomato. This pest sometimes cause damage to the extent of about 50-60% fruits (Singh and Singh, 1977).

The larvae of this pest bore into the fruit and feed inside. As a result, the fruit 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 *Helicoverpa armigera* during Kharif season, the pest started its activity in groundnut from first week of July. Thereafter, 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 is very low in sunflower. However, in pearl millet, it was at perk 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, *Helicoverpa armigera* varies considerably due to different climatic conditions throughout the year. A study revealed that the population of *Helicoverpa armigera* began to increase from the mid-January and peaked during the last week 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 *Helicoverpa armigera* on tomato was low until the first week of February and increased rapidly thereafter, 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.

# CHAPTER III
# MATERIALS AND METHODS

The study to evaluate the field infestation levels of tomato fruit borer (*Helicoverpa armigera*) was conducted during August 2018 to January 2019 in the experimental fields of Sher-e-Bangla Agricultural University (SAU), Dhaka. Required materials and methodology are described under the following sub-headings.

## 3.1. Location

The experiment was conducted in the experimental farm of SAU, Dhaka situated at latitude 23.46°N and longitude 90.23°E with an elevation of 8.45 meter above the sea level.

## 3.2. Climate

The experimental area is characterized by subtropical rainfall during the month of May to September and scattered rainfall during the rest of the year.

## 3.3. Soil

Soil of the study site was silty clay loam in texture. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with pH 5.8-6.5, CEC-25.28 (Haider *et al.,* 1991).

## 3.4 Plant materials used in the experiment

BARI Tomato-14 was used in this experiment. Tomato seeds were collected from Vegetable Division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

## 3.5 Seedbed preparation

Seedbed was prepared on 15 October, 2018 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 and stubbles were removed from the seedbed. Cow-dung was applied to the prepared seedbed at the rate of 10 t/ha. The soil was treated by sevin 50 WP @ 5 kg/ha to protect the young plants from the attack of mole crickets, ants and cutworm.

### 3.6 Seed treatment

Seeds were treated by vitavax-200 @ 5 g/kg seeds to protect some seed borne diseases such as leaf spot, blight, anthracnose, etc.

### 3.7 Seed sowing

Seeds were sown on 4 November, 2018 in the seedbed. Sowing was done thinly in lines spaced at 3cm distance. Seeds were sown at a depth of 2 cm and covered with a fine layer of soil followed by light watering by water can. Thereafter the beds were covered with dry straw to maintain required temperature and moisture. The cover of dry straw was removed immediately after emergence of seed sprout. When the seeds were germinated, shade by bamboo mat (*Chatai*) was provided to protect the young seedlings from scorching sunshine and rain.

### 3.8 Raising of seedlings

Light watering and weeding were done several times. No chemical fertilizers were applied for raising of seedlings.

### 3.9 Design of the experiment

The field experiment was laid out by Randomized Complete Block Design (RCBD) with three replications. One factor with six treatments were used in the experiment.

**Treatments**

$T_1$: Flubendiamide (Belt 24 WG); @ 0.50 g/L water

$T_2$: Spinosad (Success 2.5 SC); @ 1.2ml/L water.

$T_3$: Emamectin Benzoate (Proclaim 5G); @ 1 g/L water

$T_4$: Farmer’s practice (Cypermethrin 10 EC) @ 2ml/L water

$T_5$: Control (No pesticides)

### 3.10 Land preparation

The experimental area was first opened on 15 October 2018. 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 spaded and the clods were broken into pieces. The weeds, crop residues and stables were removed from the field. Total organic manures were applied as per recommendation and finally leveled. The soil of the plot was treated by Sevin 50 WP @ 5 kg/ha to protect the young plants from the attack of mole cricket, ants and cutworm.

### 3.11 Layout

The experimental plot was first divided into three blocks. Each block consisted of 5 plots. Thus, the total numbers of plot were 15. Different combinations of treatments were assigned to each plot as per design of the experiment. The size of a unit plot was 3m × 2m. A distance of 0.5m between the plots and 1m between the blocks were kept**.**

### 3.12 Fertilizer application

Manures and fertilizers were applied as recommended (Rashid, 2003).

Cow-dung: 10 t/ha

Urea: 500 kg/ha

TSP: 400 kg/ha

MoP: 200 kg/ha

### 3.13 Transplanting

The seedbed was watered before uprooting the seedlings to minimize the damage of roots. At the time of uprooting, care was taken so that root damage become minimum and some soil remained with the roots. Thirty days-old healthy seedlings were transplanted at the spacing of 60 cm × 40 cm in the experimental plots on 12 November 2018. Thus the 25 plants were accommodated in each unit plot. Planting was done in the afternoon. Light irrigation was given immediately after transplanting around each seedling for their better establishment. The transplanting seedlings were shaded for five days with the help of white polythene to protect them from scorching sunlight. Watering was done up to five days until they became capable of establishing on their own root system.

**Plate 01: Seedling of tomato plant**

### 3.14 Intercultural operations

#### 3.14.1 Gap filling

Very few seedlings were found to be damaged after transplanting and new seedlings from the same stock were replaced.

#### 3.14.2 Weeding

The plants were kept under careful observation. Three times weeding were done during cropping period, viz. 1st December, 15th December and 1st January, for proper growth and development of the plants.

**Plate 02: Weeding of the tomato field**

#### 3.14.3 Spading

After each irrigation soil of each plot was pulverized by spade for easy aeration and mulching was done as well.

### 3.14.4 Irrigation

Irrigation was given according to the crop need to ensure proper growth and development.

### 3.14.5 Earthing up

Earthing up was done by taking the soil from the space between the rows on $2^{nd}$ December 2018.

### 3.14.6 Insects and disease control

Few plants were damaged by mole crickets and cut worms after the seedlings were transplanted in the experimental plots. Sevin 80WP was dusted to the soil before irrigation to controlled mole crickets and cut worms on $7^{st}$ December 2018. Some of the plants were infected by alternaria leaf spot disease. Rovral 50 WP @ 20 g per 10 L of water was sprayed to prevent the spread of the disease on $25^{th}$ December 2018.

### 3.14.7 Harvesting

Fruits were harvested at 3-day intervals during early ripe stage when they attained slightly red color. Harvesting was started from 15 February, 2019 and was continued up to 15 March, 2019.

## 3.15 Data collection

Ten plants were selected randomly from each plot for data collection in such a way that the border effect could be avoided for the highest precision. Data on the following parameters were recorded from the sample plants during the course of experiment.

### 3.15.1 Number of total fruits per plant

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

### 3.15.2 Number of healthy fruits per plant

The number of fresh or healthy fruits of selected plants was counted and then the average number of fruits for each plant was determined.

**Plate 03: Tomato plant with healthy fruits**

### 3.15.3 Number of infested fruits per plant

Fruit bore infested fruits of selected plant were counted at flowering and fruiting stage.

`

**Plate 04: Infested tomato fruits after harvesting**

### 3. 15.4 Number of total fruits per plot

The number of healthy and fruit borer infested fruits were recorded from every plot. It was done five times up to the last harvest and then the mean numbers of total fruit were calculated.

### 3.15.5 Number of healthy fruits per plot

The number of fresh or healthy fruits of every replicated plot was recorded five times during harvest and then the mean number was calculated.

### 3.15.6 Number of infested fruits per plot

The number of fruit borer infested fruits of every replicated plot was recorded five times during harvest and then the mean number was calculated.

### 3.15.7 Fruits infestation (%)

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

**No. of fruit infested (%)** = $\frac{Number\ of\ infested\ fruits}{Number\ of\ total\ fruits} \times 100$

### 3.15.8 Weight of total fruits per plant (g)

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

**Plate 05: Infested tomato fruits with larval bore(s)**

### 3.15.9 Weight of healthy fruits per plant (g)

The fresh or healthy fruits of selected plants were weighed and then the average weight of fruits for each plant was determined.

### 3.15.10 Weight of infested fruits per plant (g)

Fruit borer infested fruits of selected plant were weighed.

### 3.15.11 Weight of total fruits per plot (g)

The weight of healthy and fruit borer infested fruits was recorded from each plot. It was done five times during harvest and then the mean weight was calculated.

### 3.15.12 Weight of healthy fruits per plot (g)

The weight of healthy fruits of every plot was recorded five times during harvest and then the mean weight was calculated.

### 3.15.13 Weight of infested fruits per plot (g)

The weight of fruit borer infested fruits of every plot was recorded five times during harvest and then the mean weight was calculated.

### 3.15.14 Weight of infested fruits (%)

The fresh and fruit borer infested fruits of every plot were weighted five times at each five harvest and then mean weight was calculated. The percent of infested fruits weight were calculated by the following formula:

**Percent of fruits by weight=** $\frac{Number\ of\ infested\ fruits}{Number\ of\ total\ fruits} \times 100$

### 3.15.15 Reduction of fruit infestation over control (%)

The number and weight of infested and total fruit for each treated plant and untreated control plant were recorded and the percent reductions of fruit infestation by number and by weight were calculated using the following formula:

**Percent infestation reduction over control=** $\frac{X1-X2}{X1} \times 100$

Where, X1 = the mean value of the control plant and X2 = the mean value of the treated plant.

