EVALUATION OF SOME MANAGEMENT PRACTICES AGAINST TOMATO FRUIT BORER (*HELICOVERPA ARMIGERA* Hubner) IN TOMATO

BY

MOHAMMAD RAIHANUL ISLAM

DEPARTMENT OF ENTOMOLOGY
SHER-E-BANGLA AGRICULTURAL UNIVERSITY
SHER-E-BANGLA NAGAR, DHAKA-1207, BANGLADESH

JUNE, 2014

EVALUATION OF SOME MANAGEMENT PRACTICES AGAINST TOMATO FRUIT BORER (*HELICOVERPA ARMIGERA* Hubner) IN TOMATO

BY

MOHAMMAD RAIHANUL ISLAM
REGISTRATION NO: 08-02843

A Thesis

Submitted to the faculty of Agriculture,

Sher-e-Bangla Agricultural University, Dhaka,

in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE (MS)

IN

ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2014

Approved by

…………………………………	....
Prof. Dr. Md. Serajul Islam Bhuiyan	**Dr. Tahmina Akter**
Supervisor	**Co-Supervisor**

……………………………..

Dr. Mohammed Sakhawat Hossain
Chairman
Examination Committee

DEPARTMENT OF ENTOMOLOGY
Sher-e-Bangla Agricultural University
Sher-e-Bangla Nagar, Dhaka-1207

CERTIFICATE

This is to certify that thesis entitled, "EVALUATION OF SOME MANAGEMENT PRACTICES AGAINST TOMATO FRUIT BORER (*HELICOVERPA ARMIGERA* Hubner) IN TOMATO" submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE (MS) IN ENTOMOLOGY, embodies the result of a piece of bona fide research work carried out by MOHAMMAD RAIHANUL ISLAM, Registration no. 08-02843 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.

Date: JUNE, 2014
Place: Dhaka, Bangladesh

(Prof. Dr. Md. Serajul Islam Bhuiyan)
Supervisor
Department of Entomology
Sher-e-Bangla Agricultural University
Dhaka-1207

ABBREVIATIONS AND ACRONYMS

AEZ	:	Agro-Ecological Zone
et al.	:	and others
BBS	:	Bangladesh Bureau of Statistics
BSFB	:	Brinjal Shoot and Fruit Borer
BSMRAU	:	Bangabandhu Sheikh Mujibur Rahman Agricultural University
cm	:	Centimeter
CV	:	Coefficient of variation
DAT	:	Days After Transplanting
^{o}C	:	Degree Celsius
d.f	:	Degrees of freedom
etc.	:	*et cetera*
EC	:	Emulsifiable Concentrate
FAO	:	Food and Agriculture Organization
Fig.	:	Figure
g	:	Gram
Ha	:	Hectare
I.U.	:	International Unit
P^{H}	:	Hydrogen ion concentration
q	:	quintal
J.	:	Journal
Kg	:	Kilogram
LSD	:	Least Significant Difference
L	:	Liter
m	:	Meter
MS	:	Mean sum of square
mm	:	Millimeter
MP	:	Muriate of Potash
MT	:	Metric ton
no.	:	Number
%	:	Percent
RARS	:	Regional Agricultural Research Station
RCBD	:	Randomized Complete Block Design
SAU	:	Sher-e-Bangla Agricultural University
SRDI	:	Soil Resource Development Institute
M^2	:	Square meter
Meq	:	Milli equivalents
Ppm	:	Parts per million
t	:	Ton
TSP	:	Triple Super Phosphate

ACKNOWLEDGEMENT

All the praises due to the Almighty Allah, who enabled the author to pursue his education in Agriculture discipline and to complete this thesis for the degree of Master of Science (M.S.) in Entomology.

I am proud to express my deepest gratitude, deep sense of respect and immense debtedness in to my supervisor, Professor Dr. Md. Serajul Islam Bhuiyan, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for his constant supervision, invaluable suggestion, scholastic guidance, continuous inspiration, constructive comments and encouragement during my research work and guidance in preparation of this manuscript.

I express my sincere appreciation, profound sense, respect and immense debtedness in to my respected co-supervisor, Dr. Tahmina Akter, Associate Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for providing me with all possible help during the period of research work and preparation of the thesis.

I would like to express my deepest respect and boundless gratitude to my honorable teachers, and staffs of the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for their valuable teaching, sympathetic co-operation and inspirations throughout the course of this study and research work.

Cordial thanks are also due to all field workers of SAU farm for their co-operation to complete my research work in the field.

I would like to express my last but not least profound and grateful gratitude to my beloved parents, friends and all of my relatives for their inspiration, blessing and encouragement that opened the gate of my higher studies in my life.

Dated: June, 2014 **The Author**

SAU, Dhaka

EVALUATION OF SOME MANAGEMENT PRACTICES AGAINST TOMATO FRUIT BORER *(HELICOVERPA ARMIGERA* Hubner*)* IN TOMATO

BY
MOHAMMAD RAIHANUL ISLAM

ABSTRACT

The study was conducted at the Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh during October 2013 to March 2014 to evaluate of some management practices against tomato fruit borer (*Helicoverpa armigera* Hubner) in tomato. The study comprised six treatments; T_1(Spray with soap water @ 3g/L of water), T_2(Spray with neem seed karnel water extract @ 20 g/L of water) , T_3 (Spray with neem oil + trix (4ml neem oil + 10ml trix)/L of water), T_4 (Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1ml/L of water), T_5 (Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @1ml/L of water) and T_6 (Untreated/ Control) treatment and all sprayings were done at 7 days interval. The field experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. Considering the effects of different management practices applied against tomato fruit borer at early, mid and late fruiting stage, the level of infestation followed more or less similar trend for both by number and by weight basis of tomato. Among the treatments, T_4 produced maximum numbers and weight of healthy fruit/plant as well as lowest percent fruit infestation for both by number and weight of tomato was recorded the same treatment. Among the botanicals T_3 gave the highest number of healthy fruits by number and weight basis. The treatment T_6 produced minimum number and weight of healthy fruit/plant as well as highest percent fruit infestation was recorded the same treatment. Considering the economic analysis of the different treatments in controlling tomato fruit borer, the highest benefit cost ratio was 1.79 recorded in the treatment T_4 and the minimum benefit cost ratio was 1.17 recorded in the T_6 treatment. The treatment T_4 =Ripcord 10 EC (Cypermethrin 10 EC) gave the best performance compared to the other treatments.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

Botanically Tomato (*Lycopersicon esculentum* Mill.) is a fruit but it has widely used as a vegetable. It belongs to the family Solanaceae. It ranks next to potato in the world vegetable production (FAO, 1997) and top of the list of canned vegetables (Chowhdhury, 1979). It is cultivated in all most all home gardens and also in the field due to its adaptability to wide range of soil and climate (Bose and Som, 1990). Tomato is indigenous to the Peru and Equador region in South America and it probably evolved from *Lycopersicon esculentum* var. *cerasiforme,* the cherry form. However, it was domesticated and first cultivated in Central America by the early Indian civilizations of Mexico. The Spanish explorers introduced tomato into Spain and later it was taken to Morocco, Turkey and Italy (AIS, 2010).

In 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, 2012). The recent statistics shows that tomato was grown in 23886.639 ha of land and the total production was approximately 190 thousand tons in 2011-2012 (BBS, 2013). The average yield of tomato was 40.36 ton per acre (BBS, 2013).

