DEVELOPMENT OF AN IPM APPROACH IN CONTROLLING INSECT PESTS OF TOMATO

SATHI SEN

DEPARTMENT OF ENTOMOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

DHAKA-1207

DECEMBER, 2016

DEVELOPMENT OF AN IPM APPROACH IN CONTROLLING INSECT PESTS OF TOMATO

BY

SATHI SEN

REGISTRATION NO. : 11-04557

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: JULY-DECEMBER, 2016

Approved By:

Prof. Dr. Md. Mizanur Rahman **Supervisor**	**Prof. Dr. Mohammed Sakhawat Hossain** **Co-Supervisor**

Dr. Mst. Nur Mohal Akhtar Banu
Chairman
Examination Committee

Dr. Md. Mizanur Rahman
Professor
Department of Entomology
Sher-e-Bangla Agricultural University
Dhaka, Bangladesh

CERTIFICATE

This is to certify that thesis entitled, "**DEVELOPMENT OF AN IPM APPROACH IN CONTROLLING INSECT PESTS OF 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** in **ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **Sathi Sen**, **Registration No. 11-04557** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: December, 2016
Dhaka, Bangladesh

Professor Dr. Md. Mizanur Rahman
Supervisor

Dedicated

To My

Beloved Parents

ACKNOWLEDGEMENT

The author first wants to express her enormous sense of thankfulness to the Almighty Creator for His never ending blessing, support, protection, regulation, perception and assent to successfully complete the Master of Science (MS) in Entomology.

The author like to express her deepest sense of gratitude and sincere appreciation to his honorable supervisor Dr. Md. Mizanur Rahman, Professor, Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, for his continued guidance, support, encouragement, constructive criticism and invaluable suggestions throughout the study period and gratuitous labor in conducting and successfully completing the research work and in the preparation of the manuscript.

The author also expresses her gratefulness and best regards to respected Co-Supervisor, Dr. Mohammed Sakhawat Hossain, Professor, Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, helpful comments and constant inspiration throughout the research work and preparation of the thesis.

The author also expresses heartfelt thanks to the honourable chairman and all the teachers of the Department of Entomology, SAU, for their valuable suggestions, instructions, cordial help and encouragement during the period of the study.

The author expresses her sincere appreciation to her brother, sisters, relatives, well wishers and friends for their inspiration, help and encouragement throughout his study period.

Dated: December, 2016 The Author

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

DEVELOPMENT OF AN IPM APPROACH IN CONTROLLING INSECT PESTS OF TOMATO

ABSTRACT

The study was conducted at the Central Farm of Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh during October, 2016 to April, 2017 to develop an IPM approach in controlling insect pests of tomato. The study was consists of nine treatments. These were: T_1 = Vertical Support, T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval, T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval, T_4 = Horizontal Support, T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval, T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval, T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval, T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval, T_9 = Untreated Control. The study was laid out in Randomized Complete Block Design (RCBD) with three replications. The lowest number of whitefly at vegetative (2.67), early flowering (3.20), late flowering (4.67), early fruiting (3.07), late fruiting (2.80) and ripening (2.73) stage was recorded from T_6 treatments while the highest number of whitefly at vegetative (22.40), early flowering (24.07), late flowering (27.27), early fruiting (23.60), late fruiting (22.73) and ripening (22.07) stage was recorded from untreated control. The lowest percent of infested fruit by fruit borer by weight (5.17%) was recorded from the treatment T_6 plots and the highest percent of infested fruits by yield (20.57%) was recorded from untreated control plots. The highest weight of fruit per hectare (32.26 t) was recorded from the treatment T_6 plots and the lowest yield (16.94 t) weight of fruit per hectare was recorded from untreated control (T_9). Considering the controlling of tomato fruit borer highest benefit cost ratio (2.79) was recorded in the T_6 treated plots (Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval) on the other hand the lowest cost benefit ratio (0.74) was recorded in T_4 treated plots. Among the different treatments 5 times application Marshal 20EC @ 3ml/L of water + Horizontal support was most effective than other treatments for production of tomato.

CHAPTER I
INTRODUCTION

Tomato (*Lycopersicon esculentum* Lin.) a member of the Solanaceae family, is one of the most widely grown vegetables. Tomato out ranks all others in terms of total contribution of vitamins and minerals to the diet, mainly because of the large volume consumed both in fresh and processed forms (Opena 1987). It is one of the most important popular salad vegetables and is used to make soups, conserves, pickles, ketchup's, sauces, juices etc. It is also excellent source of vitamin C and is commonly referred to as poor man's orange.

In Bangladesh, tomato is grown during Rabi season. It is cultivated in almost all homestead gardens and also in the field due to its adaptability to wide range of soil and climate. The recent statistics shows that tomato was grown in 75602 acre of land and the total production was approximately 413610 MT in 2014-15. The average yield of tomato was 5471 kg per acre (BBS 2015). A large number of tomato varieties grow in Bangladesh, most of them lost their potentiality due to genetic deterioration, diseases and insect infestations.

Among the factors that influence the low yield of tomato insect pests are one of them. The whitefly, *Bemisia tabaci* (Homoptera: Aleyrodidae) feeds under the surface of leaves and sucking of plant sap by large populations of whitefly nymphs and adults can greatly reduce the plant vigor. Chlorotic spots appear at feeding sites on the leaf surface, followed by wilting and resulting leaf shedding. Such damage to foliage at the early stages of plant growth, affects development of the reproductive structures and consequently the yield may be greatly reduced.

Among the insect pest of tomato, the tomato fruit borer and whitefly are the serious pest. Due to severe infestation, fruit as well as seed maturation hampered greatly and the viability of the seeds are also reduced. When the tomato plant in fruiting stage, fruit borer larvae bore into the young fruit and feed on the internal tissue and make tunnel inside the fruit. As a result fruit, drop off. The larvae bore inside fruit and feed on inner tissues which become deformed in shape resulting low market value.

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

A huge quantity of pesticide is used in controlling tomato fruit borer and usually found that the vegetable growers apply 10-12 sprays in a season. Thus, the fruits, which are harvested at the short intervals, are likely to retain unavoidably high level of pesticide residues which may be highly hazardous causing serious problems including pest resistance, pest outbreak, pest resurgence and environmental pollution (Fishwick 1988). As a result, these harmful insecticides dissolved into our water system and ultimately enter into the system of human, fishes and many other animals and cause severe damage to their health. Moreover, the farmers of Bangladesh are very poor and they have very limited access to buy insecticides and the spraying equipments (Husain 1984). Further, the excessive reliance on chemicals has led to the problem of resistance, resurgence, environmental pollution decimation of useful fauna & flora. In order to increase tomato production in Bangladesh, it is essential to identify cultivars capable of year-round production with higher yield and resistance to pests (Hannan *et al*. 2007).

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

1. To know the effectiveness of botanicals, synthetic insecticides and mechanical support on the infestation of whitefly and fruit borer of tomato
2. To determine the most suitable management tactics on the growth and yield of tomato and
3. To estimate benefit cost ratio regarding yield of tomato

CHAPTER II

REVIEW OF LITERATURE

Tomato is one of the important vegetable in Bangladesh and as well as many countries of the world and a major source of vitamins and minerals. Among the several constraints for growing tomato, attacks of insect pests are considered important. Insects cause damage directly by eating, grasping or sucking or indirectly by transmitting viral diseases. some of the important and informative works and research findings related to the botanical control of different insect pests of tomato so far been done at home and abroad on vegetable crop production have been reviewed in this chapter under the following heading and sub-heading :

2.1 General overview of whitefly

2.1.1 Origin and Distribution of whitefly

Bemisia tabaci was first described as a pest of tobacco in Greece in 1889. Outbreaks in cotton occurred in the late 1920s and early 1930s in India and subsequently in Sudan and Iran from the 1950s and 1961 in EL Salvador (Hirano *et al.* 1993). *B. tabaci* is widespread in the tropics and subtropics and seems to be on the move, having been recorded in many areas outside the previously known range of distribution. The whitefly has been reported as a green house pest in several temperate countries in Europe, e. g., Denmark, Finland, France, Norway, Sweden and Switzerland. Besides in green houses, the species has been reported on outdoor plants in France and Canada (Basu 1995).