### 3.15. 16 Single fruit weight

Among the total number of fruits during the period from first to final harvest the fruits, except the first and final harvests, were considered for determining the single fruit weight by the following formula:

**Single fruit weight (g) =** $\frac{Total\ weight\ of\ fruits\ harvest\ from\ 10\ selected\ plants}{Total\ number\ of\ fruits\ harvest\ from\ 10\ selected\ plants}$

### 3.15. 17 Single fruit diameters (cm)

Among the total diameter of fruits during the period from first to final harvest the fruits, except the first and final harvests, were considered for determining the single fruit diameter by the following formula:

**Single fruit diameter =** $\frac{Total\ diameter\ of\ fruits\ harvest\ from\ 10\ selected\ plants}{Total\ number\ of\ fruits\ harvest\ from\ 10\ selected\ plants}$

### 3.15.18 Yield of fruits per plot (kg)

A scale balance was used to take the weight of fruits per plot. It was measured by totaling the fruit yield of each unit plot separately during the period from first to final harvest and was recorded in kilogram (kg). It was measured by the following formula:

**Yield of fruit per plot (kg) = Weight of total fruit per plant × Number of plants per Plot.**

### 3.15.19 Yield of fruits per hectare (ton)

It was measured by the following formula,

$$\textbf{Fruit yield per hectare (ton)} = \frac{\textit{Fruit yield per plot (kg) x 10000}}{\textit{Area of plot in square meter x 1000}}$$

### 3.15.20 Effect on natural enemies

Data were collected on the number of natural enemies such as wasp, ant and spider. per plot and counted separately for each treatment through visual observation in the field.

### 3.16 Statistical analysis

The data in respect of yield, quality and yield components were statistically analyzed in MSTAT-C program. The means of all the treatments were calculated and the analysis of variance for each of the characters under study was performed by F test. The difference among the treatment means were evaluated by DMRT Test (Gomez and Gomez, 1984).

### 3.17 Economic analysis

The cost of production was analyzed in order to find out the most economic treatment of organic manures and varieties of tomato. All the non-material and material input costs and interests on running capital were considered for computing the cost of production. The interests were calculated for six months @ 13% per year. The price of one kg tomato at harvest was considered to be Tk. 12.00. Analyses were done according to the procedure determining by Alam (2004). The Benefit cost ratio (BCR) was calculated by the following formula:

$$\textbf{Benefit Cost Ratio (BCR)} = \frac{\textit{Groos return}}{\textit{Total cost of production}}$$

# CHAPTER IV

# RESULTS AND DISCUSSIONS

The experiment was conducted to evaluate some management practices against tomato fruit borer, *Helicoverpa armigera* (Hubner) in winter tomato variety BARI Tomato-14. The results have been discussed under the following sub-headings:

## 4.1 Effect of management practices in controlling tomato fruit borer in terms of number of fruits at different fruiting stages

### 4.1.1 Early fruiting stage

The significant variations were observed among different treatments by total number of fruit/plants, number of healthy fruit/plants, number of infested fruit/plant and percent fruit infestation (Table 1) at early fruiting stage in controlling tomato fruit borer for different control measures (Appendix IV). Among the treatment $T_1$ resulted highest number of healthy fruits/plants (30.23) and $T_4$ the lowest (16.89), the untreated $T_5$ gave the least fruits/plant (8.93). According to treatment flubendiamide expressed the best performance and emamectin benzoate give low performance at early fruiting stage.

**Table 1: Effect of different treatments in controlling tomato fruit borer at early fruiting stage**

| Treatment(s) | Number of fruits/plant | | | |
|---|---|---|---|---|
| | **Healthy** | **Infested** | **Total** | **%Infested** |
| **$T_1$** | 30.233 a | 0.97 d | 31.203 a | 3.11 d |
| **$T_2$** | 27.003 b | 1.2167 d | 28.22 b | 4.31 d |
| **$T_3$** | 21.37 c | 1.6733 c | 23.043 c | 7.267 c |
| **$T_4$** | 16.893 d | 2.1967 b | 19.09 d | 11.51 b |
| **$T_5$** | 8.937 e | 3.1733 a | 12.11 e | 26.193 a |
| **LSD (0.05)** | 0.7723 | 0.2839 | 0.6516 | 1.9933 |
| **CV%** | 1.96 | 8.17 | 1.52 | 10.10 |

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.
Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

The lowest number of infested fruits/plants at early stage was for $T_4$ (0.97) and highest for untreated $T_5$ (3.17). T5 shows the highest level of infestation which was different from all other treatments (Table 1). In this case, the trend of the number of infested fruit/plant was $T_5 > T_4 > T_3 > T_2 > T_1$ (Table 1).

### 4.1.2 Mid fruiting stage

The level of infestation of tomato plants by tomato fruit borer was observed by total number of fruit/plant, number of healthy fruit/plant, number of infested fruit/plant and percent fruit infestation (Table 2) at mid fruiting stage in controlling tomato fruit borer for different control measures (Appendix V). Among the treatment $T_1$ resulted highest number of healthy fruits/plants (57.18) and $T_4$ the lowest (40.76), the untreated $T_5$ gives the least fruits/plant (22.86). According to treatment flubendiamide gives the best performance and emamectin benzoate give low performance at mid fruiting stage. The lowest number of infested fruits/plant at early stage was found in $T_4$ (1.23) and highest for untreated $T_5$ (4.83). From the treatment $T_5$ the highest level of infestation was observed which was different from all other treatments (Table 1). In this case, the trend of the number of infested fruit/plant was $T_5 > T_4 > T_3 > T_2 > T_1$ (Table 2).

**Table 2: Effect of different treatments in controlling tomato fruit borer at mid fruiting stage in terms of number of fruits/plant**

| Treatment(s) | Number of fruits/plant | | | |
|---|---|---|---|---|
| | Healthy | Infested | Total | %Infested |
| $T_1$ | 57.18 a | 1.2367 e | 58.417 a | 2.117 e |
| $T_2$ | 51.067 b | 1.7467 d | 52.813 b | 3.307 d |
| $T_3$ | 47.093 c | 2.7 c | 49.793 c | 5.423 c |
| $T_4$ | 40.76 d | 3.15 b | 43.91 d | 7.173 b |
| $T_5$ | 22.867 e | 4.8333 a | 27.7 e | 17.443 a |
| **LSD (0.05)** | 0.4508 | 0.2192 | 0.5638 | 0.5252 |
| **CV%** | 0.55 | 4.26 | 0.64 | 3.93 |

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.
Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

### 4.1.3 Late fruiting stage

Significant variation was observed by total number of fruit/plant, number of healthy fruit/plant, number of infested fruit/plant and percent fruit infestation (Table 3) at late fruiting stage in controlling tomato fruit borer for different control measures (Appendix VI). For treatment $T_1$ shows highest number of healthy fruits/plants (46.66) and $T_4$ the lowest (30.94), the untreated $T_5$ gives the least fruits/plant (16.33). According to treatment flubendiamide gives the best performance and emamectin benzoate give low performance at late fruiting stage also express the reduction of performance comparing the mid fruiting stage.

**Table 3: Effect of different treatments in controlling tomato fruit borer at late fruiting stage**

| Treatment(s) | Number of fruits/plant | | | |
|---|---|---|---|---|
| | **Healthy** | **Infested** | **Total** | **%Infested** |
| **$T_1$** | 46.667 a | 1.57 e | 48.237 a | 3.257 e |
| **$T_2$** | 40.857 b | 2.12 d | 42.977 b | 4.933 d |
| **$T_3$** | 38.12 c | 3.0767 c | 41.197 c | 7.467 c |
| **$T_4$** | 30.943 d | 3.7167 b | 34.66 d | 10.72 b |
| **$T_5$** | 16.333 e | 4.6333 a | 20.967 e | 22.103 a |
| **LSD (0.05)** | 0.5481 | 0.2631 | 0.6950 | 0.5392 |
| **CV%** | 0.84 | 4.62 | 0.98 | 2.95 |

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.
Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

The lowest number of infested fruits/plant at early stage was found in $T_4$ (1.57) and highest found in untreated $T_5$ (4.63). $T_5$ shows the highest level of infestation which was different from all other treatments (Table 1). In this case, the trend of the number of infested fruit/plant was $T_5 > T_4 > T_3 > T_2 > T_1$ (Table 3).

### 4.2 Effect of treatments on percent reduction of tomato fruit borer over control at different fruiting stages

At early fruiting stage, the lowest infestation percentage was 3.11 recorded from $T_1$ treatment which was significantly different from all other treatments (Table 4).

On the other hand, the highest infestation percentage was 26.19 recorded from control ($T_5$) treatment. In this case, the trend of percent infestation was $T_5 > T_1 > T_2 > T_3 > T_4$ (Table 4 and Appendix IV) which trends to continue at mid and late fruiting stage.