Tomato is one of the most highly praised vegetables consumed widely and it is a major source of vitamins A, B and C and minerals like calcium (Bose and Som, 1990). It is a nutritious and delicious 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 (Hussain *et. al*., 2001). It is one of the most popular salad vegetables and taken with great relish. It is widely employed in cannery and made into soups, pickles, ketchup, sauces, juices etc. (Thompson and Kelly, 1983).

The yield of tomato is not satisfactory in comparison to other tomato growing countries of the world (Aditya *et al.*, 1997). A large number of tomato varieties grow in Bangladesh, most of them 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 (Hannan *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.

The tomato plants are attacked by different species of insect pests such as white fly, aphid, tomato fruit borer and leaf miner in Bangladesh. Among them tomato fruit borer, *Helicoverpa armigera* (Hubner) is one of the serious pests and causes damage 50-60 % (Singh and singh, 1977) and up to 85-93 % (Tewari, 1985). Due to severe infestation, fruit as well as seed maturation hampered greatly and the viability of the seeds are also reduced.

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 only common method for controlling tomato fruit borer in Bangladesh is the application of chemical insecticides. The use of insecticides has become indispensable in increasing vegetable crop production because of its rapid effect, ease of application and availability. Generally the farmers of Bangladesh control this pest by application of chemical insecticides. But, the application of chemical insecticides has got many limitations and undesirable side effects (Husain, 1993).

A huge quantity of pesticide is used in controlling tomato fruit borer and usually found that the vegetable growers apply 10-12 sprays in a season. Thus, the fruits, which are harvested at the short intervals are likely to unavoidably high level of pesticide residues which may be highly hazardous causing serious problems including pest resistance, pest outbreak, pest resurgence and environmental pollution (Fishwick, 1988). The farmers of Bangladesh are very poor and they have very limited access to buy insecticides and the spraying equipment (Husain, 1984). Further, the excessive reliance on chemicals has led to the problem of resistance, resurgence and environmental pollution decimation of useful fauna and flora.

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

Therefore, the present study was under taken to fulfill the following objectives:

- To reduce the use of the chemical pesticides and ecofriendly production of tomato.
- To develop a suitable integrated management practice in tomato production.

CHAPTER II

REVIEW OF LITERATURE

Tomato fruit borer is the most important insect pest of tomato in Bangladesh. Studies on development of management practices against tomato fruit borer (*Helicoverpa armigera* Hubner) in tomato have been done elsewhere but a few of them is related to this present study.

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 oe 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 larvea, rather than to trichome number/mm^2, paiyur-1 had lowest number of trichomes on all plants parts studied, but the largest calyx area per fruits (3.4 cm^2).

Rath and Nath (1995) conducted field screening of 112 tomato genotypes at Uttar Pradesh, India, during the Kharif season against *H. armigera*. Leaf trichme 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 fruit 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 cultivers 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 programmes.

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. Irripective of *T. pretiosum* recorded higher hyperparasitism than *T. chilonis*. Further, it was observed that as the trichome density increased there was an increase in oviposition by *H. armigera* and a decrease in hyperparasitism by *Trichogramma* species.

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 methods following every alternate day during marble size tomato to before ripen period. Report revealed that about 75% control is possible only by this method. But it could be possible to get better result by mechanical method + spraying of botanical pesticides (Nazim *et al.*, 2002).

2.2.3 Botanical control

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

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

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

Ali *et al.* (2009) conducted an experiment at Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during October 2006 to March 2007 to explore the effective and eco-friendly management practice(s) among seven combinations of some cultural, mechanical, botanical and chemical practices along with one untreated control applied on the susceptible variety BARI Tomato 2 against tomato fruit borer, *Halicoverpa armigera* (Hubner). Among the seven treatments, the botanical based treatment (T_6) comprising the spraying of neem oil @ 3 ml/l of water at 7 days interval along with plants supported with bamboo stick performed best in reducing 79.51% and 75.59% the fruit infestation over control by number and weight and contributed to maximum fruit yield (85.55 ton/ha), which increased 26.76% yield over control. Based on the economic analysis of the treatments, T_6 contributed the maximum benefit cost ratio which also produced maximum yield.

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

Sundarajan (2002) screened methanol extracts of selected plants namely *Anisomeles malabarica, Ocimunm canum [0. americana], O. basilicum, Euphorbia hitra, E. heteriphylla, Vitex negundo, Tagetes indica and Parthenium hysterophorus* for their insecticidal activity against the fourth instar larvae of *H. armigera* by applying dipping method of the leaf extract at various concentrations (0.25 ,0.5 ,1.0 ,1.5 and 20) on young tomato leaves. The larval mortality of more than 50% has been recorded for all the plant extracts in 2 percent test concentration (48 h) except *E. heterophylla* which recorded 47.3 percent mortality in 2 percent concentration. Among the plant extracts tested *V. negundo* is found to show higher rate of mortality (82.5%) at 2 percent concentration.

Kulat *et al.* (2001) conducted an experiment on extracts of some indigenous plant materials, which are claimed important as pest control like seed kernels of neem, *Azadiracta indica, pongamia glabra [P. pinnata]*, leaves to tobacco, *Nicotiana tabacam* and *N. indiara*, a neem, based herbal product, against *H. armigera* on chickpea cv. I.C.C.V.5 for its management in Rabi seanons of 1993-1996 at College of Agriculture, Nagpur, Maharashtra, India. The results revealed that the crop treated with the leaf ectrsct of *N. tabacum* and seed extract of *P. glabra* (5%) and *N. indiara* (1%) and neem seed kernel extract (5%) exhibited low level of population build up compared to control.

Ju *et al.* (2000) tested six desert plants chosen to study their toxicity and effects on the growth and metamorphosis of the insect pest, *Helicoverpa armigera*. An artificial diet containing 5% aqueous extracts of *Cynanchum auriculatum* or *Peganum harmala* var. multisecta showed strong toxicity to the larvae and caused mortality of 100% and 55% respectively. These two extracts at the same dosage also significantly affected metamorphosis of the insect. An artificial diet containing 1% aqueous extracts of *C. auriculatum* or 5% aqueous extracts of *P. harmala* resulted in morality of 85% and 55% respectively, and a zero emergence rate. Tests of extracts of *C. auriculatum* made at different pH showed that the pH 3 and pH 10 portions of the extracts affected the larvae growth significantly. The other plant species tested were *Euphorbia helioscopia*, *Sophora alopecuroides, Peganum nigellastrum and Thermopsis lanceolata*; extracts of these species caused either much lower morality of *K. armigera* or zero morality (*E. helioscopia*).

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

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

2.2.4 Insecticidal control

A field experiment was conduction by Hussain and Bilal (2007) during Kharif 2003-2004 to evaluate the efficacy of six insecticides at farmers field against *Helicoverpa armigera* infesting tomato. Among the treatments imidacloprid at 0.03% proved more effective followed by Deltamethrin and Fluvalinate. The sparying 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 cupermethrin, 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 asses 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 effected using systemic products such as phosphoric esters (acephate, methomyl, dimethoate) or synthetic pyrethroids (alphamethrin [alphacypermethrin], deltamethrin); the latter must be used once only so as not to favor the build-up of mites. Agronomic methods of defence 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 x 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 indicm, 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 styudy the effectiveness of nuclear pilyhedrosis 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 polyhdrosis 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 X 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 compareable 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 insectisidal 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% avaidable 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 $ha^{-1}$and 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)

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. Howerer, 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 surinf=g 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 pest attacking tomato. This pest some times 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. Ther after, the pest moves to cotton crop from last week of July and started to build up its population during the month of August to mid September. Simultaneously the pest infestation was also noticed in sunflower and peral millet during this period but the population is d[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 conderably 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 there after, reaching to 4 larvae/10 plants, percent fruit infestation was low up to the end of February while in the second week of April 50.08% and 33.04% of fruits were infested in 1984 and 1985, respectively.