2.1.2 Host range

B. tabaci is highly polyphagous and has been recorded on a very wide range of cultivated and wild plants. Greathead (1986) updated the information reported by

Mound and Hasley (1978) and listed 506 species of plants belonging to 74 families. It may be pointed out that 50% of the total number of host plants belonging to only 5 families, namely, Leguminosae, Compositae, Malvaceae, Solanaceae and Euphorbiaceae.

2.1.3 Nuture of Damage

According to Butani and Jotwani (1984) the white, tiny, scale like insects may be seen darting about near the plants or crowding in between the veins on ventral of leaves, sucking the sap from the infested parts. The pest is active during the dry season and its activity decreases with the onset of rains. As a result of their feeding the affected parts become yellowish, the leaves wrinkle and curl downwards and are ultimately shed. Besides the feeding damage, these insects also excrete honeydew which favors the development of sooty mould. In case of severe infestation, this black coating is so heavy that it interferes with the photosynthetic activity of the plant resulting in its poor and abnormal growth. The whitefly also acts as a vector, transmitting the leaf curl virus disease, causing severe loss. Sastry and Singh (1973) estimated 20-75% loss in tomato yield due to tomato leaf curl virus disease in India.

2.1.4 Seasonal Abundance

In a study in Sudan Kranz *et al.* (1977) found a sharp increase in whitefly population in September and October which was directly correlated with higher relative humidity (80-90%) and increasing temperature (36-38ºC). These conditions favor the development of the juvenile stages by shortening the duration of each stage. They indicated that the population decreases due to high mortality rate at eggs and free juvenile stages in March, April and May when the temperature is high (43-45ºC) and RH is low (8-17). On the other hand, Gerling *et al.* (1986) observed that the extreme RH, both high and low, was unfavorable for the survival of immature stages. Thus in

Sudan, Horowitz (1986) found significant drop of whitefly population levels at heavy rainy condition.

2.1.5 Life History

2.1.5.1 Egg

Eggs are pear shaped and 0.2 mm long. They are laid indiscriminately almost always on the undersurface of the young leaves (Hirano *et al.* 1993). The female can lay 119 eggs in captivity (Hussain and Trehan 1933) and 300 eggs on egg plant under field conditions (Avidov 1956). Initially the eggs are translucent, creamy white and turn into pale brown before hatching. The incubation period varies widely mainly due to varying environmental conditions especially temperature. Under outdoor condition the incubation period has been reported to be range between 3-5 days in summer and 7-33 days during winter (Azab *et al.* 1971, Hussain and Trehan 1933).The first instar nymphs (crawlers) move a very short distance over the leaf surface. Once settled, they remain sessile until they reach the adult stage, except for brief periods during molts (Hirano *et al.* 1993).

2.1.5.2 Nymphal and pupal Stages

The first instar nymphs are pale, translucent white, oval, with a convex dorsum and flat central side. They measure 0.267± 0.007 mm in length and 0.144±0.010 mm in width (Lopez- Avila 1986). The second instar nymphs are quite distinct from first instar for its size. These nymphs are 0.365± 0.026 mm long and 0.218± 0.012 mm wide at the broadest part of the thorasic region. The body of the third instar nymph is more elongated than the earlier instars, measuring 0.489± 0.022 mm in length and 0.295± 0.018 mm in breadth. The fourth instar nymphs have elliptical body measuring 0.662± 0.023 mm long and 0.440 ± 0.003 mm broad. This fourth instar (the so- called “pupae”) has red eye spots, which become eyes at the adult stage, are characteristic of this instar (Hirano *et al.* 1993).

Two distinctive characters of the pupa are the eyes and the caudal furrow. Dorsal surface of the elliptical body is convex and the thoracic and abdominal segments are pronounced. Mound (1963) showed that the pupae from which females emerge are larger than those producing males.

Duration of these stages varies and has generally been correlated with temperature or seasonal factor. Under constant conditions of 25ºC, RH 75% and light: dark 16:8 hours, the fourth instar nymph lasted 3.4 days on bean, 2.1 days on cotton and 2.0 days on tomato .The duration of pupal stage were 4.4 days on bean, 2.4 days on tomato and 1.7days on cotton (Lopez-Avila 1986).

The total duration of the immature stages of *B. tabaci* varies widely and is correlated with climate and host- plant conditions. The shortest duration of 11 days during summer (Pruthi and Samuel 1942) and the longest of 107 days during winter (Hussain and Trehan 1933) were observed in India.

2.1.5.3 Adults

Adults are soft and pale yellow, change to white within a few hours due to deposition of wax on the body and wings. Byrne and Houck (1990) revealed sexual dimorphism in wing forms: the fore and hind wings of females were larger than those of males. The mean wing expanses of females and males are 2.13 mm and 1.81mm, respectively (Byrne *et al.* 1991). Adult longevity of males on tobacco was 4 days in summer and 7days in winter, corresponding female lifespan was 8 and 12 days, respectively in India (Pruthi and Samuel 1942).

The maximum adult emergence occurs before 0800 and 1200 hours (Musuna 1985, Butler *et al.* 1991, Azab *et al.* 1971, Husain and Trehan 1933). *Bemisia tabaci* is arrhenotokus and is known to lay unfertilized eggs which give rise to males only (Sharaf Batta 1985, Mound 1983, Hussain and Trehan 1933, Azab *et al.* 1971). Unmated females produce male offsprings while mated females produce both males and females. Monsef and Kashkooli (1978) recorded 10-11 generations per year on cotton in Iran. Husain and Trehan (1933) and Pruthi and Samuel (1942) found 12 overlapping generations in India on cotton.

2.1.6 Management of Whitefly

To manage whiteflies, it is necessary to know which plants are affected by whiteflies and to understand the nature of its damage to crops, the biology of the whiteflies and their natural enemies, and how to monitor whitefly populations (sites, population dynamics, action thresholds). Also, it is critical to know the limitations of various control tactics, which include cultural controls (such as altered planting practices and physical barriers), host plant resistance, chemical controls, and natural controls.

The use of insecticides and oils to affect virus transmission by whiteflies has yielded more or less satisfactory results in a limited number of cases. Cultural control measures to reduce the disease incidence included sanitation, mixed cropping, use of reflective surfaces by way of mulches, physical barriers and cultivation of resistant varieties. No strategy for control of whitefly borne geminiviruses has proved effective in practice (Brown and Bird 1992).

Many reports, from cultural to transgenics have been published on the management of Tomato in the world. Few works are reviewed under the following subheading:

2.1.6.1 Sanitation

To manage the leaf curl disease tomato fields should be kept weed free and TYLCV infected plants should be clean out immediately. Tomato fields should be cleaned up immediately after harvest. TYLCV resistant cultivars should be used if available (Schuster and Polston 1999).

2.1.6.2 Use of Reflective Surfaces

B. tabaci is strongly attracted to yellow plastic or straw mulches and killed by reflected heat. Mulching of tomatoes and cucumber fields with saw dust, straw or yellow polythene sheets markedly reduced the incidence of TYLCV and cucumber vein virus and populations of the whitefly vector (Cohen and Melamed-Madjar 1978). In West Bengal, India, the incidence of yellow mosaic disease of okra was 24.3% in plots with yellow polythene mulch against 58.6% in control (Khan and Mukhopadhyay 1985).