**Table 4: Effect of different treatments on the tomato fruit borer and fruit Infestation by number against tomato fruit borer at different fruiting stage**

| Treatment(s) | % Fruit Infestation | | | | |
|---|---|---|---|---|---|
| | **Early fruiting stage** | **Mid fruiting stage** | **Late fruiting stage** | **Mean** | **% Reduction over control** |
| **$T_1$** | 3.11 d | 2.117 e | 3.257 e | 2.828 | 87.09 |
| **$T_2$** | 4.31 d | 3.307 d | 4.933 d | 4.183 | 80.91 |
| **$T_3$** | 7.267 c | 5.423 c | 7.467 c | 6.719 | 69.34 |
| **$T_4$** | 11.51 b | 7.173 b | 10.72 b | 9.801 | 55.273 |
| **$T_5$** | 26.193 a | 17.443 a | 22.103 a | 21.913 | 00 |
| **LSD (0.05)** | 1.9933 | 0.5252 | 0.5392 | -- | -- |
| **CV%** | 10.10 | 3.93 | 2.95 | -- | -- |

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.
Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

### 4.3 Effect of treatments in controlling tomato fruit borer in terms of weight of fruits at different fruiting stages

#### 4.3.1 Early stage of fruiting

The significant variations were observed among the different treatments used for the control of tomato fruit borer by total weight of fruit/plant, weight of healthy fruit/plant, weight of infested fruit/plant and percent fruit infestation (Table 5) at early fruiting stage in controlling tomato fruit borer for different control measures (Appendix VII). Considering the treatment $T_1$ highest weight of healthy fruits/plants (1105g) was observed and $T_4$ the lowest (825.2), the untreated $T_5$ gives the least fruits/plant (650.7). As per treatment flubendiamide resulted the best performance and emamectin benzoate give low performance at early fruiting stage. The lowest number of infested fruits/plant at early stage was for $T_1$ (16.03g) and highest for untreated $T_5$ (109.37g). $T_5$ shows the highest level of infestation which was different from all other treatments (Table 1). In this case, the trend of the number of infested fruit/plant was $T_5 > T_4 > T_3 > T_2 > T_1$ (Table 5)

**Table 5: Effect of different treatments in controlling tomato fruit borer at early fruit harvesting stage**

| Treatment(s) | Healthy | Infested | Total | %Infested |
|---|---|---|---|---|
| **$T_1$** | 1105 a | 16.03 e | 1121.1 a | 1.433 e |
| **$T_2$** | 965.6 b | 39.55 d | 1005.2 b | 3.933 d |
| **$T_3$** | 903.9 c | 51.56 c | 955.4 c | 5.397 c |
| **$T_4$** | 825.2 d | 65.66 b | 890.8 d | 7.373 b |
| **$T_5$** | 650.7 e | 109.37 a | 760 e | 14.39 a |
| **LSD (0.05)** | 3.6312 | 6.1609 | 3.6386 | 0.6884 |
| **CV%** | 0.22 | 5.80 | 0.20 | 5.62 |

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.
Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

### 4.3.2 Mid fruiting stage

Significant variation was observed by total weight of fruit/plant, weight of healthy fruit/plant, weight of infested fruit/plant and percent fruit infestation (Table 6) at early fruiting stage in controlling tomato fruit borer for different control measures (Appendix VIII). Considering the treatment $T_1$ highest weight of healthy fruits/plants (1109g) was obseved and $T_4$ the lowest (847.7g), the untreated $T_5$ gives the least fruits/plant (690g). As per treatment flubendiamide gives the best performance and emamectin benzoate give low performance at mid fruiting stage. The lowest number of infested fruits/plant at mid stage was for $T_1$ (27.17g) and highest for untreated $T_5$ (89.97g). $T_5$ shows the highest level of infestation which was different from all other treatments (Table 1). In this case, the trend of the number of infested fruit/plant was $T_5 > T_4 > T_3 > T_2 > T_1$ (Table 6)

**Table 6: Effect of different treatments in controlling tomato fruit borer at mid fruit harvesting stage**

| Treatment(s) | Healthy | Infested | Total | %Infested |
|---|---|---|---|---|
| **$T_1$** | 1109.1 a | 27.167 e | 1136.2 a | 2.39 e |
| **$T_2$** | 1018.3 b | 42.04 d | 1060.3 b | 3.963 d |
| **$T_3$** | 945.8 c | 52.523 c | 998.3 c | 5.263 c |
| **$T_4$** | 847.7 d | 74.6 b | 922.3 d | 8.087 b |
| **$T_5$** | 690 e | 89.977 a | 779.9 e | 11.54 a |
| **LSD (0.05)** | 3.170 | 5.879 | 3.119 | 0.612 |
| **CV%** | 0.18 | 5.45 | 0.17 | 5.21 |

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.
Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

### 4.3.3 Late fruiting stage

Significant variation was observed by total weight of fruit/plant, weight of healthy fruit/plant, weight of infested fruit/plant and percent fruit infestation (Table 7) at early fruiting stage in controlling tomato fruit borer for different control measures (Appendix IX). Considering the treatment $T_1$ shows highest weight of healthy fruits/plants (1160.6g) and $T_4$ the lowest (870.2g), the untreated $T_5$ gives the least fruits/plant (702.6g). As per treatment flubendiamide gives the best performance and emamectin benzoate give low performance at late fruiting stage.

The lowest number of infested fruits/plant at late stage was for $T_1$ (37.63g) and highest for untreated $T_5$ (109.72g). $T_5$ shows the highest level of infestation which was different from all other treatments (Table 1). In this case, the trend of the number of infested fruit/plant was $T_5 > T_4 > T_3 > T_2 > T_1$ (Table 6)

**Table 7: Effect of different treatments in controlling tomato fruit borer at late fruit harvesting stage**

| **Treatment(s)** | **Healthy** | **Infested** | **Total** | **%Infested** |
|---|---|---|---|---|
| **$T_1$** | 1160.6 a | 37.63 e | 1198.2 a | 3.14 e |
| **$T_2$** | 1046.8 b | 56.91 d | 1103.7 b | 5.157 d |
| **$T_3$** | 942.3 c | 79.01 c | 1021.3 c | 7.733 c |
| **$T_4$** | 870.2 d | 116.78 a | 987 d | 11.833 b |
| **$T_5$** | 702.6 e | 109.72 b | 812.3 e | 13.51 a |
| **LSD (0.05)** | 2.395 | 3.627 | 2.677 | 0.371 |
| **CV%** | 0.13 | 2.41 | 0.14 | 2.38 |

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.
Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

### 4.4 Effect of management practices in controlling tomato fruit borer on percent reduction over control at different fruiting stages

At early fruiting stage, the lowest percent infestation was 1.43 recorded from $T_1$ treatment which was significantly different from all other treatments (Table 8). On the other hand, the highest percent infestation was 14.39 recorded from control ($T_5$) treatment (Figure 1). In this case, the trend of percent infestation was $T_5 > T_4 > T_3 > T_2 > T_1$ (Table 8 and Appendix VII). The trend was similar for mid and late fruiting stage.

**Table 8: Effect of different treatments on the fruit Infestation due to tomato fruit borer at different fruit stages**

| Treatment(s) | Early fruiting stage | Mid fruiting stage | Late fruiting stage | Mean | % Reduction over control |
|---|---|---|---|---|---|
| $T_1$ | 1.433 e | 2.117 e | 3.257 e | 2.269 | 87.38 |
| $T_2$ | 3.933 d | 3.307 d | 4.933 b | 4.057 | 77.43 |
| $T_3$ | 5.397 c | 5.423 c | 7.467 c | 6.095 | 66.09 |
| $T_4$ | 7.373 b | 7.173 b | 10.72 d | 8.422 | 53.15 |
| $T_5$ | 14.39 a | 17.443 a | 22.103 a | 17.978 | 00 |
| **LSD (0.05)** | 0.6884 | 0.5252 | 0.5392 | -- | -- |
| **CV%** | 5.62 | 3.93 | 2.95 | -- | -- |

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.
Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

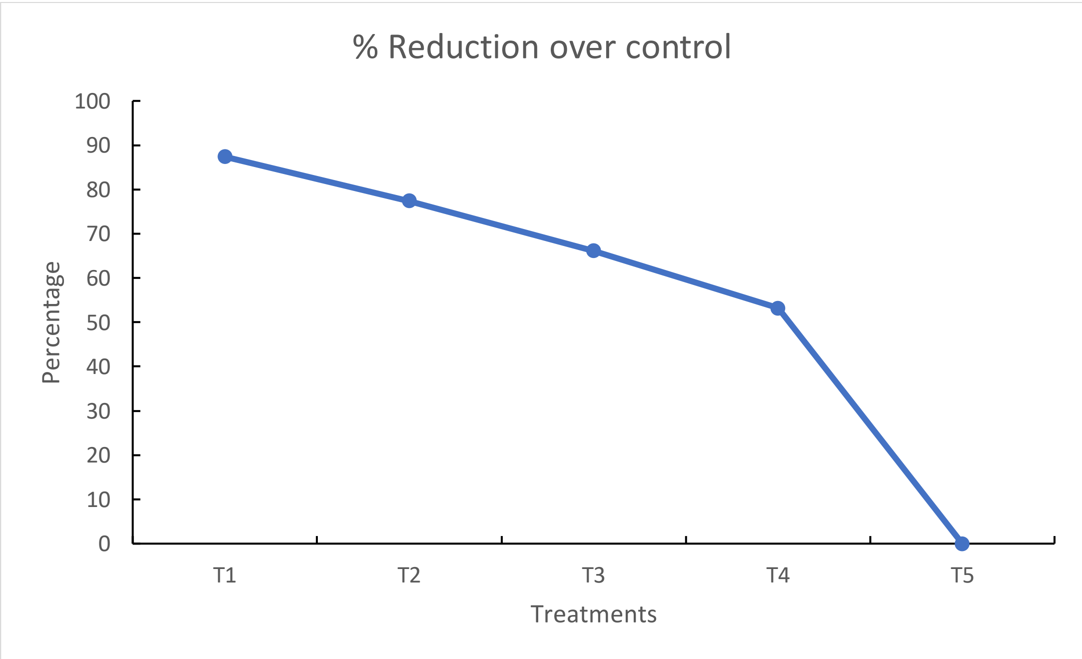



**Figure 1: Effect of different treatments on the fruit Infestation (by weight) percentage reduction over control.**

### 4.5 Single fruit weight

Significant variation was observed in case of weight of single fruit under the present study (Table 9 and Appendix X). The highest fruit weight observed for the treatment $T_1$ (165.11g) and the lowest for control $T_5$ (63.9g).