CHAPTER III

MATERIALS AND METHODS

This chapter deals with the materials and methods which are used in carrying out the experiment. It includes a short description of location of the experiment, characteristics of soil, climate, materials used, land preparation, manuring and fertilizing, transplanting and gap filling, staking, after care, harvesting and collection of data.

3.1 Location

The field experiment was conducted in the Central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 during the period from October 2013 to March 2014. The location of the experimental site was at in 23.75^{0}N latitude and 90.34^{0}E longitudes with an elevation of 8.45 meter from the sea level (Anonymous, 1999).

3.2 Climate of the experimental area

The climate of the experimental area is subtropical in nature. It is characterized by heavy rainfall, high temperature, high humidity and relatively long day during kharif season (April to September) and a scanty rainfall associated with moderately low temperature, low humidity and short day period during rabi season (October to March). Details of the meteorological data in respect of monthly maximum, minimum and average temperature, rainfall, relative humidity, average sunshine hours and soil temperature during the period of experiment are presented in Appendix II.

3.3 Soil of the experimental field

Soil of the study site was silty clay loam in texture. The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28) with p^H 5.8-6.5, ECE 25-28. The analytical data of the soil sample collected from the experimental area were determined in the Soil Resources Development Institute (SRDI), Soil Testing Laboratory, Khamarbari, Dhaka and have been presented in Appendix III.

3.4 Plant materials used in the experiment

BARI tomato-2 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, 2013 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, 2013 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. Healthy 30 days old seedlings were transplanted into the experimental field on 5 december, 2013.

Plate 01: Seedling of the tomato plant

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 = Spray with soap water @ 3 g/L of water

T_2 = Spray with neem seed kernel water extract @ 20 g/L of water

T_3 = Spray with neem oil + trix @ (4 ml neem oil + 10ml Trix)/L of water

T_4 = Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1 ml/L of water

T_5 = Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @ 1ml/L of water

T_6 = Control (Untreated)

3.10 Layout

The experimental plot was first divided into three blocks. Each block consisted of 6 plots. Thus, the total numbers of plot were 18. 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.

3.11 Land preparation

The experimental area was first opened on 15 October 2013 by a disc plough to open direct sunshine to kill soil borne pathogens and soil inhabitant insects. It was prepared by several ploughing and cross ploughing with a power tiller followed by laddering to bring about a good tilth. The land was leveled, corners were shaped and the clods were broken into pieces. The weeds, crop residues and stables were removed from the field. Total organic manures were applied 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.

3.12 fertilizer application

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

Cow dung : 10 t ha^{-1}

Urea : 500 kg ha^{-1}

TSP : 400 kg ha^{-1}

MoP : 200 kg ha^{-1}

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 2013. Thus the 30 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.

3.14 Intercultural operations

3.14.1 Gap filling

Very few seedlings were found 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.

3.14.3 Spading

After each irrigation soils of each plot were pulverized by spade for easy aeration.

3.14.4 Irrigation

Irrigation was given by 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 2nd December 2013.

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. Seven 80WP was dusted to the soil before irrigation to controlled mole crickets and cut worms on 7st December 2013. Some of the plants were infected by alternaria leaf spot disease. Rovral 50 WP @ 20 g per 10 litre of water was sprayed to prevent the spread of the disease on 25th December 2013.

Plate 02: Experimental field in the farm of Sher-e-Bangla Agricultural University during the study period.

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, 2014 and was continued up to 15 March, 2014.

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.

3.15.3 Number of infested fruits per plant

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

Plate 03: Tomato plant with healthy fruits

Plate 04: Healthy 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:

$$\textbf{Percent fruit infestation by number} = \frac{\textbf{Number of infested fruits}}{\textbf{Number of total fruits}} \times \textbf{100}$$

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)

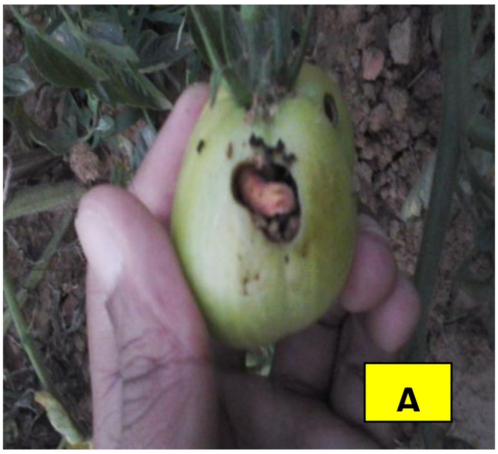


Plate 06: Infested fruit with caterpillar (A) infested fruit of longitudinal section through larval excreta (B) and a caterpillar of fruit borer(C).

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 were 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 was 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:

$$Percent\ fruit\ infestation\ by\ weight = \frac{\boldsymbol{Weight\ of\ infested\ fruits}}{\boldsymbol{Weight\ of\ total\ fruits}} \times \mathbf{100}$$

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, X_1 = The mean value of the control plant and X_2 = 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:

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

3.15. 17 Single fruit diameter (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:

$$\text{Single fruit diameter (cm)} = \frac{\text{Total diameter of fruits harvest from 10 selected Plants}}{\text{Total number of fruits harvest from 10 selected Plants}}$$

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 plant per Plot

3.15.19 Yield of fruits per hectare (ton)

It was measured by the following formula,

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

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 Duncan's Multiple Range Test (DMRT) (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. 5.00. Analyses were done according to the procedure determining by Alam (2004). The Benefit cost ratio (BCR) was calculated by the following formula:

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

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-2 (Ratan). 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

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 1) at early fruiting stage in controlling tomato fruit borer for different control measures (Appendex IV).

The highest total number of fruit/plant was 29.63 recorded in treatment T_4 which is significantly different from all other treatments (Table 1). On the other hand, the lowest total number of fruit/plant was 8.70 recorded in control treatment T_6 (Table 1). Treatment T_5 showed second highest result was 26.37 which was significantly different from all other treatments (Table 1). From these results it is revealed that Cypermethrin gave the better result against tomato fruit borer which was similar to the findings obtained by Alam (2004).

Accordingly the treatment T_4 also produced the maximum number of healthy fruits was 28.97 but the lowest number of healthy fruits was 5.44 harvested from control (T_6) treatment (Table 1). The rest of the treatments gave intermediate level of performance and produced optimum number of healthy fruit/plant.

Table 1: Effect of different treatments in controlling tomato fruit borer at early fruiting stage in terms of number of fruits/ plant

Treatment(s)	Number of fruits/plant			
	Total	Healthy	Infested	% Infestation
T_1	11.60 e	9.34 e	2.26 b	19.48 b
T_2	15.33 d	13.73 d	1.60 c	10.44 c
T_3	17.60 c	16.44 c	1.16 d	6.59 d
T_4	29.63 a	28.97 a	0.66 e	2.23 f
T_5	26.37 b	25.21 b	1.16 d	4.41 e
T_6	8.70 f	5.44 f	3.26 a	37.47 a
$LSD_{0.05}$	1.806	1.352	0.2508	1.468
CV (%)	5.45	4.45	8.43	5.25

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 = Spray with soap water @ 3 g/L of water

T_2 = Spray with neem seed kernel water extract @ 20 g/L of water

T_3 = Spray with neem oil + trix @ (4 ml neem oil + 10ml Trix)/L of water

T_4 = Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1 ml/L of water

T_5 = Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @ 1ml/L of water

T_6 = Control (Untreated)

The lowest number of infested fruit/plant was 0.66 recorded in T_4 treatment and the highest number of infested fruit/plant was 3.26 recorded in control treatment T_6 (Table 1). The treatments T_1 (2.26), T_2 (1.60), T_3 (1.16) and T_5 (1.16) showed intermediate 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 $T_6 > T_1 > T_2 > T_3 > T_5 > T_4$ (Table 1).