2.1.6.3 Polyethylene Mulch

Cohen and Melamed-Madjar (1978) reported that soil mulching with yellow polyethylene sheets can delay the spread of TYLCV for at least 20 days. A combined treatment of mulching with yellow polyethylene sheets and 1% sprays of azinphos-methyl starting 20 days after germination was found to be most effective in preventing the spread of TYLCV of tomato.

Five mulch types, i.e. silver, black, white/black and black/white plastic and paper were evaluated in terms of their effect on growth, yield and fruit quality of tomato and incidence of *Tomato yellow leaf curl virus* (TYLCV). Silver colored mulch reduced disease incidence by 80% and increased the yield 2 times as compared to control (Suwwan *et al.* 1988).

Csizinsky *et al*. (1995) conducted field experiment on the effect of six different plastic mulches like blue, orange, red, aluminum, yellow, white/black on fruit yields and insect vectors of tomato. Aluminum and orange mulches reduced the whitefly numbers, delayed virus infection and increased the yield. Virus symptom development was not delayed and yield did not increase in yellow mulch in spite of lower number of whiteflies. They concluded that under high insect stress, the insect repellent, soil-microclimate-modifying and biologically beneficial effects of the mulch be considered when a mulch color is selected for tomato production.

Molla (2000) worked on different mulching materials (blue, aluminum, yellow, black, transparent polyethylene, rice straw, dried natural grass) and weed control on tomato yellow leaf curl virus (TYLCV). Mulching reduced the disease incidence by 50% as compared to control. Aluminum colored mulch had the lowest disease incidence but higher yield was obtained from yellow colored mulch.

2.1.6.4 Trap crop

Al-Musa (1982) studied the effect of some inter crops on TYLCV of tomato. In field trial cucumber, eggplant and corn were planted in alternate rows of tomato 30 days before the tomato seedlings were transplanted. TYLCV was effectively delayed in cucumber interplanted plots whereas; corn or eggplant was not found suitable.

El-Serwiy *et al*. (1987) studied the effect of intercropping aubergine, okra, pepper and cucumber with tomato on the incidence of TYLCV and *B. tabaci* in plastic green houses in Iraq. Adult whiteflies preferred to oviposit on aubergines than on tomato. The incidence of TYLCV was reduced by 10-26% in tomato plots intercropped with *Capsicum* during first 3 months after transplanting.

Xienqui (2000) evaluated the effect of interplanting tomato with vegetable soybean, corn, sweet potato, cucumber, okra on whitefly population and incidence of TYLCV in the field. All the crop combination partially reduced TYLCV infection. Among the intercrops cucumber and vegetable soybean were much preferred by whiteflies as compared to others.

The impact of whitefly transmitted geminiviruses on tomato yield depends on plant age at the time of infection and is highest during the first eight weeks after germination. This is the critical period. In order to delay the *Tomato yellow mottle* geminivirus (ToYMoV) in tomato, some living ground covers were evaluated by Hilje (2000) in Costa Rica.

2.1.6.5 Chemical Control of Whiteflies

Chemical control of whiteflies is both expensive and increasingly difficult. If the rate of whitefly re-infestation is great enough, the cost of effective insecticide treatments may be prohibitive. Besides the cost of treatment, other factors involved in chemical control decisions are the need for thorough coverage, the risk of secondary pest outbreaks, the risk of whiteflies developing insecticide resistance, and the regulatory restrictions on the use of insecticides. These factors have to be weighed against the expected returns for a given crop at a given planting date. Many systemic and contact insecticides have been tested for control of whiteflies, but few gave effective control. Currently registered systemic insecticides, such as oxamyl, have been only partially effective. Certain contact insecticide combinations, especially pyrethroids such as fenpropathrin or bifenthrin plus organo-phosphates such as acephate or metamidophos, have provided excellent control in greenhouse and field studies as long as there was thorough coverage of the foliage. However, by exposing pest populations to two types of chemicals at once, combinations may accelerate selection for resistance to both materials. Therefore, tank mixes should be resorted to only when single applications are not effective. Other products with contact activity, such as oils, soaps and K-salts of fatty acids, can be very effective with thorough coverage, but in field tests they are often less effective because of poor coverage. Good coverage of the foliage with contact insecticides is essential for best results. Most whiteflies are located on the undersides of leaves where they are protected from overtop applications, and the immature stages (except for the crawler) are immobile and do not increase their exposure to insecticides by moving around the plant. Use drop nozzles where appropriate, adequate pressure, and calibrate and maintain equipment carefully. Specific insecticides should be selected according to the stage(s) of whitefly to be controlled. The effectiveness of the few currently registered insecticides could be lost if they are excessively and repeatedly applied. There are techniques for monitoring resistance to determine which insecticides are still active against whiteflies. Generally, if an insecticide treatment is properly made with sufficient coverage and yet is ineffective, then that whitefly population should be tested for resistance to the product. There is a possibility that treating a resistant whitefly population with certain insecticides could actually accelerate population growth. This could be because more eggs are laid when the insect is under biochemical stress, or because beneficial arthropods are eliminated. To minimize this potential problem, insecticide applications should be used judiciously and combined with non-chemical control tactics. Furthermore, distinct classes of chemical compounds should be rotated at least every other spray. Distinct classes of insecticide include the pyrethroids (Ambush, Asana, Danitol, Karate, etc.), organo-phosphates (Orthene, Monitor, Lorsban), carbamates (Vydate), chlorinated hydrocarbons

(Thiodan), insect growth regulators (Applaud, fenoxicarb), oils, and soaps and detergents. Resistance to soaps and oils is unlikely to ever develop, so these materials should be used as much as possible.

The effectiveness of 19 insecticides and insecticides combinations against the Aleyrodid, *Bemisia tabaci* were evaluated in Venezuela by Marcano and Gonzalz (1993) and they observed that the most effective insecticides against eggs and nymphs of the pest were: Imidacloprid (91.67 and 78.61 litres/ha); Mineral oil +Imidacloprid (88.85 and 71.33 litres/ha); Cyfluthrin + Methamidophos (87.85 and 69.08 litres/ha); Buprofezin (86.1 and 53.19 litres/ha); Lambda-cyhalothrin (86.1 and 47.47 liters/ha); Profnofos + Cypermethrin (85.93 and 70.18 litres/ha).

Imidacloprid (a systemic chloronicotinyl insecticide) gained major importance for control of *Bemisia tabaci* in both field and protected crops, in view of extensive resistance to Organophosphorous, Pyrethroid and Cyclodiene insecticides (Cahil *et al.* 1995).

Azam *et al.* (1997) conducted an experiment during 1993-95 with some insecticides (Carbofuran, Endosulfan, Dimethoate, Buprofezin and Triazophos) for the control of *B. tabaci* and yellow leaf curl bigeminivirus (TYLCV) and found that Endosulfan had the most affect to control *Bemisia tabaci.*

The plots treated with seed bed netting and two spray of Imidacloprid 200SL had the lowest number of Whitefly and it was statistically similar with the treatment seed bed netting with the spraying Nimbicidine and seed treatment only (Anon. 2005).

2.1.6.6 Pesticide and oil spray

Sastry (1989) reported that incidence of TYLCV can be reduced through dipping roots of tomato seedlings in a 0.1% carbofuran solution for 1hr followed by 2 foliar sprays of agricultural spray oil at 20 and 30 days after transplanting.

Butler *et al*. (1991) conducted a study to assess several plant derived oils to control sweet potato whitefly (*Bemisia tabaci*) in tomato. House hold cooking oils like corn, peanut, safflower; soybean and sunflower were used as 1% foliar spray. Oil spray significantly reduced whitefly adults and immature for 5 days following application as compared to control. For home gardeners use of on the shelf cooking oils and liquid detergents available in most homes is recommended as a safe and economic solution for the control of whitefly.