### 4.6 Single fruit diameter

Significant variation was observed in case of diameter of single fruit under the present study (Table 9 and Appendix X). The highest fruit diameter observed for the treatment $T_1$ (13.8mm) and the lowest for control $T_5$ (5.9mm).

**Table 9: Effect of different treatments in controlling tomato fruit borer during total cropping season in terms of weight of individual fruit, diameter of individual fruit and yield/ plot**

| Treatment(s) | Single fruit weight (g) | Single fruit diameter (mm) | Yield per plot (Kg)/6m$^2$ |
|---|---|---|---|
| **$T_1$** | 165.11 a | 13.8 a | 47.633 a |
| **$T_2$** | 150.5 b | 12.233 b | 42.833 b |
| **$T_3$** | 129.45 c | 10.967 c | 38.033 c |
| **$T_4$** | 116.26 d | 8.9 d | 34.233 d |
| **$T_5$** | 63.9 e | 5.9 e | 20.033 e |
| **LSD (0.05)** | 1.1182 | 0.7500 | 0.5017 |
| **CV%** | 0.47 | 3.84 | 0.73 |

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.
Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

### 4.7 Yield per plot (kg)

Significant variation was observed in case of yield per plot under the present study (Table 9 and Appendix X). The highest yield (kg/plot) observed for the treatment $T_1$ (47.63kg) and the lowest for control $T_5$ (20.03kg).

### 4.8 Yield (ton/ ha)

Significant variation was observed in case of total yield per hectare, healthy yield per hectare and infested yield per hectare under the present study (Table 10 and Appendix XI). The highest yield (ton/ha.) observed for the treatment $T_1$ (16.96 ton/ha.) and the lowest for control $T_5$ (9 ton/ha.).

**Table 10: Effect of different treatments in controlling tomato fruit borer during total cropping season in terms of yield (ton/ ha)**

| Treatment(s) | Healthy fruits | Infested fruits | Fruit yield Ton/ha. |
|---|---|---|---|
| **$T_1$** | 16.787 a | 30.847 a | 16.967 a |
| **$T_2$** | 15.247 b | 27.587 b | 15.533 b |
| **$T_3$** | 13.547 c | 24.487 c | 14.467 c |
| **$T_4$** | 12.81 d | 21.423 d | 13.1 d |
| **$T_5$** | 7.533 e | 12.5 e | 9 e |
| **LSD (0.05)** | 0.1474 | 0.4789 | 0.3084 |
| **CV%** | 0.59 | 1.09 | 1.19 |

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.
Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

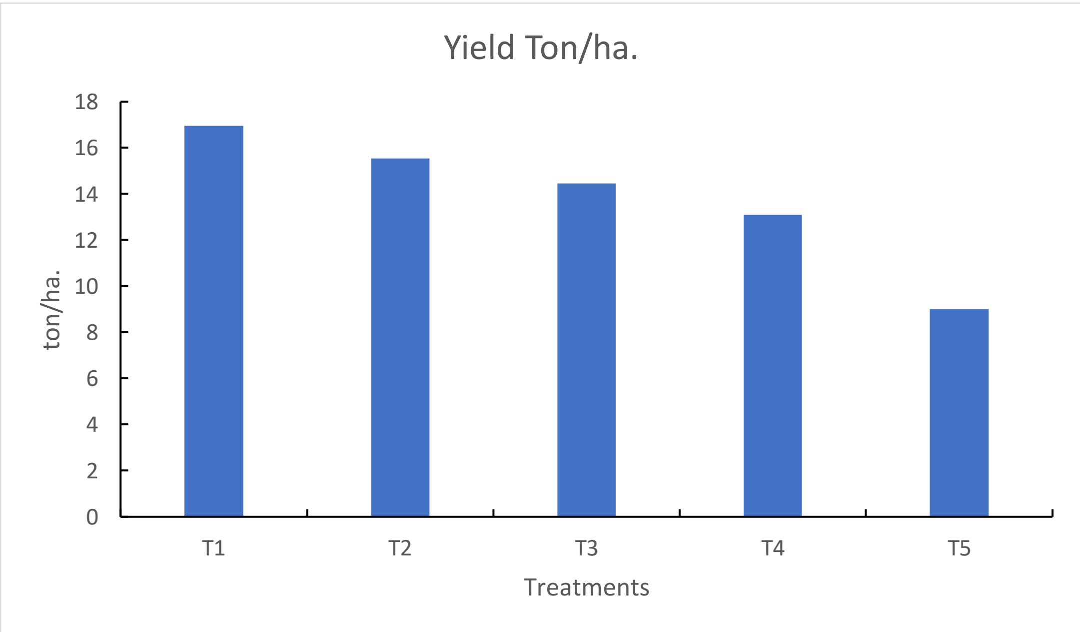



**Figure 2: Effect of different treatments in controlling tomato fruit borer during total cropping season in terms of yield (ton/ha.)**

### 4.9 Economic analysis

#### 4.9.1 Cost of pest management

It was observed that recorded the lowest cost of pest management was 00.00 Tk./ ha recorded in control treatment $T_5$ (Table 11). The pest management cost obtained from the treatment $T_1$ was 10,000.00 Tk./ ha., $T_2$ was 12,000.00 Tk./ ha, $T_3$ was 22,000.00 Tk./ ha and $T_4$ was 29,000.00 Tk./ ha.

#### 4.9.2 Total cost of production

It was observed that the total cost of production obtained from the treatment $T_1$ was 92,000.00 Tk./ ha, $T_2$ was 90,000.00 Tk./ ha, $T_3$ was 1,02,000.00 Tk./ ha and $T_4$ was 1,09,000.00 Tk./ ha.

#### 4.9.3 Gross return

The highest gross return was 1,94,640.00 Tk./ ha recorded in treatment $T_3$ and the lowest gross return was 93,480.00 Tk./ ha recorded in control treatment $T_5$ (Table 11). The gross return obtained from the treatment $T_1$ was 1,30,320.00 Tk./ ha, $T_2$ was 1,55,640.00 Tk./ ha and $T_4$ was 1,80,640.00 Tk./ ha.

#### 4.9.4 Net return

The highest net return was 85,640.00 Tk./ ha recorded in treatment $T_3$ (Table 11). On the other hand, the lowest net return was 13,480.00 Tk./ ha recorded in control treatment $T_5$ (Table 11). The net return obtained from the treatment $T_1$ was 40,320.00Tk./ha, $T_2$ was 53,640.00 Tk./ ha and $T_4$ was 65,640.00 Tk./ ha.

#### 4.9.5 Benefit cost ratio (BCR)

Considering the control of tomato fruit borer, the highest benefit cost ratio was 1.79 recorded from the treatment $T_3$ (Table 11). On the other hand, the lowest benefit cost ratio was 1.17 recorded from the treatment $T_5$ (table 11). From these results it is revealed that the trend of the benefit cost ratio was observed due to application of the different management practices against tomato fruit borer was $T_3 > T_4 > T_2 > T_1 > T_5$ (Table 11).

**Table 11: Economic analysis of different treatments applied against tomato fruit borer**

| Treatment(s) | Yield (t/ha) | Cost of pest management (Tk. ha$^{-1}$) | Total cost of production (Tk. ha$^{-1}$) | Gross return (Tk. ha$^{-1}$) | Net Return (Tk. ha$^{-1}$) | Benefit Cost Ratio (BCR) |
|---|---|---|---|---|---|---|
| $T_1$ | 10.86 | 10,000.00 | 90,000.00 | 1,30,320.00 | 40,320.00 | 1.45 |
| $T_2$ | 12.97 | 12000.00 | 102000.00 | 155640.00 | 53640.00 | 1.53 |
| $T_3$ | 16.22 | 29,000.00 | 1,09,000.00 | 1,94,640.00 | 85,640.00 | 1.79 |
| $T_4$ | 15.22 | 33,000.00 | 1,13,000.00 | 1,80,640.00 | 65,640.00 | 1.59 |
| $T_5$ | 7.79 | 00.00 | 80,000.00 | 93,480.00 | 13,480.00 | 1.17 |