4.1.2 Mid 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 2) at mid fruiting stage in controlling tomato fruit borer for different control measures (Appendex V).

Among different treatments in this study, the highest total number of fruit /plant was 57.60 recorded in treatment T_4 which was not significantly different from T_5 was 55.83 but significantly different from all other treatments (Table 2). On the other hand, the lowest total number was 22.47 of fruit/plant was recorded in control treatment T_6 (Table 2).

Accordingly the treatment T_4 also produced the maximum number of healthy fruits 56.47 which was not significantly different from T_5 was 54.13 but significantly different from all other treatments (Table 2). On the other hand, the lowest number of healthy fruits was 17.91 harvested from control (T_6) treatment (Table 2). The rest of the treatment gave intermediate level of activity and produced optimum number of healthy fruit/plant.

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			
	Total	Healthy	Infested	% Infestation
T_1	35.30 d	31.57 d	3.73 b	10.57 b
T_2	40.80 c	37.64 c	3.16 c	7.74 c
T_3	46.50 b	43.94 b	2.56 d	5.50 d
T_4	57.60 a	56.47 a	1.13 f	1.96 f
T_5	55.83 a	54.13 a	1.70 e	3.05 e
T_6	22.47 e	17.91 e	4.56 a	20.29 a
$LSD_{0.05}$	4.955	2.372	0.2228	1.080
CV (%)	6.32	5.81	5.81	10.56

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 = Spray with soap water @ 3 g/L of water

T_2 = Spray with neem seed kernel water extract @ 20 g/L of water

T_3 = Spray with neem oil + trix @ (4 ml neem oil + 10ml Trix)/L of water

T_4 = Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1 ml/L of water

T_5 = Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @ 1ml/L of water

T_6 = Control (Untreated)

The lowest number of infested fruit/plant was 1.13 recorded in T_4 treatment and the highest number of infested fruit/plant was 4.56 recorded in control treatment T_6 (Table 2). The treatments T_1 (3.73), T_2 (3.16) and T_3 (2.56) showed intermediate level of infestation which was different from all other treatments

(Table 2). In this case, the trend of the number of infested fruit/plant was $T_6 > T_1 > T_2 > T_3 > T_5 > T_4$ (Table 2).

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 (Appendex VI).

Among different treatments in the study, the highest total number of fruit /plant was 46.67 recorded in treatment T_4 which significantly different from all other treatments (Table 3). On the other hand, the lowest total number of fruit/plant was 11.90 recorded in control treatment T_6 (Table 3).

Accordingly the treatment T_4 also produce the maximum number of healthy fruits was 45.11 which significantly different from all other treatments (Table 3). On the other hand, the lowest number of healthy fruits was 7.40 harvested from control (T_6) treatment (Table 3). The rest of the treatment gave intermediate level of activity and produced optimum number of healthy fruit/plant.

The lowest number of infested fruit/plant was 1.56 recorded in T_4 treatment and the highest number of infested fruit/plant was 4.50 recorded in control treatment T_6 (Table 3). The treatments T_1 (3.33), T_2 (2.86), (2.30) and T_5 (1.87) showed intermediate level of infestation which was different from all other treatments (Table 3). In this case, the trend of the number of infested fruit/plant was $T_6 > T_1 > T_2 > T_3 > T_5 > T_4$ (Table 2).

Table 3: Effect of different treatments in controlling tomato fruit borer at late fruiting stage in terms of number of fruits/ plant

Treatment(s)	Number of fruits/plant			
	Total	Healthy	Infested	% Infestation
T_1	25.77 d	22.44 d	3.33 b	12.92 b
T_2	31.47 c	28.61 c	2.86 c	9.09 c
T_3	38.83 b	36.53 b	2.30 d	5.92 d
T_4	46.67 a	45.11 a	1.56 f	3.34 f
T_5	40.00 b	38.13 b	1.87 e	4.69 e
T_6	11.90 e	7.40 e	4.50 a	37.82 a
$LSD_{0.05}$	5.071	3.709	0.2877	1.158
CV (%)	8.59	6.31	5.75	8.87

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 = Spray with soap water @ 3 g/L of water

T_2 = Spray with neem seed kernel water extract @ 20 g/L of water

T_3 = Spray with neem oil + trix @ (4 ml neem oil + 10ml Trix)/L of water
T_4 = Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1 ml/L of water

T_5 = Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @ 1ml/L of water

T_6 = Control (Untreated)

4.2 Effect of management practices on percent reduction of tomato fruit borer over control at different fruiting stages

At early fruiting stage, the lowest infestation percentage was 2.23 recorded from T_4 treatment which was significantly different from all other treatments (Table 4). On the other hand, the highest infestation percentage was 37.47 recorded from control (T_6) treatment (Table 4). In this case, the trend of percent infestation was $T_6 > T_1 > T_2 > T_3 > T_5 > T_4$ (Table 4 and Appendix IV).

Accordingly at mid fruiting stage, the lowest infestation percentage was 1.96 recorded from T_4 treatment which significantly different from all other treatments (Table 4). On the other hand, the highest infestation percentage was 20.29 recorded from control (T_6) treatment (Table 4). In this case, the trend of percent infestation was $T_6 > T_1 > T_2 > T_3 > T_5 > T_4$ (Table 4 and Appendix V).

Accordingly at late fruiting stage, the lowest infestation percentage was 3.34 recorded from T_4 treatment which significantly different from all other treatments (Table 4). On the other hand, the highest infestation percentage was 37.82 recorded from control (T_6) treatment (Table 4). In this case, the trend of percent infestation was $T_6 > T_1 > T_2 > T_3 > T_5 > T_4$ (Table 4 and Appendix VI).

It was observed that the highest % reduction over control was 92.12 in the treatment T_4 which was significantly from all other treatments (Table 4). On the other hand, the lowest % reduction over control was recorded in the treatment T_1 was 55.02 (Table 4). Intermediate level of % reduction over control was observed in the treatment T_2, T_3, T_5 and range from 71.47 to 87.28 (Table 4).

Table 4: Effect of different treatments on the 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	19.48 b	10.57 b	12.92 b	14.33	55.02
T_2	10.44 c	7.74 c	9.09 c	9.09	71.47
T_3	6.59 d	5.50 d	5.92 d	6.00	81.17
T_4	2.23 f	1.96 f	3.34 f	2.51	92.12
T_5	4.41 e	3.05 e	4.69 e	4.05	87.28
T_6	37.47 a	20.29 a	37.82 a	31.86	0.00
$LSD_{0.05}$	1.468	1.080	1.158	--	--
CV (%)	5.25	10.56	8.87	--	--

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 = Spray with soap water @ 3 g/L of water

T_2 = Spray with neem seed kernel water extract @ 20 g/L of water

T_3 = Spray with neem oil + trix @ (4 ml neem oil + 10ml Trix)/L of water

T_4 = Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1 ml/L of water

T_5 = Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @ 1ml/L of water

T_6 = Control (Untreated)

4.3 Effect of management practices in controlling tomato fruit borer in terms of weight of fruits at different fruiting stages

4.3.1 Early stage of fruiting

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 5) at early fruiting stage in controlling tomato fruit borer for different control measures (Appendex VII).