Csizinsky *et al*. (1997) evaluated various color mulches with oil sprays to control whitefly population which transmits *Tomato mottle virus* (TMoV) in Florida. Orange, yellow, black and white and aluminum mulches together with weekly application of soybean oil emulsion (93%) were used in the field. Virus symptom developed slowly in the plots where orange + oil yellow + oil and aluminum mulches were used as compared to control. Use of yellow mulch with soybean oil was suggested to manage TMoV in tomatoes.

Rao *et al*. (1999) studied the effect of recommended and sublethal doses of some insecticides on the biology and population of *Bemisia tabaci*. Results showed that synthetic pyrethroids like deltamethrin, fenvalerate, permethrin and cypermethrin popularly used on cotton have contributed to resurgence of whitefly on cotton. The failure of these insecticides to control the whitefly also suggests the development of resistance to the chemicals.

Mason *et al*. (2000) studied the effect of 'Thiamethoxam' a new neonicotinoid insecticide in preventing transmission of *Tomato yellow leaf curl virus* (TYLCV) by the whitefly *Bemisia tabaci*. Results have demonstrated that foliar and drench applications of thiamethoxam could prevent TYLCV transmission by B. *tabaci*. Thiamethoxam proved to be very effective in preventing virus acquisition because up to 8 weeks after foliar application, no whitefly survived the 24h feeding period and later on, there was a high mortality of acquiring adults. They suggested that integration of resistant variety and one or two foliar applications of thiamethoxam could be effective to reduce TYLCV damage in tomato crop.

Savary (2000) reported that Imidacloprid and Cypermethrin/ imidacloprid in rotation were effective in reducing the TYLCV disease incidence by 50%. It was suggested that these two insecticides could be used in an IPM package.

Ahmed *et al*. (2001) used 'confidor' (imidacloprid) at four rates (47.6, 71.4, 95.2 and 119 g a.i. /ha) for indirectly controlling *Tomato yellow leaf curl virus* (TYLCV) in the field plantings of tomato. IPM practices and two applications of confidor at the two highest rates immediately after planting and 6 weeks later protected tomato plants against the disease until 12 weeks after sowing. All rates of confidor reduced disease incidence as compared to standard chemical (cypermethrin) application. Confidor treated plots had higher yield than control plots. When applied immediately after planting, confidor's long lasting systemic activities protected the crop against the disease during early stages of growth. In addition it reduced the number of sprays and increased yield of tomato.

2.1.7 Integrated Management of whitefly

Ioannou and Iordanou (1987) reported that TYLCV disease on tomato could be delayed by roguing the infected, overwintered tomato plants and use of virus free plants produced in covered seedbeds. The author opined that the most effective and economic method of TYLCV control is the development of resistant variety. But until such cultivars are bred or available, yield loss due to TYLCV could be minimized through integrating effective alternative cultural practices.

Green and Kalloo (1994) reviewed various aspects of TYLCV including control options. Several options are available to reduce TYLCV incidence in the field. These are use of insecticides, mineral oils, reflective mulches, mixed cropping or trap crop, elimination of weed host, adjustment of date of planting to avoid high insect density and cultivation of tolerant lines. These approaches alone or in combination have been found to be effective in reducing TYLCV menace in many situations.

Traboulsi (1994) reviewed many aspects of whitefly (*Bemisia tabaci*). One study report in the article suggested that B. *tabaci* is not a single species but a species complex, mostly in tropical and subtropical regions but also in temperate regions. About 40 virus diseases transmitted by *B. tabaci* are mentioned worldwide. In many parts of the world *B. tabaci* is a striking example of how a secondary pest can rise to the rank of a major one over a short period of time as a result of excessive use of insecticide.

For the management of TYLCV, use of insect proof netting, sticky traps, intercropping, various planting date, drip irrigation or colored plastic mulches are suggested. Insect proof netting permanently affixed to greenhouse doors and windows is widely used and is the only preventive control measure feasible in many situations.

Coarse mesh net can be used with frequent insecticide application. Rouging is also a good practice for reducing the source of primary infection. *Lycopersicon chilense* is a promising potential source for breeding tomatoes resistant to TYLCV.

Ramappa *et al*. (1998) suggested some control measures, which delay the *Tomato leaf curl virus* (ToLCV) infection in tomato. The techniques include use of nylon net to protect the seedling, intercropping, use of barrier crops, crop rotation, siting new tomato fields away from obvious sources of infection and use of resistant / tolerant cultivars. Applications of these measures have already proved successful in reducing yield loss due to TYLCV of tomato in Israel and Tobacco leaf curl in Karnataka, India.

Schuster and Polston (1999) suggested a number of practices for the management of TYLCV through reduction of whitefly population. Practices include destruction of crop residue after harvest, use of virus free transplants, aluminum polyethylene as soil mulch, use of admire at transplanting, spraying of crop oil (0.25-0.5 percent) as whitefly repellent and rouging.

Jiang *et al*. (2000) reported that whitefly transmitted viruses are very difficult to control with chemical insecticide alone, because single viruliferous adult is able to transmit TYLCV with Phloem contact lasting less than 2 minutes. Therefore modern control methods must be developed to interfere with the acquisition and transmission cycle and several pest management tactics should be integrated for efficient whitefly transmitted virus disease control.

Hilje *et al*. (2001) reviewed cultural practices for the management of *Bemisia tabaci* and associated viral diseases. Practices include manipulation of planting date, removal of weed, netting, trap crop, living and inert mulches.

Number of vector and virus inoculum can often be avoided by planting early or late. Eradicating one weed species (*Cynanchum acutum*) in Jordan Valley of Israel controlled spread of TYLCV. Growing of seedlings in insect proof net (variety of mesh size) house or cultivation of plants in enclosed greenhouse or under an insect proof structure have been found effective in delaying TYLCV spread. Various intercropping or trap cropping have been suggested like cucumber, green beans, squash, eggplant in tomato crop. But use of trap crop sometimes can aggravate the disease situation i.e. instead of reducing it can lead to increased disease situation. Colored plastic mulches including aluminum, silver, transparent, white and yellow have been proven to be effective in reducing incidence of whitefly transmitted viruses. The report suggested that a wide variety of cultural practices are available for the management of *B. tabaci* worldwide, although great variations are found with respect to different crop situations and geographic locations.

Kalb (2004) suggested few measures for the management of TYLCV of tomato. These include growing seedlings in an insect proof net house (50 meshes or fine), spraying infected plants with imidacloprid before rouging, interplanting tomato with bait plants like cucumber, application of systemic insecticides as soil drenches during seedling stage. Rotation of insecticides is necessary otherwise resistance may develop in the vector. Chemical control is ineffective when disease incidence is high. Other methods suggested include spraying of soap solution (1%) or oil but there is a risk of phytotoxicity. Few resistant or tolerant commercial varieties are also available against some strains of TYLCV in Taiwan.

2.2 General overview of Fruit borer

2.2.1 Origin and distribution

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

2.2.2 Host Range of tomato fruit borer

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

2.2.3 Life history of tomato fruit borer

2.2.3.1 Egg

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

2.2.3.2 Larva

The fully grown larva is about 40 mm in length, general colour varies from almost black, brown or green to pale yellow or pink and is characterized by having a dark band along the back to each side of which there is a pale band. The larval period varies from 15.35 days (Singh and Singh 1977).