**Market price of tomato: Tk. 12.00/kg for healthy and Tk. 0.00/kg for infested fruit.**

Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

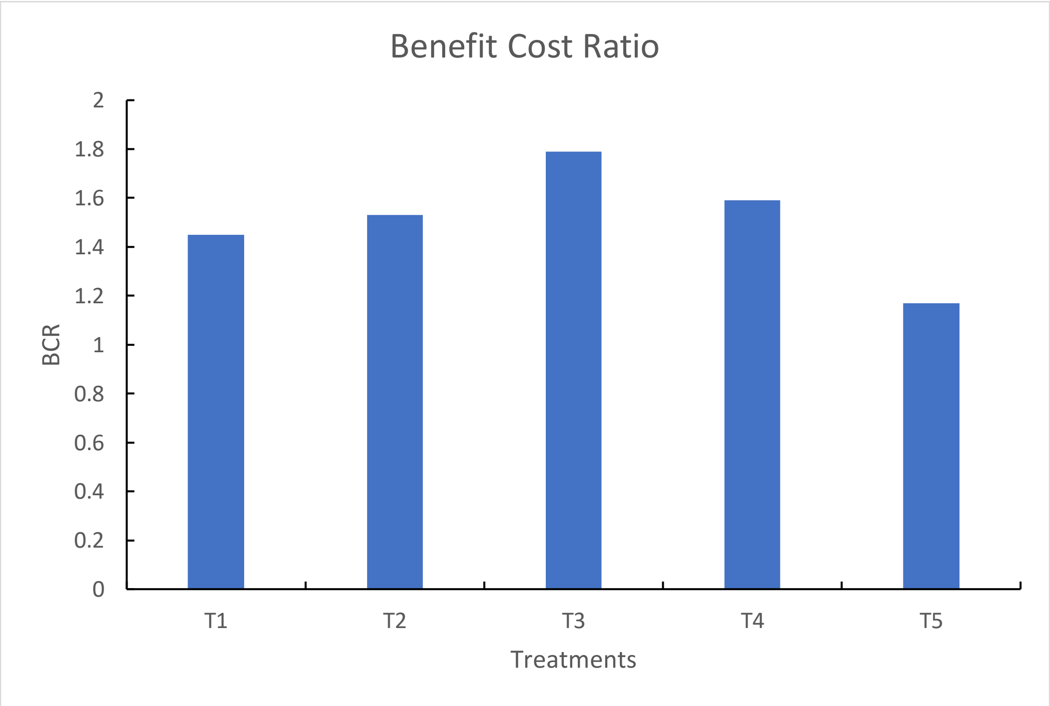



**Figure 3: Economic analysis of different treatments applied against tomato fruit borer**

## 4.10. Effect on natural enemies

### 4.10.1. Wasp

The significant variations were observed among the different treatments of number of Wasp. At 20 DAT, there was no significantly variation found among the treatments. But at 60 DAT the highest number of wasp was observed (6.00) for $T_5$: untreated control and lowest 1.33 for $T_1$ : flubendiamide (Belt 24 WG). Which is statistically similar to $T_2$: spinosad (Success 2.5 SC) (2.00). Considering the percent reduction of number of wasps per five plants, among different management practices, the highest 64.54% reduction over control was achieved in $T_1$ treatment. And lowest for (9.82%) $T_4$ treatment (Table 12).

**Table 12: Effect of treatments on incidence of wasp**

| Treatments | Incidence of wasp | | | | |
|---|---|---|---|---|---|
| | 20 DAT | 40 DAT | 60 DAT | Mean | %Reduction over control |
| $T_1$ | 2.66 b | 1.67 d | 1.33 d | 1.88 | 64.54 |
| $T_2$ | 3.66 ab | 3.33 c | 2.00 d | 2.96 | 51.92 |
| $T_3$ | 3.67 ab | 3.66 bc | 3.33 c | 3.55 | 25.03 |
| $T_4$ | 4.33 a | 4.67 b | 4.67 b | 4.56 | 9.82 |
| $T_5$ | 4.67 ab | 6.00 a | 6.00 a | 5.56 | 00 |
| LSD (0.05) | 1.21 | 1.05 | 1.239 | -- | -- |
| CV% | 16.99 | 14.55 | 13.93 | -- | -- |

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.
Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

From these above findings it was revealed that among different treatments the $T_1$: flubendiamide (Belt 24 WG) reduce highest number of wasps as synthetic treatment

### 4.10.2. Spiders

The significant variations were observed among the different treatments used for the management practices in terms of number of spiders per five plants recorded from the cabbage field. At 20 DAT, there was no significantly variation found among the treatments. But at 60 DAT the highest number of spider was observed (6.33) for $T_5$: Untreated control and lowest 1.00 for $T_1$ : flubendiamide (Belt 24 WG). Which is statistically similar to $T_2$: spinosad (Success 2.5 SC) (1.33). Considering the percent reduction of number of spiders per five plants, among different management practices, the highest 70.11% reduction over control was achieved in $T_1$ treatment. And lowest for (14.74%) $T_4$ treatment (Table 13).

**Table 13: Effect of treatments on incidence of spider**

| **Treatments** | **Incidence of spider** | | | | |
|---|---|---|---|---|---|
| | **20 DAT** | **40 DAT** | **60 DAT** | **Mean** | **%Reduction over control** |
| **$T_1$** | 2.33 d | 1.33 c | 1.00 d | 1.56 | 70.11 |
| **$T_2$** | 3.00 c | 1.67 c | 1.33 d | 2.00 | 61.68 |
| **$T_3$** | 3.33 bc | 3.67 b | 4.33 c | 3.78 | 27.59 |
| **$T_4$** | 3.67 b | 4.33 b | 5.00 b | 4.33 | 14.74 |
| **$T_5$** | 4.33 a | 5.33 a | 6.33 a | 5.22 | 00 |
| **LSD (0.05)** | 0.643 | 0.842 | 0.59 | -- | -- |
| **CV%** | 10.25 | 13.69 | 8.78 | -- | -- |

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.
Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

From these above findings it was revealed that among different treatments the $T_1$ : flubendiamide (Belt 24 WG) reduce highest number of spider as synthetic treatment.

**4.10.3. Ants**

The significant variations were observed among the different treatments due to management practices in terms of number of ants. At 20 DAT, there was no significantly variation found among the treatments. But at 60 DAT the highest number of ant was observed (7.33) for $T_5$: Untreated control and lowest 1.33 for $T_1$: flubendiamide (Belt 24 WG). Which is statistically similar to $T_2$: Spinosad (Success 2.5 SC) (2.00). Considering the percent reduction of number of ants per five plants, among different management practices, the highest 61.34% reduction over control was achieved in $T_1$ treatment. And lowest for (0.09%) $T_4$ treatment (Table 14).

**Table 14: Effect of management practices on incidence of ants**

| **Treatments** | **Incidence of ants** | | | | |
|---|---|---|---|---|---|
| | **20 DAT** | **40 DAT** | **60 DAT** | **Mean** | **%Reduction over control** |
| **$T_1$** | 2.67 b | 1.67 d | 1.33 d | 1.89 | 61.34 |
| **$T_2$** | 3.33 ab | 3.33 c | 2.00 d | 2.89 | 40.90 |
| **$T_3$** | 3.67 ab | 3.67 bc | 4.66 c | 4.00 | 29.16 |
| **$T_4$** | 4.33 a | 4.67 ab | 5.67 b | 4.89 | 0.09 |
| **$T_5$** | 3.33 ab | 5.33 a | 7.33 a | 5.33 | 00 |
| **LSD (0.05)** | 1.031 | 1.190 | 0.909 | -- | -- |
| **CV%** | 15.80 | 16.94 | 11.50 | -- | -- |

In the column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly at 5% level of probability.
Treatments: [$T_{1:}$ flubendiamide (Belt 24 WG); $T_{2:}$ spinosad (Success 2.5 SC); $T_{3:}$ emamectin benzoate (Proclaim 5G); $T_4$: Farmer's practice (Cypermethrin 10 EC), $T_{5:}$ untreated control];

From these above findings it was revealed that among different treatments the $T_1$: flubendiamide (Belt 24 WG) reduce highest number of ants as synthetic treatment. Findings of the experiment revealed that insecticidal treatment produced maximum yield among the treatments but keeping the environmental point in view less hazards botanicals may be recommended as treatment against insect pests of tomato by sacrificing yield. The number of natural enemies count was high mirrors the relatively less effect by the natural enemies of tomato by the trial pesticides especially $T_1$: flubendiamide (Belt 24 WG). In addition, data on the effects of flubendiamide on several beneficial arthropods, results indicated little to no mortality on many beneficial insects such as Wasp, ant and spider.

# CHAPTER V

# SUMMARY AND CONCLUSION

Tomato fruit borer is one of the most harmful insect in our country. This is mostly control by the chemical insecticides, which are available in the market. But the present investigation was undertaken for the evaluation of some management practices against tomato fruit borer. The experiment included 5 treatments $T_5$: Untreated (No pesticides), $T_1$: flubendiamide (Belt 24WG), $T_2$: spinosad (Success 2.5 SC), $T_3$: emamectin benzoate (Proclaim 5G), $T_4$: Farmer's practice (Admire 200SL@0.5ml/L + Voliam Flexi 300SC@.5ml/L of water spray). All the sprayings were done at 7days interval. The field experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Data on number of total, healthy and infested fruits/plant, weight of total, healthy and infested fruits/plant, weight of single fruit/plant, diameter of single fruit/plant, yield per plot and total, healthy and infested yield per hectare were recorded and at last economic analysis was done and the recorded data were analyzed statistically.

From recording of the data, it was observed that the treatment $T_1$ shows highest number of healthy fruits/plants (30.23) and $T_4$ the lowest (16.89), the untreated $T_5$ gives the least fruits/plant (8.93). According to treatment flubendiamide (Belt 24WG) gives the best performance and emamectin benzoate (Proclaim 5G) give low performance at early fruiting stage, the lowest number of infected fruits/plant at early stage was for $T_4$ (0.97) and highest for untreated $T_5$ (3.17). $T_5$ shows the highest level of infestation which was different from all other treatments. Among the treatment $T_1$ shows highest number of healthy fruits/plants (57.18) and $T_4$ the lowest (40.76), the untreated $T_5$ gives the least fruits/plant (22.86). According to treatment flubendiamide gives the best performance and emamectin benzoate give low performance at mid fruiting stage, the lowest number of infected fruits/plant at early stage was for $T_4$ (1.23) and highest for untreated $T_5$ (4.83). $T_5$ shows the highest level of infestation which was different from all other treatments. For treatment $T_1$ shows highest number of healthy fruits/plants (46.66) and $T_4$ the lowest (30.94), the untreated $T_5$ gives the least fruits/plant (16.33). According to treatment flubendiamide gives the best performance and emamectin benzoate give low performance at late fruiting stage also express the reduction of performance comparing the mid fruiting stage. At early fruiting stage, the lowest infestation percentage was 3.11 recorded from $T_1$ treatment which was significantly different from all other treatments (Table 4). On the other hand, the highest infestation percentage was 26.19 recorded from control ($T_5$) treatment. In this case, the trend of percent infestation was $T_5 > T_1 > T_2 > T_3 > T_4$ which trends to continue at mid and late fruiting stage.