Among different treatments in the study, the highest total weight of fruit/ plant was 1059.49 g recorded in treatment T_4 which significantly different from all other treatments (Table 5). On the other hand, the lowest total weight of fruit/plant was 764.51 g recorded in control treatment T_6 (Table 5). Treatment T_5 showed second highest result was 1007.73 g which was significantly different from all other treatments (Table 5). In this case, the trend of total weight of fruit/plant was $T_4 > T_5 > T_3 > T_2 > T_1 > T_6$ (Table 5).

Accordingly the treatments T_4 also produce the maximum weight of healthy fruits/plant was 1047.05 g and the lowest weight of healthy fruits was 673.31 g harvested from control (T_6) treatment (Table 5). The rest of the treatment gave intermediate level of activity and produced optimum weight of healthy fruit/plant.

The lowest weight of infested fruit/plant was 12.44 g recorded in T_4 treatment and the highest weight of infested fruit/plant was 91.20 g recorded in control treatment T_6 (Table 5). The treatments T_1 (75.57 g), T_2 (64.74 g), T_3 (50.36 g) and T_5 (39.70 g) showed intermediate level of infestation which was different from all other treatments (Table 5). In this case, the trend of the weight of infested fruit/plant was $T_6 > T_1 > T_2 > T_3 > T_5 > T_4$ (Table 5).

Table 5: Effect of different treatments in controlling tomato fruit borer at early fruit harvesting stage in terms of fruit weight/ plant (g)

Treatment(s)	Total weight of fruits/plant (g)	Weight of Healthy fruits/plant(g)	Weight of Infested fruits/plant (g)	% Infestation
T_1	804.01 e	728.44 e	75.57 b	9.41 b
T_2	849.70 d	784.96 d	64.74 c	7.64 c
T_3	925.40 c	875.04 c	50.36 d	5.41 d
T_4	1059.49 a	1047.05 a	12.44 f	1.18 f
T_5	1007.73 b	968.03 b	39.70 e	3.94 e
T_6	764.51 f	673.31 f	91.20 a	11.88 a
$LSD_{0.05}$	13.71	10.53	4.836	0.765
CV (%)	7.21	3.53	8.63	7.41

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 = Spray with soap water @ 3 g/L of water

T_2 = Spray with neem seed kernel water extract @ 20 g/L of water

T_3 = Spray with neem oil + trix @ (4 ml neem oil + 10ml Trix)/L of water

T_4 = Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1 ml/L of water

T_5 = Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @ 1ml/L of water

T_6 = Control (Untreated)

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 (Appendex VIII).

Among different treatments in the study, the highest total weight of fruit /plant was 1126.74 g recorded in treatment T_4 which significantly different from all other treatments (Table 6). On the other hand, the lowest total weight of fruit/plant was 790.67 g recorded in control treatment T_6 (Table 6). Treatment T_5 showed second highest result was 1058.10 g which was significantly different from all other treatments (Table 6). In this case, the trend of total weight of fruit/plant was $T_4 > T_5 > T_3 > T_2 > T_1 > T_6$ (Table 6).

Accordingly the treatment T_4 also produces the maximum weight of healthy fruits/plant was 1093.24 g and the lowest weights of healthy fruits was 689.97 g harvested from control (T_6) treatment (Table 6). The rest of the treatment gave intermediate level of activity and produced optimum weight of healthy fruit/plant.

The lowest weight of infested fruit/plant was 33.50 g recorded in T_4 treatment which was not significantly different from T5 was 37.86 g but significantly different from all other treatments (Table 6). On the other hand, the highest weight of infested fruit/plant was 100.70 g recorded in control treatment T_6 (Table 6). The treatments T_1 (93.14 g), T_2 (75.52 g) and T_3 (51.29 g) showed intermediate level of infestation which was different from all other treatments (Table 6). In this case, the trend of the weight of infested fruit/plant was $T_6 > T_1 > T_2 > T_3 > T_5 > T_4$ (Table 6).

Table 6: Effect of different treatments in controlling tomato fruit borer at mid fruit harvesting stage in terms of fruit weight/ plant (g)

Treatment(s)	Total weight of fruits/plant (g)	Weight of Healthy fruits/plant(g)	Weight of Infested fruits/plant (g)	% Infestation
T_1	846.19 e	753.05 e	93.14 b	11.08 a
T_2	933.57 d	858.05 d	75.52 c	8.03 b
T_3	988.36 c	937.07 c	51.29 d	5.22 c
T_4	1126.74 a	1093.24 a	33.50 e	2.93 d
T_5	1058.10 b	1020.24 b	37.86 e	3.61 cd
T_6	790.67 f	689.97 f	100.70 a	12.79 a
$LSD_{0.05}$	47.58	39.582	6.411	1.899
CV (%)	10.44	12.84	6.69	8.82

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 = Spray with soap water @ 3 g/L of water

T_2 = Spray with neem seed kernel water extract @ 20 g/L of water

T_3 = Spray with neem oil + trix @ (4 ml neem oil + 10ml Trix)/L of water

T_4 = Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1 ml/L of water

T_5 = Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @ 1ml/L of water

T_6 = Control (Untreated)

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 (Appendex IX).

Among different treatments in the study, the highest total weight of fruit /plant was 1193.38 g recorded in treatment T_4 which was significantly different from all other treatments (Table 7). On the other hand, the lowest total weight of fruit/plant was 815.65 g recorded in control treatment T_6 (Table 7). Treatment T_5 showed second highest result was 1108.47 g which was significantly different from all other treatments (Table 7). In this case, the trend of total weight of fruit/plant was $T_4 > T_5 > T_3 > T_2 > T_1 > T_6$ (Table 7).

Accordingly the treatment T_4 also produce the maximum weight of healthy fruits/plant was 1150.31 g and the lowest weight of healthy fruits was 704.95 g harvested from control (T_6) treatment (Table 7). The rest of the treatment gave intermediate level of performance and produced optimum weight of healthy fruit/plant.

The lowest weight of infested fruit/plant was 43.07 g recorded in T_4 treatment and the highest weight of infested fruit/plant was 110.70 g recorded in control treatment T_6 (Table 7). The treatments T_1 (107.20 g), T_2 (100.80 g), T_3 (77.83 g) and T_5 (57.24 g) showed intermediate level of infestation which was different from all other treatments (Table 7). In this case, the trend of the weight of infested fruit/plant was $T_6 > T_1 > T_2 > T_3 > T_5 > T_4$ (Table 7).

Table 7: Effect of different treatments in controlling tomato fruit borer at late fruit harvesting stage in terms of fruit weight/ plant (g)

Treatment(s)	Total	Healthy	Infested	% Infestation
T_1	888.39 d	781.19 d	107.2 a	12.15 a
T_2	1022.28 c	921.48 c	100.8 ab	9.78 b
T_3	1050.35 c	972.52 c	77.83 c	7.44 c
T_4	1193.38 a	1150.31 a	43.07 e	3.58 d
T_5	1108.47 b	1051.23 b	57.24 d	5.20 d
T_6	815.65 e	704.95 e	110.7 a	13.54 a
$LSD_{0.05}$	42.80	35.37	10.07	1.822
CV (%)	7.95	11.30	9.11	11.27

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 = Spray with soap water @ 3 g/L of water

T_2 = Spray with neem seed kernel water extract @ 20 g/L of water

T_3 = Spray with neem oil + trix @ (4 ml neem oil + 10ml Trix)/L of water

T_4 = Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1 ml/L of water

T_5 = Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @ 1ml/L of water

T_6 = Control (Untreated)

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 1.18 recorded from T_4 treatment which was significantly different from all other treatments (Table 8). On the other hand, the highest percent infestation was 11.88 recorded from control (T_6) treatment (Table 8). In this case, the trend of percent infestation was $T_6 > T_1 > T_2 > T_3 > T_5 > T_4$ (Table 8 and Appendix VII).