2.2.3.3 Pupa

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

2.2.3.4 Adult

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

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

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

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

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

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

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

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

Mehta *et al*. (2001) studied the management of tomato fruit borer, *Helicoverpa armigera* (Hubner) with nine insecticidal treatments and conducted for 3 seasons during 1995-1997 at Palampur (Himachal Pradesh). Overall effectiveness was expressed as reduction in borer damaged tomato fruits and increase in fruit yield indicated the superiority of Deltamethrin alone or in combination all through the experimentation. Application of Deltamethrin resulted in lowest fruit damage (4.27%) followed by Cypermethrin (8.98%) and Acephate (9.16%). Among the biopesticides tested, Bt treated plots had lowest fruit infestation (10.68%) as compared to HaNPV (11.95%) and Azadirachtin (14.68%). A mixture of Deltamethrin+Bt application revealed a fruit damage of 5.58 percent while untreated control had 24.2 percent fruit damage. The mean fruit yield was highest in Deltamethrin + Bt. treated plots followed by Deltamethrin, Acephate and Cypermethrin.

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

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

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

2.2.5 Control measures for tomato fruit borer

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

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

Money-Maker and Royesta were evaluated to screen out the suitable resistant/susceptible genotypes against the fruit borer in Pakistan (Sajjad *et al*. 2011). The results imparted that the percentage of fruit infestation and larval population per plant on tested genotypes of tomato varied significantly. Lower values of host plant susceptibility indices (HPSI) were recorded on resistant genotypes. Sahil, Pakit and Nova Mecb could be used as a source of resistance for developing tomato genotypes resistant to tomato fruit borer. Bihari and Narayan (2010) conducted an experiment on the effects of tobacco leaf extract, tea extract, neem [*Azadirachta indica*] leaf extract (NLE), neem seed kernel extract (NSKE), jatropha [*Jatropha* sp.] leaf extract, jatropha kernel extract, karanj [*Pongamia pinnata*] leaf extract, karanj kernel extract, tulsi [*Ocimum tenuiflorum*] leaf extract (TLE), onion-garlic bulb extract (OGBE) and chilli fruit extract (CFE) on the performance of tomato and incidence of fruit borer (*Helicoverpa* sp.) were studied in Allahabad. NSKE, TLE and CFE recorded the highest number of flower clusters per plant (83.45, 80.85 and 80.10, respectively) and incidence of fruit set per plant (32.47, 32.10 and 32.00). The highest cost-benefit ratios were obtained with NLE, OGBE and CFE (1:51, 1:50 and 1:47).

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

A field experiment was conduction by Hussain and Bilal (2007) during Kharif 2003-2004 to evaluate the efficacy of six insecticides at farmers field against *Helicoverpa armigera* infesting tomato. Among the treatments imidacloprid at 0.03% proved more effective followed by Deltamethrin and Fluvalinate. The spraying of these insecticides on tomato resulted in significantly higher reduction of larval population. The field data showed that Imidacloprid gave a significantly higher increase in yield (>78%) over control followed by Deltamethrin. Imidacloprid (0.03%) avoided 46% yield loss on tomato crop. Tomato fruit borer has been found to cause a yield loss of up to 35% in tomato and up to 37.79% in Karnataka, India (Dhandapani *et al*. 2003). Sharma *et al.* (2003) reported that some 82 tomato germplasms were screened for their resistance to the tomato fruit borer. *H. armigera,* during 1996-97 at Ludhiana, Punjab, India. The total number of healthy and infested fruits was counted at every harvest and cumulative percent fruit damage was assessed. Fruit infestation varied from zero in Tomato Royal FM and WIR 4285 to 30.03% in L274.

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

Again the aforementioned characters for V-282 line were 80.74 cm, 1.18 cm, 9.396, 21.57 sq.cm, 1.24 mg/g, 17 and 30, respectively.

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

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

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

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

Mehta *et al.* (2000) reported that studies on the management of tomato fruit borer, *Helicoverpa armigera* (Hubner) with nine insecticidal treatments were conducted for 3 seasons during 1995-1997 at Palampur (Himachal Pradesh), India. 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. Satpathy *et al.* (1999) reported that in field trials in Varanasi, Uttar Pradesh, India, nuclear polyhedrosis virus applied with half the recommended dose of Endosulfan (350 g a.i./ha) gave effective control of *H. armigera* on tomato. Application of crude NPV at 300 LE was also effective when applied at 5-days interval. The results indicated that fruit damage was reduced in all treatments. Lowest infestations and highest yields of marketable fruits (7.388 t/ha) were recorded with the 0.44 kg Profenofos + Cypermethrin trectment.

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

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

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

Parihar and Singh (1986) reported that the larval population of *Heliothis armigera [Helicoverpa armigera]* on tomato and losses caused by this pest were studied in the

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

2.2.6 Integrated pest management (IPM) for fruit borer

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

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

Sathish and Raguraman (2007) carried out experiment to evaluate the biological activity of organic amendments against the fruit borer, *Helicoverpa armigera.* Safety of botanicals and biopesticides against egg parasitoid, *Trichogramma chilonis* Ishii and biochemical effects of *Pseudomonas florescens* on tomato under pot culture conditions were tested. The feeding and infestation of the larvae of *H. armigera* were significantly low in FYM + *Azospirillum* + SSB + *Phosphobacteria* + Neem cake and followed by FYM + *Azospirillum* + SSB + *Phosphobacteria* + mahua cake applied plants. *Trichogramma* parasitization on *H. armigera* eggs was adversely affected by Neem oil 3% on treated plants followed by NSKE + Spinosad. Under laboratory condition among the microbial pesticide tested Spinosad (75 g a.i./ha), *HaNPV* + Spinosad + *Bt* (1.5 xl012 POBs/ha +75 g a.i./ha +15000 IU/mg (2 lit/ha), Spinosad +

Bt (75 g a.i./ha +15000 IU/mg (2 lit/ha) showed superiority in exhibiting higher insecticidal toxicity (100 per cent mortality on 72 h) to all instars of *H. armigera* larvae. Biochemical parameters like phenol content, Peroxidase and Phenyl alanine ammonialyase (PAL) activity recorded higher levels in *Pseudomonas florescens* seed treatment @ 30 g/kg of seed and foliar spray @ 1 g/litre treated tomato plants. These biochemical components were negatively correlated to *H. armigera* infestation in tomato.

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

Karabhantanal *et al*. (2005) carried out investigation during 2001 and 2002 in Kharif season in Karnataka, India to evaluate different Integrated pest management (IPM) module against tomato fruit borer, *Helicoverpa armigera*. The result revealed that the IPM module consisting of trap crop (15 row of tomato; 1 row marigold) + *Trichoghamma pretiosum* (45000%/ha) –NSKE (5%)-Ha NPV (250LE/ha)-Endosulfan 35 EC (1250ml/ha) was significantly superior over the rest of the modules tested in restricting the larvae population (100% after the fourth spray). As a result of which, the lowest fruit damage (11.87%), highest marketable fruit yield (224.56q/ha) and additional net profit (22935/ha was observed) in this module, but was comparable with the recommended package of practice and IPM module consisting of nomuraea rilevi (2.0 x 1011 conidia/ha) NSLE (5%) HaNPV (250le/ha)-Endosulfan 35EC (1250ml/ha).

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

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

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

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

CHAPTER III
MATERIALS AND METHODS

The experiment was conducted in the central farm of Sher-e Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2016 to April 2017 to evaluate integrated pest management packages against major insect pests in tomato. The materials and methods used for conducting the experiment were presented in this chapter under the following headings:

3.1 Location of the Experimental Site

The present experiment was carried out in the field of Central Farm and in the laboratory of Entomology Department of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The location of the experimental site is $23^{0}74'$ N latitude and $90^{0}25'$ E longitude and an elevation of 8.1 m from sea level.

3.2 Soil

The soil of the research field is medium high land with adequate irrigation facilities and low organic matter content. The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage facilities during the experimental period. The research area belongs to the Madhupur Tract under AEZ No. 28 and was dark grey terrace soil.