The highest fruit weight observed for the treatment $T_1$ (165.11g) and the lowest for control $T_5$ (63.9g). The highest fruit diameter observed for the treatment $T_1$ (13.8mm) and the lowest for control $T_5$ (5.9mm). The highest yield (kg/plot) observed for the treatment $T_1$ (47.63kg) and the lowest for control $T_5$ (20.03kg). The highest yield (ton/ha.) observed for the treatment $T_1$ (16.96 ton/ha.) and the lowest for control $T_5$ (9 ton/ha.).

Considering the control of tomato fruit borer, the highest benefit cost ratio was 1.79 recorded from the treatment $T_3$ as emamectin benzoate (Proclaim 5G). On the other hand, the lowest benefit cost ratio was 1.17 recorded from the treatment $T_5$. From these results it is revealed that the trend of the benefit cost ratio was observed due to application of the different management practices against tomato fruit borer was $T_3 > T_4 > T_2 > T_1 > T_5$.

At 60 DAT the highest number of wasp was observed (6.00) for $T_5$ : Untreated control and lowest 1.33 for $T_1$ : flubendiamide (Belt 24 WG). Which is statistically similar to $T_2$: spinosad (Success 2.5 SC) (2.00). Considering the percent reduction of number of wasps per five plants, among different management practices, the highest 64.54% reduction over control was achieved in T1 treatment. And lowest for (9.82%) $T_4$ treatment. But at 60 DAT the highest number of field spider was observed (6.33) for $T_5$: untreated control and lowest 1.00 for $T_1$ : flubendiamide (Belt 24 WG). Which is statistically similar to $T_2$: spinosad (Success 2.5 SC) (1.33). Considering the percent reduction of number of field spider per five plants, among different management practices, the highest 70.11% reduction over control was achieved in $T_1$ treatment. And lowest for (14.74%) T4 treatment. at 60 DAT the highest number of ants was observed (7.33) for $T_5$: Untreated control and lowest 1.33 for $T_1$: flubendiamide (Belt 24 WG). Which is statistically similar to $T_2$: spinosad (Success 2.5 SC) (2.00). Considering the percent reduction of number of ants per five plants, among different management practices, the highest 61.34% reduction over control was achieved in $T_1$ treatment. And lowest for (0.09%) $T_4$ treatment.

**Conclusion**

The experiment on bio-efficacy of different modern insecticidal treatments revealed that flubendiamide (Belt 24 WG) was found most effective against tomato fruit borer followed by spinosad (Success 2.5 SC) and emamectin Benzoate (Proclaim 5G), and resulted higher yield, while Farmer's practice (Cypermethrin 10 EC) proved least effective.

Findings of the experiment revealed that insecticidal treatment produced maximum yield among the treatments but keeping the environmental point in view and less hazards botanicals may be recommended as treatment against tomato fruit borer.

**Recommendations**

Considering the experimental results of the study further investigation in the following areas may be recommended as follows.

1. Further study may be needed for ensuring the efficiency of botanical pesticides in relation to growth and yield performance in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.
2. More mechanical treatments against tomato fruit borer may be needed to include for future study as sole or different combination to avoid total rely on insecticides.
3. Safe use of pesticides should be practiced in farmer's level to avoid the harmful effect of pesticides.
4. Pesticide companies should be taken different steps to create awareness among the farmers about the harmful effect of pesticides.

# CHAPTER VI
# REFERENCES


Abbas, Ghulam & Hassan, Najamul & Haq, Ikramul & Karar, Haider. (2015). Effect of Selected Insecticides on *Helicoverpa armigera* Hubner (Lepidoptera: *Noctuidae*) on Tomato (*Lycopersicon esculentum* Mill.) and Their Successful Management. *Advances in Entomology*. 03. 16-23.

Aditya, T.L., Rahman, L., Alam, M.S. and Ghoseh, A.K. (1997). Correlation and path co-efficient analysis in tomato. Bangladesh *J. Agril. Sci.* **26**(1): 119-122.

Alam, S.N. (2004). Training manual on insect disease management of vegetable disease crops, Horticulture Research Centre, BARI, Gazipur, p. 4-5.

Ali, M.R., Yesmin, M., Alam, M.M., Akter, T. and Hoque, M.A. (2009). Ecofriendly management of tomato fruit borer. Title code: IJSAT/091108. pp. 39-44.

AIS. (2010). Tomatoes: Background, origin and distribution. Printed and published by: Dept. of Agri. Forestry and Fisheries, Obtainable from: Resource Centre, Directorate Agril. Info. Services, Private Bag X144, PRETORIA, 0001.

Ambule, A.T., Radadia, G.G., Shinde, C.U., Patil, D.L. (2015), Relative efficacy of newer insecticides against Helicoverpa armigera (Hubner) in tomato under South Gujarat condition. *Inter. J. of Plant Prot*. **8**(2):250-255

Anonymous. (1999). Statistical Year Book of Agricultural Statistics of Bangladesh. Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. p. 125.

Arora, A., Ashok, K.K. and Kumar, A. (2012). Bio pesticide formulation to control tomato Lepidoptera pest menace. *Current Sci*. **102**(7): 1051-1057.

Ayvaz, A., Karasu, E., Karaborklu, S. and Yilmaz, S. (2008). Dispersal ability and parasitism performance of egg parasitoid *Trichogramma evanescene* westwood (Hymenoptera: *Trichogrammatidae*) in field and storage conditions. *Turkey. J. Biol.* 32: 27-33.

BBS (Bangladesh Bureau of Statistics). (2018). Statistical Tear Book of Bangladesh 2012. Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. p. 56.

BBS (Bangladesh Bureau of Statistics). (2018). Statistical Tear Book of Bangladesh. Statistics Division, Ministry of Planning, Government of the People's Republic of Bangladesh, Dhaka. p. 38.

Bihari, M. and Narayan, S. (2010). Evaluation of biocidal efficacy of botanicals against tomato fruit borer (*Helicoverpa armigera* Hubner) at field level. *J. Inter academicia*. **14**(3): 293-297.

Bose, T.K. and Som, M.G. (1990). Vegetable crops in India, Naya prokash, 206 Bidhan Sarani, Calcutta, India, p.249.

Brar, K.S., Rahman, H., Dhaliwal, H.S. and Cheema, D.S. (2003). Field screening of different species if Lycopersicon against tomato borer, *Helicoverpa armigera* (Hubner). *J. Insect Sci.* **8**(2): 196-197.

Chowdhury, R., Halagundegowda, G.R., Meenakshi and Krishnamurthy, K.N. (2017). Regression Analysis to Identification of Stable Genotypes of Finger Millet for Plant Height across *India. Int. J. Curr. Microbiol. App. Sci.* **6**(2): 1179-1186.

Dilbagh, S., Narang, D.D. and Singh, D. (1990). Control of tomato fruit borer, *Helicoverpa armigera* (Hubner) with synthetic pyrethroids. *Indian J. Entom* **52**(4): 534-540.

Divakar, B.J., Pawar, A.D. (1987). Biocontrol of tomato fruit borer, *Helicoverpa armigera* (Hubner) in Karnataka. *India J. Plant Portect*. **15**(1): 57-61.

Ewing, K.P., Parencia, C.R. Jr. and Ivy, E.E. (1947). Cotton insects control with benzene hexachloride, along or in mixture with DDT. *J. Econ. Ent.* 40:374-381.

FAO. (2018). FAO production Year Book 2018. Basic Data Unit. Statistic Division, FAO. Rome, Italy. 5:125-127.

Fishwick, R.B. (1988). Pesticide residues in grain arising from postharvest treatments. *Aspects Appl. Biol.* **17**(2): 37-46.

Gajendra, C., Ganguli, R.N., Kaushik, U.K., Dubey, V.K. and Chandrakar, G. (1998). Integrated pest and disease management in tomato: an economic analysis. *Agril. Econ Res. Rev*. 19: 269-280.

Ganguly, R.N. and Dubey, V.K. (1998). Integrated management of tomato fruit borer with insecticides, neem products and virus. *Madras Agril. J*. **84**(2): 82-84.

Gomez, K.A. and Gomez, A.A. (1984). Statistical procedures for Agricultural Research. A Wiley Int. Sci. Publ. John Wiley and Sons. New York, Brisbane, Singapore. Pp. 139-240.

Gopal, S. and Senguttuvan, T. (1997). Integrated management of tomato fruit borer and its natural enemies. *J. Hort. Forestry.* **2**(5): 108-111.

Hannan, M.M., Ahmed, M.B., Razvy, M.A., Karim, R. and Khatun, M. (2007). Heterosis and correlation of yield and yield components in tomato (*Lycopersicon esculentum* Mill.). *American-Eurasia J. Sci. Res*. 2: 146-150.

Hassall, K.A. (1990). In: The Biochemistry and uses of pesticides, Second Ed., ELBS/Macmillan. pp. 135-138.

Husain, M. (1993). Controlling tomato fruit borer under Bangladesh conditions. *Bangladesh J. Pestology*. **17**(5): 25-38.

Husain, M. (1984). Controlling rice borer under Bangladesh conditions. *Bangladesh J. Pestology*. **8**(8): 28-30.

Husain, M., Begum, M. and Jahangir, M. (1998). Comparative susceptibility of several strains/varieties of tomato fruit borer, *Helicoverpa armigera*. *Bangladesh J. Nuclear Agric.* 14: 91-93.