Accordingly at mid fruiting stage, the lowest percent infestation was 2.93 recorded from T_4 treatment which was significantly different from all other treatments (Table 8). On the other hand, the highest percentage of infestation was 12.79 recorded from control (T_6) treatment which was not significantly different from T_1 was 11.08 but significantly different from all other treatments (Table 8). In this case, the trend of percentage of infestation was $T_6 > T_1 > T_2 > T_3 > T_5 > T_4$ (Table 8 and Appendix VIII).

Accordingly at late fruiting stage, the lowest percentage of infestation was 3.58 recorded from T_4 treatment which was not significantly different from T_5 was 5.20 but significantly different from all other treatments (Table 8). On the other hand, the highest percentage of infestation was 13.54 recorded from control (T_6) treatment which was not significantly different from T_1 was 12.15 but significantly different from all other treatments (Table 8). In this case, the trend of infestation percentage was $T_6 > T_1 > T_2 > T_3 > T_5 > T_4$ (Table 8 and Appendix IX).

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

Treatment(s)	% Fruit Infestation				
	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean	% Reduction over control
T_1	9.41 b	11.08 a	12.15 a	10.88	14.60
T_2	7.64 c	8.03 b	9.78 b	8.48	33.44
T_3	5.41 d	5.22 c	7.44 c	6.02	52.75
T_4	1.18 f	2.93 d	3.58 d	2.56	79.91
T_5	3.94 e	3.61 cd	5.20 d	4.25	66.64
T_6	11.88 a	12.79 a	13.54 a	12.74	0.00
$LSD_{0.05}$	0.765	1.899	1.822	--	--
CV (%)	7.41	8.82	11.27	--	--

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 = Spray with soap water @ 3 g/L of water

T_2 = Spray with neem seed kernel water extract @ 20 g/L of water

T_3 = Spray with neem oil + trix @ (4 ml neem oil + 10ml Trix)/L of water

T_4 = Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1 ml/L of water

T_5 = Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @ 1ml/L of water

T_6 = Control (Untreated)

It was observed that the highest percentage of reduction over control was 79.91 in the treatment T_4 which was significantly different from all other treatments (Table 8). On the other hand, the lowest percentage of reduction over control was 14.60 recorded in the treatment T_1 (Table 8). Intermediate level of percentage of reduction over control was observed in the treatment T_2, T_3, T_5 and range from 33.44 to 66.64 (Table 8).

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 weight of single fruit was 163.7 g recorded in treatment T_4. On the other hand, the lowest weight of single fruit was 68.86 g recorded in control treatment (T_6) which was statistically similar with treatment T_1 (81.73 g) (Table 9). The result obtained from the treatment T_5 (140.9 g) was showed second result compared to other treatments (Table 9). From these results it is revealed that the trend of the weight of single fruit was observed due to the application of the different management practices against tomato fruit borer was $T_4 > T_5 > T_3 > T_2 > T_1 > T_6$ (Table 9).

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 diameter of single fruit was 13.14 mm recorded in treatment T_4. On the other hand, the lowest diameter of single fruit was 5.62 mm recorded in control treatment (T_6) (Table 9). The result obtained from the treatment T_5 was 11.53 mm ranked second result compared to other treatments (Table 9). From these results it is revealed that the trend of decreasing diameter of single fruit was observed due to application of the different management practices against tomato fruit borer was $T_4 > T_5 > T_3 > T_2 > T_1 > T_6$ (Table 9).

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	Single fruit weight (g)	Single fruit diameter (mm)	Yield per plot (Kg)/6m^2
T_1	81.73 de	7.017 e	28.23 e
T_2	96.00 cd	8.63 d	31.80 d
T_3	110.60 c	10.26 c	36.93 c
T_4	163.70 a	13.14 a	48.19 a
T_5	140.90 b	11.53 b	42.37 b
T_6	68.86 e	5.62 f	18.65 f
$LSD_{0.05}$	15.71	0.8838	2.377
CV (%)	7.83	5.18	3.80%

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 = Spray with soap water @ 3 g/L of water

T_2 = Spray with neem seed kernel water extract @ 20 g/L of water

T_3 = Spray with neem oil + trix @ (4 ml neem oil + 10ml Trix)/L of water

T_4 = Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1 ml/L of water

T_5 = Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @ 1ml/L of water

T_6 = Control (Untreated)

4.7 Yield (Kg/plot)

Significant variation was observed in case of yield per plot under the present study (Table 9 and Appendix X). The highest yield per plot was 48.19 kg recorded in treatment T_4 and the lowest yield per plot was 18.65 kg recorded in control treatment (T_6) (Table 9). The result obtained from the treatment T_5 was 42.37 kg showed second and other treatment result was T_1 (28.23 kg), T_2 (31.80 kg) and T_3 (36.93 kg) (Table 9). From these results it is revealed that the trend of the weight and diameter of single fruit was observed due to application of the different management practices against tomato fruit borer was $T_4 > T_5 > T_3 > T_2 > T_1 > T_6$ (Table 9).

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 per hectare was 16.41ton recorded in treatment T_4 which was significantly different from all other treatments (Table 10). On the other hand, the lowest yield per hectare was 9.47 ton recorded in control treatment T_6 which was statistically similar with T_1 (11.46 ton) (Table 10). The result obtained from the treatment T_5 was 15.45 ton showed second and other treatment result was T_2 (12.40 ton) and T_3 (14.22 ton) (Table 10). From these results it is revealed that the trend of the total yield per hectare was observed due to application of the different management practices against tomato fruit borer was $T_4 > T_5 > T_3 > T_2 > T_1 > T_6$ (Table 10).

Accordingly, the highest healthy yield per hectare was 16.22 ton recorded from T_4 treatment which significantly different from all other treatments (Table 10). On the other hand, the lowest healthy yield per hectare was 7.79 ton recorded from control treatment (T_6) which was statistically different from T_1 (10.14 ton) but significantly different from all other treatments (Table 10). The result obtained from the treatment T_5 was 15.22 ton showed second and other treatment result was T_2 (10.86 ton) and T_3 (12.97 ton) (Table 10). From these results it is revealed that the trend of the healthy yield per hectare was observed due to application of the different management practices against tomato fruit borer was $T_4 > T_5 > T_3 > T_2 > T_1 > T_6$ (Table 10).

The lowest infested yield per hectare was 0.19 ton recorded in T_4 treatment which was not significantly different from T_5 was 0.23 ton but significantly different from all other treatments (Table 10). On the other hand, the highest infested yield per hectare was 1.68 ton recorded in control treatment T_6 which was not significantly different from T_2 was 1.54 ton but significantly different from all other treatments (Table 10). The treatment T_1 (1.32 ton) and T_3 (1.25 ton) showed intermediate level of infestation which was different from all other treatments (Table 10). From these results it is revealed that the trend of the infestation yield per hectare was observed due to application of the different management practices against tomato fruit borer was $T_4 > T_5 > T_3 > T_2 > T_1 > T_6$ (Table 10).