3.3 Planting materials

Under the present research work, the seeds of tomato of the BARI-5 were sown in seed bed. The tomato seeds were collected from Bangladesh Agricultural Research Institute (BARI). The seedlings were produced in seedbed near the farm yard of Sher-e-Bangla Agricultural University. The age of the seedling was 30 days during transplanting (Plate 1).

3.4 Design and layout of the Experiment

The experiment was laid out at Randomized Complete Block Design (RCBD) with three replications and nine treatments including a control option. The layout of the experiment was prepared for distributing the treatment combinations in each plot of each block equally. There were 27 unit plots altogether in the experiment. The size of the each plot was 3 m × 1 m. The distance between block to block and plot to plot was 1.0 m and 0.5 m, respectively.

3.5 Treatments of the Experiment

Nine treatments were considered in this study and the treatments were:

T_1 = Vertical Support

T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_4 = Horizontal Support

T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_9 = Untreated Control

3.6 Seed treatment

Seeds were treated with Vitavex-200 @ 0.25% before sowing to prevent seeds from the attack of soil borne disease. Furadan 5G @ 1.2 kg ha^{-1} was also used against soil inhibiting insect pests.

3.7 Seedbed preparation

Seedbed was prepared on October, 2016 for raising seedlings of tomato and the size of the seedbed was 3m×1m. For making seedbed, the soil was well ploughed and converted into loose friable and dried masses to obtained good tilth. Weeds, stubbles and dead roots were removed from the seedbed. Cow dung was applied to the prepared seedbed at the rate of 10 t/ha.

Plate 1. Raising of tomato seedlings

3.8 Preparation of the main field

The selected experimental field was opened in the First week of October 2016 with a power tiller and was exposed to the sun for a week for sun drying. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to obtain a good tilth for the growth of tomato seedlings (Plate 2). Weeds and stubbles were removed and finally obtained a desirable tilth of soil. The experimental field was partitioned into unit plots in accordance with the experimental design.

Plate 2. Preparation of main field

3.9 Application of manure and fertilizers

Well decomposed cowdung as per recommendation was applied at the time of final land preparation (Rashid 1993). The sources of fertilizers used for N, P and K were urea (500 kg/ha), TSP (400 kg/ha), MP (200 kg/ha), respectively (Rashid 1993). The entire amounts of TSP, MP were applied during final land preparation. Only urea was applied in three equal installments at 30 and 45 and 60 Days after planting (DAT).

3.10 Intercultural operation

After establishment of seedlings, various intercultural operations were accomplished for better growth and development. After 15 days of transplanting a single healthy seedling and luxuriant growth per pit was allowed to grow discarding the others, propping of each plant by bamboo stick was provided on about 1.0 m in height from ground level for additional support and to allow normal creeping (Plate 4). Weeding and mulching in the plot were done, whenever necessary (Plate 3).

Plate 3. Intercultural operation

Plate 4. Providing additional support by bamboo stick

3.11 Horizontal and Vertical support

Horizontal and vertical support was given with bamboo stick during vegetative stage (Plate 5). Horizontal support was given at T_4, T_5 and T_6 treatments. On the other hand vertical support was given at T_1, T_2 and T_3 treatments.

Plate 5. Horizontal and Vertical support with bamboo stick

3.12 Irrigation

Light over-head irrigation was applied with a watering can in the plots immediately after germination of seed. Irrigation was also applied two times considering the moisture status of field.

3.13 Data collection

The data were recorded on the incidence of white fly, leaf miner infested leaves and fruit borer infested shoots, infested and healthy fruit and yield contributing characters and yield of tomato.

3.13.1 Incidence of whitefly

For recording data on whitefly, five (5) plants from each plot were randomly selected and tagged. Five fully expanded compound leaves from top, middle and bottom of each plant were checked silently without jerking the plant *in situ* at an interval of 10 days commencing from vegetative to ripening stage and counted the number of whitefly up to the last harvesting of the fruit.

3.13.2 Fruit borer infestation

Total number of fruits and infested fruits (bored) were recorded at each harvest and continued up to the last harvest. Infested fruits recorded at each observation were pooled and finally expressed in percentage. The damaged fruits were spotted out by the presence of holes made by the larvae.

The percentage of borer infested fruits was calculated using the following formula:

$$\text{\% Borer infested fruits (By number)} = \frac{\text{No. of infested fruits}}{\text{Total number of fruits}} \times 100$$

$$\text{\% Borer infested fruits (By weight)} = \frac{\text{Weight of infested fruits}}{\text{Total weight of fruits}} \times 100$$

$$\text{\% decrease of fruit infestation} = \frac{\text{Yield of control plot} - \text{Yield of treated plot}}{\text{Yield of control plot}} \times 100$$

3.13.3 Healthy and infested fruit

The number of the healthy and infested fruit was counted at each harvest and continued up to the last harvest from the plants (Plate 6). Healthy fruits recorded at each observation were pooled and finally expressed in percentage.

Plate 6. Fruits infested by fruit borer

3.13.4 Benefit Cost Ratio (BCR)

Economic analysis of different control practices was calculated. In this study, the untreated control did not require any pest management cost**.**

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

3.14 Statistical analysis of data

The recorded data were compiled and tabulated for statistical analysis. Analysis of variance was done with the help of computer package MSTAT program (Gomez and Gomez, 1976). The treatment means were separated by Duncan's Multiple Range Test (DMRT).

CHAPTER IV
RESULTS AND DISCUSSION

The present experiment was conducted in the central farm of Sher-e-Bangla Agricultural University during October 2016 to April 2017 to develop an IPM approach in controlling insect pests of Tomato. Data on whitefly abundance and fruit borer infestation and their effect on yield and yield contributing characters were recorded. The results are presented and discussed and possible interpretations are given under the following headings and sub-headings:

4.1 Number of whitefly

At vegetative, early and late flowering, fruiting and ripening stages, statistically significant variation was recorded in number of' whitefly per plot in tomato (Appendix III).

At vegetative stage the lowest number of whitefly per plot (2.67) was recorded from the treatment T_6 plots having application of Marshal 20EC (@ 3.0ml/L of water + vertical support) at 7 days interval which was statistically similar (3.00) to that of T_8 treated plots using Marshal 20EC (@ 3.0 ml/L of water + No support) applied at 7 days interval (Table 1). No significant difference was found between the effects of (Neem oil 3ml/L of water + vertical support) T_2 (4.07) and (Neem oil 3ml/L of water + horizontal support) T_5 (4.33) applied at 7 days interval in controlling whitefly. On the other hand the highest (22.40) number of whitefly per plot was recorded from T_9 untreated plots which was significantly different than other treatments (Table 1).

At early flowering stage the lowest number of whitefly per plot (3.20) was recorded from T_6 treated plots which was statistically similar (3.73) with that of treatment T_8, while the highest (24.07) number of white fly per plot was recorded from untreated control plot(T_6) which was significantly different than other treatment (Table 1). Statistically significant and similar results were found in T_2 (5.27) and T_5 (5.60) treated plots utilizing as application of Neem oil (@ 3ml/L of water + vertical support) and Neem oil (@ 3ml/L of water + horizontal support) at 3 days interval, respectively. At late flowering stage lowest number of white fly per plot (4.67) was recorded from T_6 and T_8 (4.27) treated plots, while the highest (27.27) number of white fly per plot was recorded from untreated control (T_9) which was significantly different from other treatments (Table 1).