Hussain, B. and Bilal, A.S. (2006). Biology and management of tomato fruit borer, *Helicoverpa armigera* (Hubner) using African marigold as trap crop (online available at: http://dspaces.uok.edu.in/handle/l/262).

Hussain, B. and Bilal, A.S. (2007). Efficacy of different insecticides on Tomato fruit borer *Helicoverpa armigera*. *J. Entom*. 4: 64-67.

Hussain, S.I., Khokhar, K.M., Mahmood, T., Laghari, M.H. and Mahmud, M.M. (2001). Yield potential of some exotic and local tomato cultivars grown for summer production. *Pakistan J. Biol. Sci*. 4: 1215-1216.

Jiirgen, K, Heinij, S. and Werner, K. (1977). Pests in tropical crops. In disease, pests and weeds intropical crops. Jonh Wiley and Sond, New York, Brisbane, Toronto. pp. 476-781.

Ju, Y.W., Zhao, B.G., Cheng, X.F. and Bi, Q.S. (2000). Bioactivities of six desert plants extracts to *Helicoverpa armigera* Hubner. *J. Nanj. Univ*. **24**(5): 81-83.

Karabhantanal, S.S. and Kulkarni, K.A. (2002). Implication of tritrophic interactions in the management of the tomato fruit borer, *Helicoverpa armigera* (Hubner). *Pest Manage and Econ Zoo.* **10**(2): 183-186.

Karabhantanal, S.S., Awaknavar, J.S. and Patil, B.V. (2005). Management of the tomato fruit borer, *Helicoverpa armigera* (Hubner). *Karntaka J. Agril. Sci*. **18**(4): 977-981.

Karim, M.A. (1994). Insect pest management of vegetable crops. Proceeding of a symposium on recent advances in vegetable development of Bangladesh. pp. 198-199.

Khanam, U.K.S., Hossain, M., Ahmad, N., Uddin, M.M. and Hossain, M.S. (2003). Varietal screening of tomato fruit borer, *Helicoverpa armigera* (Hubner) and associated tomato plant characters. *Pakistan. J. Biol. Sci*. **6**(3): 255-263.

Kulat, S.S., Nandanwar, V.N., Zada, N.N. and Tirthkar, S.S. (2001). Evaluation of some indigenous plant products for the management of *Helicoverpa armigera* (Hubner) on chickpea. *J. Appl. Zool. Res*. **12**(2-3):96-98.

Mehta, P.K., Rah, P.C. and Nath, P. (2000). Influence of plant and fruit characters of tomato on fruit borer infestation. Bull Entom New Delhi. **36**(1-2):60-62.

Mehta, P.K., Vaidya, D.N. and Kashyap, N.P. (2001). Management of tomato fruit borer *Helicoverpa armigera* (Hubner) using insecticides and bio pesticides. *Himachal J. Agril. Res*. **26**(1-2): 50-53.

Mishra, P.N., Singh, M.P. and Nautiyal, M.C. (1996). Varietal resistance in tomato against fruit borer, *Helicoverpa armigera*. *Indian J. Entom*. **58**(3): 222-225.

Mishra, S.N. and Mishra, N.C. (1995). Genetic parameters and varietal performance of tomato in North eastern Ghal Zone of Orissa. Environ. Ecol. **13**(1): 182-187.

Nazim, U.M., Zaman, K., Rahman, M.M. and Bhauddin, M. (2002). Annual report of IPM-Crop, Bangladesh site. Pp. 53-55.

Nachiappan, R.M. and Subramanium, T.R. (1974). Studies on mass culturing of *Heliothis armigera* (Hub.) (Noctuidae: *Lepidoptera*), on semi-synthetic diets. II. Effects on the development of per-imaginal instars. *Madras Agric. J.* **61**(1-2): 813.

Ogunwolu, E.O. (1989). Effects and insecticidal suppression of damage caused by *Helicoverpa armigera* (Hub.) on rain fed tomato in Nigeria. Crop Pest Management. **35**(4): 406-409.

Pandey, R.R., Gurung, T.B. and Gutung, G. (1997). Monitoring and management of tomato fruit borer *Helicoverpa armigera* (Hubner) and its egg parasite in the western hills. Working-Paper Lumle regional Agricultural Research Center. No. 97. **24**(3):14.

Parihar, S.B.S. and Singh, B.R. (1986). Incidence of *Helicoverpa armigera* (Hubner) a fruit borer on tomato. *Indian J. Plant Prot*. **13**(2): 133-136.

Patel, C.C. and Koshiya, D.J. (2016). Seasonal abundance of American boll worm on different crop host at Junagodh (Gujarat). *Indian J. Entom* **59**(4): 396-401.

Patel, J.R., Borad, P.K., Ratanpara, H.C. and Shah, B.R. (1991). Need based control of *Helicoverpa armigera* (Hubner) on tomato with endo-sulfan. *Indian J. Plant Procet*. **19**(1): 78-80.

Patil, S., Kotikal, Y.K., Revanappa, K.K. and Patil, D.R. (1997). Effects of intercropping tomatoes on the infestation of tomato fruit borer, *Helicoverpa armigera* (Hubner). *Adv. Agril. Res* 8:141-146.

Perring, T.M., Farrar, C.A. and Toscano, N.C. (1988). Relationships among tomato planting date, potato aphids and natural enemies. *J Econ. Entom* **81**(4): 1107-1112.

Pinto, M.L., Agro, A., Salerno, G. and Pero, E. (1997). Serious attacks of the tomato moth *Helicoverpa armigera* (Hubner). *Info Agratio*. ***53***(9): 67-69.

Pokhakar, D.S., Chaudhary, S.D. and Verma, S.K. (1999). Utilization of nuclear polyhedrosis virus in the iterated control of fruit borer on tomato (*Lycopersicon esculentum* Mill.). *Indian J. Agril, Sci*. **69**(3): 185-188.

Rashid, M.M. (2003). Shabjibigan (in Bangla). 3rd Edition. Rashid Pub. House, Dhaka. p. 526.

Rath, P.C. and Nath, P. (1995). Influence of plant and fruit characters of tomato on fruit borer infestation. Bull Entom New Delhi, India. **36**(1-2): 60-62.

Rath, P.C. and Nath, P. (2001). Assessment of fruit damage in various genotypes of tomato by fruit borer, *Helicoverpa armigera* (Hubner). Shaishpa *J. Bio. Sci***.** **8**(1): 63-64.

Sajjad, M., Ashfaq, M., Suhail, A. and Akhtar, S. (2011). Screening of tomato genotypes for resistance to tomato fruit borer, *Helicoverpa armigera* (Hubner) in Pakistan. *Pakistan. J. Agri. Sci*. **48**(1): 59-62.

Satpathy, S., Samarjit, R., Chattopadhyay, M. and Rai, S. (1999). Field evaluation of NPV and insecticides against tomato fruit borer, *Helicoverpa armigera* (Hubner). *Insect Environ***.** **5**(3): 117-118.

Sharma, D.K., Dhaliwal, M.S., Cheema, D.S. and Single, S. (2003). Screening of tomato germplasm against tomato fruit borer, *Helicoverpa armigera* (Hubner). *J. Res. Punjab Agril. Univ*. **40**(1): 24-26.

Singh, H. and Singh, G. (1977). Biology studies on tomato fruit borer, *Helicoverpa armigera* Hub. in Punjab. *Indian J. Entomol*. **27**(2): 154-164.

Singh, S.R. (1972). The cotton boll worm, tomato fruit borer, *Helicoverpa armigera* Hub. (Lepidoptera: Noctuidae) on cabbage. *Entom Rev*.51: 27.

Sivaprakasam, N. (1996). Screening of tomato genotypes for resistance against fruit borer, *Helicoverpa armigera. Madras Agric. J.* **83**(7): 473-474.

Sundarajan, G. (2002). Evaluation of some plant extracts against *Helicoverpa armigera* (Hubner). *Environ and Ecol*. 19(1): 210-212.

Subapriya, R. and Nagini, S. (2005). Medical properties of neem leaves. *Med. Chem Anticancer Agents*. **5**(2): 149-156.

Sundarajan, G. and Kumuthakalavalli, R. (2000). Effect of leaf extracts of selected plants against the leaves of *Helicoverpa armigera*. *Environ Ecol*. **18**(1): 119-125.

Sundeep, K., Dilbagh, S., Kaur, S. and Singh, D. (2000). Economics of controlling *Helicoverpa armigera* (Hubner) through suitable varieties and cultural practices in tomato. *J. Veg. Sci*. **27**(2): 185-188.

Tewari, G.C. (1985). Field efficacy of synthetic pyrithroids against *Helicoverpa armigera* (Hubner) infesting tomato. *Singapore J. Prim. Indus*. **13**(1): 51-56.