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

Treatment	Total	Healthy	Infested
T_1	11.46 e	10.14 f	1.32 c
T_2	12.40 d	10.86 e	1.54 b
T_3	14.22 c	12.97 c	1.25 d
T_4	16.41 a	16.22 a	0.19 f
T_5	15.45 b	15.22 b	0.23 e
T_6	9.47 f	7.79 e	1.68 a
$LSD_{0.05}$	0.305	0.444	0.127
CV (%)	7.14	8.51	7.67

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 = Spray with soap water @ 3 g/L of water

T_2 = Spray with neem seed kernel water extract @ 20 g/L of water

T_3 = Spray with neem oil + trix @ (4 ml neem oil + 10ml Trix)/L of water

T_4 = Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1 ml/L of water

T_5 = Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @ 1ml/L of water

T_6 = Control (Untreated)

4.9 Economic analysis

4.9.1 Cost of pest management

It was observed that the highest cost of pest management was 33,000.00 Tk./ ha recorded in treatment T_5 and the lowest cost of pest management was 00.00 Tk./ ha recorded in control treatment T_6 (Table 11). The pest management cost obtained from the treatment T_1 was 12,000.00 Tk./ ha, T_2 was 10,000.00 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 highest total cost of production was 1,13,000.00 Tk./ ha recorded in treatment T_5 and the lowest total cost of production was 80,000.00 Tk./ ha recorded in control treatment T_6 (Table 11). 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_4 and the lowest gross return was 93,480.00 Tk./ ha recorded in control treatment T_6 (Table 11). The gross return obtained from the treatment T_1 was 1,21,680.00 Tk./ ha, T_2 was 1,30,320.00 Tk./ ha, T_3 was 1,55,640.00 Tk./ ha and T_5 was 1,82,640.00 Tk./ ha.

4.9.4 Net return

The highest net return was 85,640.00 Tk./ ha recorded in treatment T_4 (Table 11). On the other hand, the lowest net return was 13,480.00 Tk./ ha recorded in control treatment T_6 (Table 11). The net return obtained from the treatment T_1 was 29,680.00Tk./ha, T_2 was 40,320.00 Tk./ha, T_3 was 53,640.00 Tk./ ha and T_5 was 67,640.00 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_4 (Table 11). On the other hand, the lowest benefit cost ratio was 1.17 recorded from the treatment T_6 (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 $T_4 > T_5 > T_3 > T_2 > T_1 > T_6$ (Table 11).

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

Treatment	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	10.14	12,000.00	92,000.00	1,21,680.00	29,680.00	1.32
T_2	10.86	10,000.00	90,000.00	1,30,320.00	40,320.00	1.45
T_3	12.97	22000.00	102000.00	155640.00	53640.00	1.53
T_4	16.22	29,000.00	1,09,000.00	1,94,640.00	85,640.00	1.79
T_5	15.22	33,000.00	1,13,000.00	1,80,640.00	65,640.00	1.59
T_6	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 = Spray with soap water @ 3 g/L of water

T_2 = Spray with neem seed kernel water extract @ 20 g/L of water

T_3 = Spray with neem oil + trix @ (4 ml neem oil + 10ml Trix)/L of water

T_4 = Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1 ml/L of water

T_5 = Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @ 1ml/L of water

T_6 = Control (Untreated)

CHAPTER V

SUMMARY

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 six treatments T_1= Spray with soap water @ 3g/L of water, T_2=Spray with neem seed karnel water extract @ 20 g/L of water , T_3= Spray with neem oil + trix (4ml neem oil + 10ml trix)/L of water, T_4= Spray with Ripcord 10 EC (Cypermethrin 10 EC) @ 1ml/L of water, T_5= Spray with Sumicidin 20 EC (Fenvalerate 20 EC) @1ml/L of water and T_6= Untreated Control treatment. All the sprayings were done at 7 days 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 highest total number of fruits/plant at early, mid and late stage were 29.63, 57.60 and 46.67 respectively were with treatment of Ripcoed 10 EC (Cypermethrin 10 EC) and the lowest total number of fruits/plant at early, mid and late stage were 8.70, 22.47 and 11.90 respectively were with treatment of control. The lowest infested number of fruits/plant at early, mid and late stage were 0.66, 1.13, 1.56 respectively were with treatment of Ripcoed 10 EC (Cypermethrin 10 EC) and the highest infested number of fruits/plant at early, mid and late stage were 3.26, 4.56 and 4.50 respectively were with treatment of control. Similarly the lowest infested percentage were 2.23%, 1.96% and 3.34% at early, mid and late stage was with treatment of Ripcoed 10 EC (Cypermethrin 10 EC). The percentage of reduction over control 92.12% was the highest with the same treatment.

The data obtained from the selected plants was observed that the highest weight of fruit/plant at early, mid and late stage were 1059.49 g, 1126.74 g and 1193.38 g respectively and similarly the lowest percent infestation was 1.18%, 2.93% and 3.58% respectively was with the treatment of Ripcoed 10 EC (Cypermethrin 10 EC). The percent reduction over control 79.91% was the highest with the same treatment.

The highest weight of single fruit, diameter of single fruit and yield per plot was 163.7 g, 13.14 mm and 48.19 kg respectively were recorded in treatment of Ripcoed 10 EC (Cypermethrin 10 EC). The lowest weight of single fruit, diameter of single fruit and yield per plot were 68.86 g, 5.62 mm and 18.65 kg respectively was recorded in control treatment.

From recording of data it was observed that the highest total yields was 16.41 t/ha was with treatment of Ripcoed 10 EC (Cypermethrin 10 EC) and the lowest infested yield was 0.19 ton/ha was with same treatment. The lowest total yield was 9.47 t/ha respectively was with treatment of untreated control and the highest infested yield was 1.68 t/ha respectively was with same treatment. Among the botanicals neem oil performs well in all parameters including number of fruit per plant, weight of fruit per plant and also in yield per plant.

Economic analysis also represented that the treatment of Ripcoed 10 EC (Cypermethrin 10 EC) had the best performance on gross return, net return and benefit cost ratio. It was observed that the highest gross return 194640.00 Tk./ ha, net return 85640.00 Tk./ ha and benefit cost ratio was 1.79 obtained with the same treatment.

CHAPTER VI

CONCLUSION AND RECOMENDATIONS

Conclusion

Tomato growers of Bangladesh are used insecticides more frequently. Improper application along with impurity of marketed insecticides is suspected for control failure and repeated use of insecticides. The botanical pesticide required more time to control insect than the chemical pesticides. Though it is time consuming we should practice it to use for our future generation to maintain a healthy environment and also reduce the risk of occurrence of diseases like cancer. So we should encourage to the farmers to use of botanicals and also create awareness about the proper use of chemical pesticides.

Recommendations

Considering the above experimental results of the present 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 and botanical treatments against tomato fruit borer may be needed to include for future study as sole or different combination to avoid total rely on insecticides.
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 VII

REFERENCES

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.

Alam, S. N. (1999). Training manual on insect disease management of vegetable disease crops. Horticulture Res. Center, BARI, Gazipur, pp. 4-5.\

Ali, M. R., Yesmin, M., Alam, M. M., Akter, T. and Hoque, M. A. (2009). Eco-friendly 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.

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). Biopesticide 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). (2013). 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). (2012). 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. Interacademicia.* **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, B. (1979). Vegetables (Sixth Rev. En.). The Directorate of National Book Trust, New Delhi, India. p.45.

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. (1997). FAO production Year Book 1996. 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, Secod 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 insecticids 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 biopesticides. *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 massculturing 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 Manamegent.* **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. (1997). 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 endosulfan. *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). *Information 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**(ii): 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). Medicial 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.