At early fruiting stage the lowest number of whitefly per plot (3.07) was recorded from the treatment T_6 which was statistically similar (3.53) with that of treatment T_8 while the highest (23.60) number of white fly per plot was recorded from untreated control plots which was significantly different from all other treated plots. At late fruiting stage the lowest number of whitefly per plot (2.80) was recorded from the treatment T_6 which was statistically similar (3.13) with that of treatment T_8, while the highest (22.73) number of whitefly per plot was recorded from untreated control which was significantly different than treated plots. At ripening stage the lowest number of whitefly per plot (2.73) was also recorded from T_6 treated plots which was statistically identical (3.07) that of the treatment T_8. On the other hand the highest (22.07) number of whitefly per plot was recorded from untreated control plots (T_9) which was significantly different from other treatments.

Table 1. Effect of different control approaches against white fly in the tomato field per plot during the cultivation period of October 2016 to April 2017

Treatments	No. of Whitefly/plot					
	Vegetative Stage	Flowering stage		Fruiting Stage		Fruit ripening Stage
		Early	Late	Early	Late	
T_1	9.07 c	12.20 c	15.20 c	11.93 c	9.53 c	9.13 c
T_2	4.07 f	5.27 e	6.20 f	5.07 f	4.20 ef	4.07 e
T_3	5.27 de	6.40 d	7.27 de	6.07 de	5.27 de	5.20 d
T_4	10.73 b	13.27 b	16.80 b	12.87 b	11.07 b	10.67 b
T_5	4.33 ef	5.60 e	6.80 ef	5.33 ef	4.47 e	4.27 e
T_6	2.67 g	3.20 f	4.67 g	3.07 g	2.80 g	2.73 f
T_7	5.80 d	7.07 d	7.73 d	6.87 d	5.87 d	5.87 d
T_8	3.00 g	3.73 f	4.27 g	3.53 g	3.13 fg	3.07 f
T_9	22.40 a	24.07 a	27.27 a	23.60 a	22.73 a	22.07 a
LSD	**0.95**	**0.67**	**0.68**	**0.91**	**1.18**	**0.82**
CV (%)	**7.35**	**4.33**	**3.64**	**6.02**	**7.32**	**6.32**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

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

T_1 = Vertical Support

T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_4 = Horizontal Support

T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_9 = Untreated Control

From the above results it was found that Marshal 20EC (@ 3.0ml/L of water + vertical support and Marshal 20EC (@ 3.0 ml/L of water + No support) at 7 days interval was most effective in reduction of whitefly incidence. The systemic action and quick knockdown properties of chemicals might have helped in reducing whitefly population in the entire cultivation period. At early flowering stage of tomato similar results were also obtained by Azam *et al*. (1997) and Alam *et al.* (1994). Similar result had been reported by Maleque *et al.* (2002). The results of Neem oil (@ 3ml/L of water + vertical support) and Neem oil (@ 3ml/L of water + horizontal support) had significant effect on whitefly controlling. But the performance of only vertical support and horizontal support was poor as compared to that of untreated control.

4.2 Fruit borer infestation

4.2.1 Fruit infestation by number at early fruiting stage

Statistically significant variation was recorded in number of healthy and infested fruit, percent fruit infestation at early fruiting stage against tomato fruit borer using different integrated pest management practices under the present trial (Appendix III). The highest number of healthy fruits per plot (18.87) was recorded in T_6, which was statistically similar with T_8 (18.20 fruits/plot), followed by T_2 (17.20 fruits/plot) and T_5 (16.53 fruits/plot) respectively (Table 2). On the other hand, the lowest number of healthy fruits per plot (10.27) was recorded in T_9, which was statistically similar with T_1 (12.67 fruits/plot) and T_4 (11.93 fruits/plot) treatments. Accordingly, the highest number of infested fruit per plot (3.13) was recorded in T_9, which was statistically different from all other treatments and the lowest number of infested fruits per plot was recorded in T_6 (1.27 fruits/plot), which was statistically similar with T_8 (1.47 fruits/plot). Considering the level of infestation, the lowest percent fruit infestation

(6.29%) was recorded in T_6, which was statistically similar with T_8 (7.49%), followed by T_2 (9.69%). On the other hand, the highest percent fruit infestation was recorded in T_9 (23.41%), which was significantly different from other treatments (Table 2). Fruit infestation reduction over control in number was estimated and the highest percent decrease of fruit infestation over control (73.12%) was observed in T_6 (Table 2), followed by T_8 (67.76%), T_2 (58.07%) and T_5 (54.56%).Whereas the lowest reduction of fruit infestation over control was observed in T_4 (20.62%) followed by T_1 (27.17%) and T_7 (36.29%). The result agrees with the findings of Rahman *et al*. (2011) who reported that spraying of chemical insecticides and botanicals comparatively effective against tomato fruit borer.

Table 2. Effect of different control practices on fruit infestation by number at early fruiting stage

Treatments	Tomato fruit by number			
	Healthy	**Infested**	**% Infestation**	**%infestation decrease over control**
T_1	12.67 cd	2.60 b	17.01 bc	27.17 ef
T_2	17.20 a	1.80 de	9.69 ef	58.07 bc
T_3	14.33 bc	2.27 bcd	13.71 d	40.91 d
T_4	11.93 cd	2.73 ab	18.58 b	20.62 f
T_5	16.53 ab	1.93 cde	10.53 e	54.56 c
T_6	18.87 a	1.27 f	6.29 g	73.12 a
T_7	13.87 c	2.40 bc	14.81 cd	36.29 de
T_8	18.20 a	1.47 ef	7.49 fg	67.76 ab
T_9	10.27 d	3.13 a	23.41 a	--
LSD	**2.52**	**0.45**	**2.60**	**10.03**
CV (%)	**9.78**	**11.95**	**11.14**	**12.10**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

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

T_1 = Vertical Support

T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_4 = Horizontal Support

T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_9 = Untreated Control

4.2.2 Fruit infestation by weight at early fruiting stage

Statistically significant variation was recorded by weight of healthy and infested fruit, percent infestation at early fruiting stage using integrated pest management practices for controlling tomato fruit borer (Appendix IV).The highest weight of healthy fruit per plot (1949.20 g) was recorded from the treatment T_6 which was statistically identical with T_8 (1811.90 g), T_2 (1717.60 g) and T_5 (1629.10 g) respectively (Table 3). On the other hand the lowest (858.40 g) weight of healthy fruit was recorded from the untreated control (T_9) which was followed by T_4 (1055.30 g) and T_1 (1125.70). The lowest weight of infested fruit (109.33 g) was recorded from the treatment T_6 which was followed (129.33 g) by the treatment T_8, while the highest weight of infested fruit (262.13 g) was recorded from untreated control. The lowest percent of infested fruit by weight (5.32%) was recorded from the treatment T_6 which was followed by the treatment T_8 (6.76%). On the other hand the highest percent of infested fruit by weight (23.41%) was recorded from untreated control.

Fruit infestation reduction over control by weight was calculated as the highest (77.30%) from the treatment T_6 followed by T_8 (70.97%) and the lowest reduction over control was obtained from the treatment T_4 (24.14%) and T_1 (31.69%) (Table 3). From the findings it is revealed that T_6 had to potential to produce the highest number of healthy fruit and the lowest number of infested fruit and the lowest percent of fruit infestation by weight.