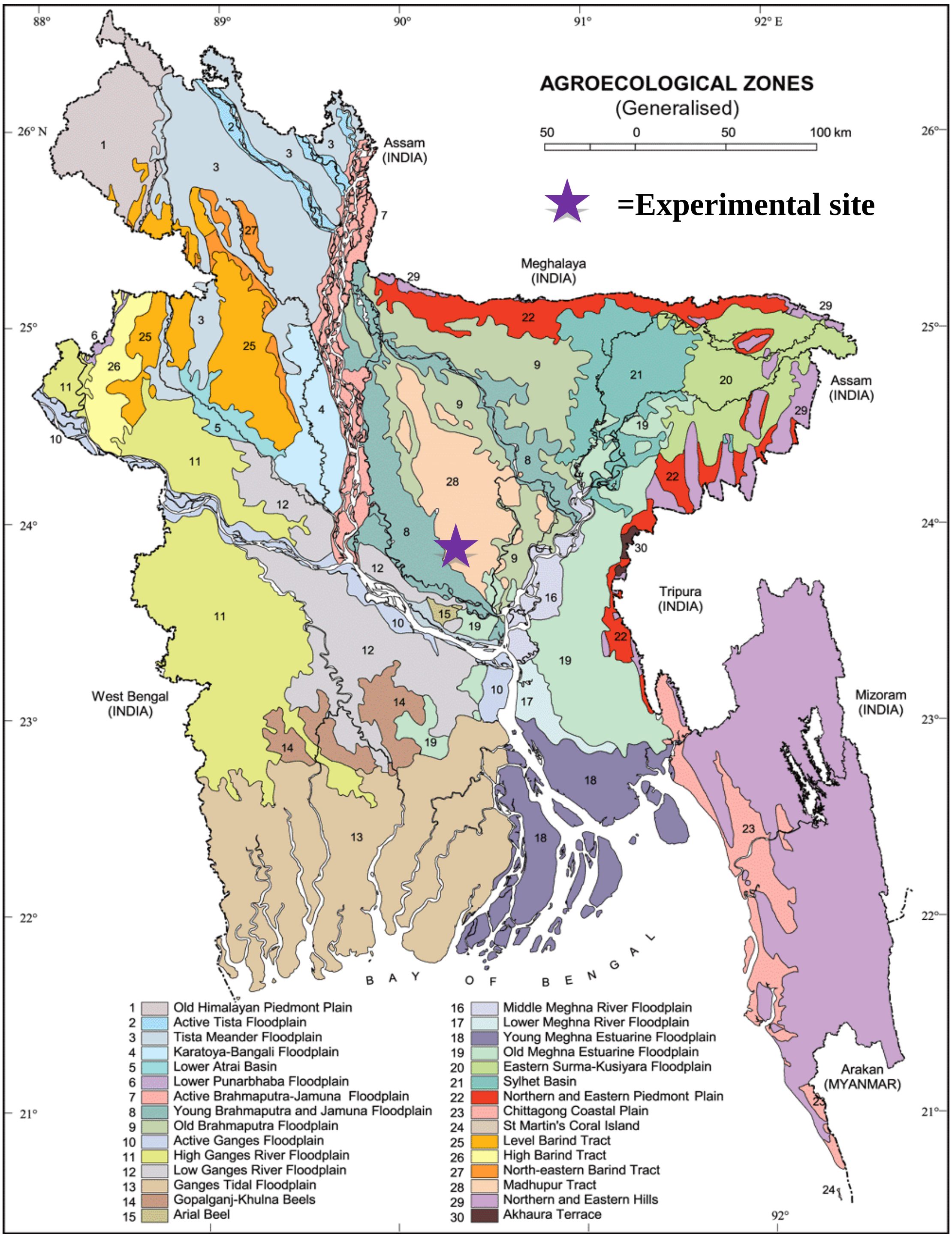
Thomson, H.C. and Kelly, W.C. (1983). Vegetable Crops. 5th Edn. Tata McGraw Hill Publishing Co. Ltd. New Delhi. p. 611.

Usman, M., Inayatullah, M., Sohail, A.U.K. and Shah, S.F. (2012). Effect of egg parasitoid, *Trichogramma chilonis* in combination with *Chrysoperla carnea* and neem seed extract against tomato fruit worm, *Helicoverpa armigera. Sarhad J. Agric*. **28**(2): 23-27.

Walunj, A.R., Pawar, S.A., Khaire, V.M. and Dareker, K.S. (1999). Evaluation of insecticides mixtures for control of tomato fruit borer. Tests of Agrochemicals and cultivars. CH. 20: 10-11.

# APPENDICES

## Appendix I. Map showing the experimental site under study



**Appendix II. Characteristics of soil of experimental field**

**A. Morphological characteristics of the experimental field**

| Morphological features | Characteristics |
|---|---|
| **Location** | Sher-e-Bangla Agricultural University Agronomy research field, Dhaka |
| **AEZ** | AEZ-28, Modhupur Tract |
| **General Soil Type** | Shallow Red Brown Terrace Soil |
| **Land type** | High land |
| **Soil series** | Tejgaon |
| **Topography** | Fairly leveled |

**B. The initial physical and chemical characteristics of soil of the experimental site (0 - 15 cm depth)**

| Physical characteristics | |
|---|---|
| **Constituents** | **Percent** |
| **Sand** | 26 |
| **Silt** | 45 |
| **Clay** | 29 |
| **Textural class** | Silty clay |
| **Chemical characteristics** | |
| **Soil characters** | **Value** |
| **pH** | 5.6 |
| **Organic carbon (%)** | 0.45 |
| **Organic matter (%)** | 0.78 |
| **Total nitrogen (%)** | 0.03 |
| **Available P (ppm)** | 20.54 |
| **Exchangeable K (me/100 g soil)** | 0.10 |

**Appendix III. Monthly meterological information during the period from November, 2018 to April, 2019**

| Year | Month | Air temperature ($^0C$) | | Relative humidity (%) | Total rainfall (mm) |
|---|---|---|---|---|---|
| | | Maximum | Minimum | | |
| 2018 | November | 28.10 | 11.83 | 58.18 | 47 |
| | December | 25.00 | 9.46 | 69.53 | 00 |
| 2019 | January | 25.2 | 12.8 | 69 | 00 |
| | February | 27.3 | 16.9 | 66 | 39 |
| | March | 31.7 | 19.2 | 57 | 23 |
| | April | 33.50 | 25.90 | 64.50 | 119 |

**Source : Meterological Centre, Agargaon, Dhaka (Climate Division)**

**Appendix IV: Effect of different control measure in controlling tomato fruit borer at early cropping stage in terms of number of fruits/plant**

| Sources | Degree of freedom | Mean sum square | | | |
|---|---|---|---|---|---|
| | | Healthy | Infected | Total | %Infested |
| Replications | 2 | 0.14 | 0.004 | 0.195 | 0.315 |
| Treatments | 4 | 212.81 | 2.308 | 171.052 | 263.011 |
| Error | 8 | 0.16 | 0.022 | 0.12 | 1.121 |

**Appendix V: Effect of different control measures in controlling tomato fruit borer at mid cropping stage in terms of number of fruits/plant**

| Sources | Degree of freedom | Mean sum square | | | |
|---|---|---|---|---|---|
| | | Healthy | Infected | Total | %Infested |
| Replications | 2 | 0.022 | 0.045 | 0.079 | 0.218 |
| Treatments | 4 | 517.591 | 5.848 | 414.642 | 111.768 |
| Error | 8 | 0.057 | 0.013 | 0.09 | 0.078 |

**Appendix VI: Effect of different control measures in controlling tomato fruit borer at mid cropping stage in terms of number of fruits/plant**

| Sources | Degree of freedom | Mean sum square | | | |
|---|---|---|---|---|---|
| | | Healthy | Infected | Total | %Infested |
| Replications | 2 | 0.041 | 0.017 | 0.005 | 0.229 |
| Treatments | 4 | 408.136 | 4.502 | 330.221 | 168.081 |
| Error | 8 | 0.085 | 0.019 | 0.136 | 0.082 |

**Appendix VII: Effect of different control measures in controlling tomato fruit borer at early harvesting stage in terms of weight of fruits/plant**

| Sources | Degree of freedom | Mean sum square | | | |
|---|---|---|---|---|---|
| | | Healthy | Infected | Total | %Infested |
| Replications | 2 | 1 | 2.45 | 6.7 | 0.020 |
| Treatments | 4 | 85225.8 | 3621.27 | 53897.8 | 72.368 |
| Error | 8 | 3.7 | 10.71 | 3.7 | 0.133 |

**Appendix VIII: Effect of different control measures in controlling tomato fruit borer at mid harvesting stage in terms of weight of fruits/plant**

| Sources | Degree of freedom | Mean sum square | | | |
|---|---|---|---|---|---|
| | | Healthy | Infected | Total | %Infested |
| **Replications** | **2** | 0.022 | 0.045 | 0.079 | 0.218 |
| **Treatments** | **4** | 517.591 | 5.848 | 414.642 | 111.768 |
| **Error** | **8** | 0.057 | 0.013 | 0.09 | 0.078 |

**Appendix IX: Effect of different control measures in controlling tomato fruit borer at late harvesting stage in terms of weight of fruits/plant**

| Sources | Degree of freedom | Mean sum square | | | |
|---|---|---|---|---|---|
| | | Healthy | Infected | Total | %Infested |
| **Replications** | **2** | 0.041 | 0.017 | 0.005 | 0.229 |
| **Treatments** | **4** | 408.136 | 4.502 | 330.221 | 168.081 |
| **Error** | **8** | 0.085 | 0.019 | 0.136 | 0.082 |

**Appendix X: Effect of different treatments in controlling tomato fruit borer during total cropping season in terms of weight of individual fruit, diameter of individual fruit and yield plot$^{-1}$**

| Sources | Degree of freedom | Mean sum square | | |
|---|---|---|---|---|
| | | Single fruit weight | Single fruit weight | Single fruit weight |
| **Replications** | 2 | 1.63 | 0.542 | 0.893 |
| **Treatments** | 4 | 4566.38 | 28.300 | 332.016 |
| **Error** | 8 | 0.35 | 0.1587 | 0.071 |

**Appendix XI: Layout of the experimental field**