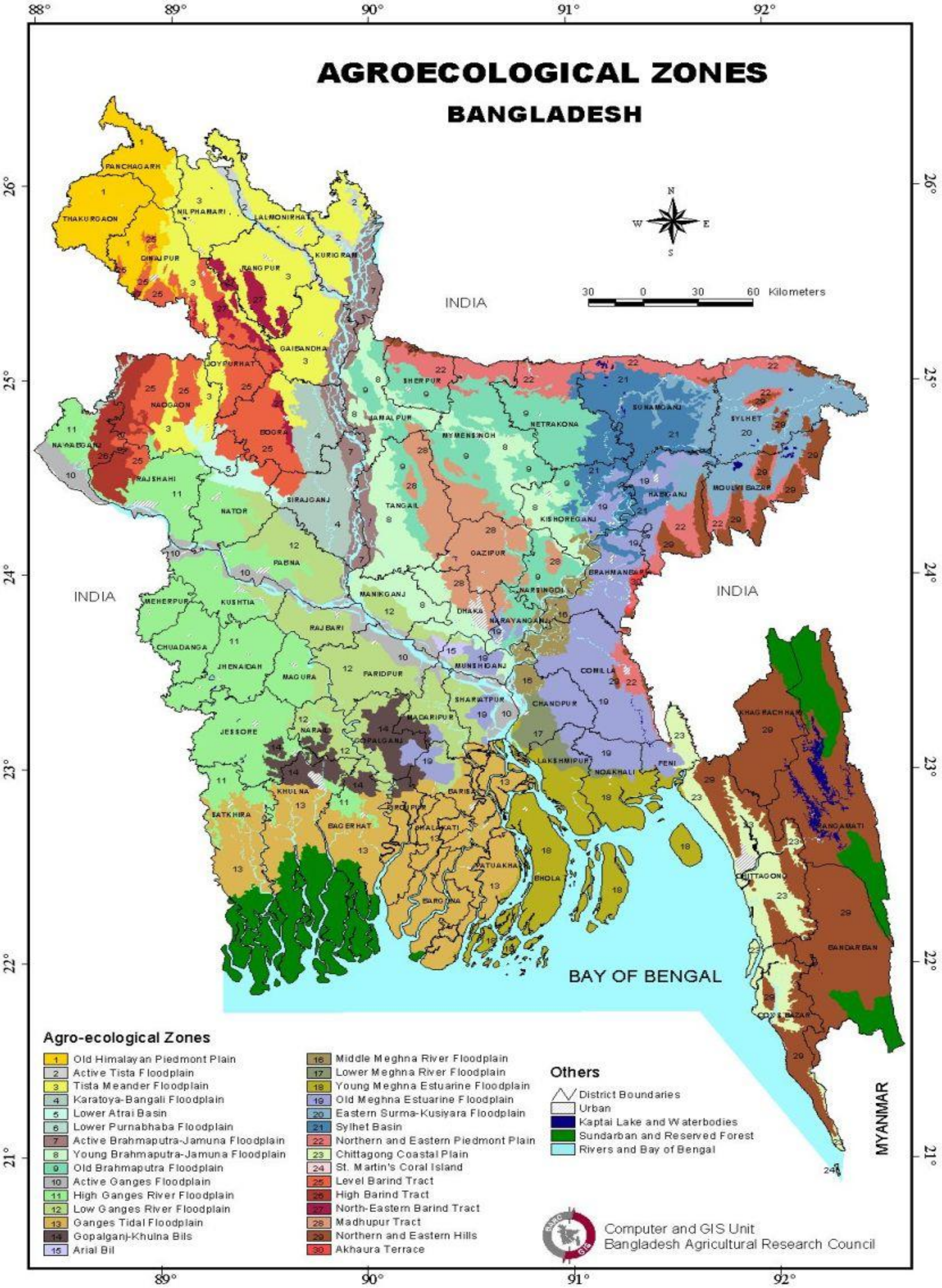
Thomson, H. C. and Kelly, W. C. (1983). Vegetable Crops. 5th Edn. Tata McGraw Hill Publishing Co. Ltd. New Delhi. p. 611.

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 sxtract 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. Agro-Ecological Zones of Bangladesh



Appendix II: Monthly record of air temperature, rainfall, relative humidity, soil temperature and Sunshine of the experimental site during the period from October 2013 to March 2014

Month	Average air temperature (°C)			Average relative humidity (%)	Total rainfall (mm)	Total Sunshine per day (hrs)
	Maximum	Minimum	Mean			
October, 2013	34.8	18.0	26.4	77	227	5.8
November, 2013	29.7	20.1	24.9	65	5	6.4
December, 2013	26.9	15.8	21.35	68	0	7.0
January, 2014	24.6	12.5	18.7	66	0	5.5
February, 2014	33.7	23.8	28.81	69	185	7.8
March, 2014	36.7	20.3	28.5	70	205	7.7

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

Appendix III: Characteristics of Horticulture Farm soil is analyzed by Soil Resources Development Institute (SRDI), Khamarbari, Farmgate, Dhaka

A. Morphological characteristics of the experimental field

Morphological features	Characteristics
Location	Central Ferm, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	High land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Cropping Pattern	Fallow- Tomato

B. Physical and chemical properties of the initial soil

Characteristics	Value
%Sand	27
%Silt	43
%clay	30
Textural class	Silty-clay
pH	6.1
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.077
Available P (ppm)	20.00
Exchangeable K (mel 1 00 g soil)	0.10
Available S (ppm)	45

Source : SRDI, 2013

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

Source of variance	Degrees of freedom	Total fruit	Healthy fruit	Infested fruit	% infestation
Replication	2	0.030	0.026	0.003	0.184
Treatment	5	2.43*	4.38**	0.33**	43.92*
Error	10	4.144	2.844	0.102	6.651

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

Source of variance	Degrees of freedom	Total fruit	Healthy fruit	Infested fruit	% infestation
Replication	2	0.711	0.193	0.020	1.279
Treatment	5	2.93**	4.39**	1.80**	48.28**
Error	10	0.861	2.745	0.007	0.754

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

Source of variance	Degrees of freedom	Total fruit	Healthy fruit	Infested fruit	% infestation
Replication	2	0.389	0.638	0.001	2.509
Treatment	5	3.44**	2.93**	0.35**	46.06*
Error	10	1.189	0.676	0.006	2.299

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

Source of variance	Degrees of freedom	Total fruit	Healthy fruit	Infested fruit	% infestation
Replication	2	24.042	38.937	42.667	0.141
Treatment	5	4065.09*	3865.82**	233.64*	44.92**
Error	10	56.832	48.389	7.067	0.177

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

Source of variance	Degrees of freedom	Total fruit	Healthy fruit	Infested fruit	% infestation
Replication	2	126.50	119.38	0.21	0.017
Treatment	5	4827.86*	4294.37*	245.22*	47.74**
Error	10	68.90	48.39	12.418	1.090

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

Source of variance	Degrees of freedom	Total fruit	Healthy fruit	Infested fruit	% infestation
Replication	2	581.657	497.392	0.167	0.06
Treatment	5	5783.51*	5439.49**	237.75*	46.18**
Error	10	553.522	502.487	7.767	1.003

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}

Source of variance	Degrees of freedom	Single fruit weight	Single fruit diameter	Yield (Kg/plot)
Replication	2	0.667	1.299	2.667
Treatment	5	39.928**	16.947**	60.35**
Error	10	10.467	5.498	11.867

Appendix XI: Effect of different treatments in controlling tomato fruit borer during total cropping season in terms of yield (t ha^{-1})

Source of variance	Degrees of freedom	Total fruit	Healthy fruit	Infested fruit
Replication	2	10.245	13.167	0.211
Treatment	5	268.12*	378.54*	9.73**
Error	10	5.60	5.97	0.38