Table 3. Effect of different control practices on fruit infestation by weight at early fruiting stage

Treatments	Tomato fruit by weight (g)			
	Healthy	**Infested fruit**	**% infestation**	**%infestation decrease over control**
T_1	1125.70 def	213.90 b	15.98 b	31.69 e
T_2	1717.60 ab	153.80 d	8.42 de	63.64 bc
T_3	1402.20 bcd	197.80 bc	12.35 c	46.87 d
T_4	1055.30 ef	228.10 ab	17.72 b	24.14 e
T_5	1629.10 abc	166.47 cd	9.40 d	59.46 c
T_6	1949.20 a	109.33 e	5.32 f	77.30 a
T_7	1344.10 cde	199.00 bc	12.96 c	44.23 d
T_8	1811.90 a	129.33 de	6.76 ef	70.97 ab
T_9	858.40 f	262.13 a	23.41 a	--
LSD	**303.20**	**40.37**	**2.47**	**9.87**
CV (%)	**12.23**	**12.65**	**11.44**	**10.78**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

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

T_1 = Vertical Support

T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_4 = Horizontal Support

T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_9 = Untreated Control

4.2.3 Fruit infestation by number at mid fruiting stage

Statistically significant variation was recorded in number of healthy and infested fruit, percent fruit infestation at mid fruiting stage against tomato fruit borer using different integrated pest management practices under the present trial (Appendix V). The highest number of healthy fruits per plot (31.33) was recorded in T_6, which was statistically similar with T_8 (29.80 fruit/plot). On the other hand, the lowest number of healthy fruits per plot (16.60) was recorded in T_9, which was significantly different from other treatments (Table 4). Accordingly, the highest number of infested fruit per plot (4.40) was recorded in T_9, followed by T_4 (3.93 fruits/plot) and T_1 (3.87 fruits/plot) treatments. The lowest number of infested fruits per plot was recorded in T_6 (2.13) and T_8 (2.33), which was statistically similar with T_2 (2.53 fruits/plot) and T_5 (2.73 fruits/plot). Considering the level of infestation, the lowest percent fruit infestation (6.38%) was recorded in T_6, which was statistically similar with T_8 (7.31%) and T_2 (8.64%). On the other hand, the highest percent fruit infestation was recorded in T_9 (21.02%), which was significantly different with other treatments (Table 2). This result agrees with the findings of Ali *et al.* (2009) who reported that insecticide, botanicals along with plants support performed best against fruit borer. Fruit infestation reduction over control in number was estimated and the highest percent decrease of fruit infestation over control (69.39%) was observed in T_6 (Table 2), followed by T_8 (64.58%), T_2 (59.07%) and T_5 (55.65%).Whereas the lowest reduction of fruit infestation over control was observed in T_4 (21.14%) followed by T_1 (30.47%) treatments.

Table 4. Effect of different control practices on fruit infestation by number at mid fruiting stage

Treatments	Tomato fruit by number			
	Healthy	**Infested**	**% Infestation**	**%infestation decrease over control**
T_1	22.67 de	3.87 a	14.58 b	30.47 c
T_2	27.07 bc	2.53 cd	8.64 cde	59.07 ab
T_3	25.13 cd	3.07 bc	10.89 c	48.22 b
T_4	20.33 e	3.93 a	16.39 b	21.14 c
T_5	26.70 bc	2.73 bcd	9.32 cd	55.65 ab
T_6	31.33 a	2.13 d	6.38 e	69.39 a
T_7	24.60 cd	3.20 b	11.47 c	45.11 b
T_8	29.80 ab	2.33 d	7.31 e	64.58 a
T_9	16.60 f	4.40 a	21.02 a	--
LSD	**3.46**	**0.59**	**2.63**	**13.15**
CV (%)	**8.02**	**10.82**	**12.90**	**15.27**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

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

T_1 = Vertical Support

T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_4 = Horizontal Support

T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_9 = Untreated Control

4.2.4 Fruit infestation by weight at mid fruiting stage

Statistically significant variation was recorded by weight of healthy and infested fruit, percent infestation at mid fruiting stage using integrated pest management practices for controlling tomato fruit borer (Appendix VI).The highest weight of healthy fruit per plot (3146.30 g) was recorded from the treatment T_6 which was statistically identical with T_8 (2876.70 g). On the other hand the lowest (1338.20 g) weight of healthy fruit was recorded from the untreated control (T_9) which was statistically similar with T_4 (1722.40 g) treatments (Table 5). The lowest weight of infested fruit (179.80 g) was recorded from the treatment T_6 which was followed by the treatment T_8 (200.73 g) and T_2 (210.40 g), while the highest weight of infested fruit (359.70 g) was recorded from untreated control followed by T_4 (320.20 g) treatments. The lowest percent of infested fruit by weight (5.43%) was recorded from the treatment T_6 which was followed by the treatment T_8 (6.62%) and T_2 (7.55%). On the other hand the highest percent of infested fruit by weight (21.23%) was recorded from untreated control.

Fruit infestation reduction over control by weight was calculated as the highest (74.15%) from the treatment T_6 followed by T_8 (68.14%), T_2 (64.55%) and T_5 (60.69%) respectively (Table 5) and the lowest percent reduction over control was obtained from the treatment T_4 (24.80%) and T_1 (35.12%). From the findings it was revealed that T_6 had to potential to produce the highest number of healthy fruit and the lowest number of infested fruit and the lowest percent of fruit infestation by weight was also evident.

Table 5. Effect of different control practices on fruit infestation by weight at mid fruiting stage

Treatments	Tomato fruit by weight (g)			
	Healthy	Infested fruit	% infestation	%infestation decrease over control
T_1	1947.30 de	310.00 b	13.76 b	35.12 c
T_2	2624.70 bc	210.40 de	7.55 cde	64.55 ab
T_3	2383.70 c	258.20 c	9.86 c	53.53 b
T_4	1722.40 ef	320.20 ab	15.75 b	24.80 c
T_5	2532.90 bc	230.10 cd	8.33 cd	60.69 ab
T_6	3146.30 a	179.80 e	5.43 e	74.15 a
T_7	2314.50 cd	260.10 c	10.06 c	52.66 b
T_8	2876.70 ab	200.73 de	6.62 de	68.14 a
T_9	1338.20 f	359.70 a	21.23 a	--
LSD	**386.00**	**43.65**	**2.52**	**12.56**
CV (%)	**9.61**	**9.74**	**13.30**	**13.23**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

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

T_1 = Vertical Support

T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_4 = Horizontal Support

T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_9 = Untreated Control

4.2.5 Fruit infestation by number at late fruiting stage

Statistically significant variation was recorded in number of healthy and infested fruit, percent fruit infestation at late fruiting stage against tomato fruit borer using different integrated pest management practices under the present trial (Appendix VII). The highest number of healthy fruits per plot (43.20) was recorded in T_6, which was statistically similar with T_8 (41.33 fruit/plot). On the other hand, the lowest number of healthy fruits per plot (24.83) was recorded in T_9, followed by T_4 (27.70 fruits/plot) and T_1 (29.87 fruits/plot) treatments (Table 6). Accordingly, the highest number of infested fruit per plot (5.07) was recorded in T_9, followed by T_4 (4.40 fruits/plot) treatments. The lowest number of infested fruits per plot was recorded in T_6 (2.60), which was statistically similar with T_8 (2.73 fruits/plot), T_2 (3.07 fruits/plot) and T_5 (3.13 fruits/plot) respectively. Considering the level of infestation, the lowest percent fruit infestation (5.69%) was recorded in T_6, which was statistically similar with T_8 (6.23%), T_2 (7.50%) and T_5 (7.96%) treatments. On the other hand, the highest percent fruit infestation was recorded in T_9 (17.00%), which was significantly different with other treatments (Table 6). Fruit infestation reduction over control in number was estimated and the highest percent decrease of fruit infestation over control (65.96%) was observed in T_6 (Table 2), followed by T_8 (63.45%) and T_2 (55.49%).Whereas the lowest reduction of fruit infestation over control was observed in T_4 (19.28%) followed by T_1 (27.15%) treatments.

Table 6. Effect of different control practices on fruit infestation by number at late fruiting stage

Treatments	Tomato fruit by number			
	Healthy	**Infested**	**% Infestation**	**%infestation decrease over control**
T_1	29.87 de	4.20 bc	12.38 b	27.15 e
T_2	37.80 bc	3.07 def	7.50 cd	55.49 abc
T_3	33.93 cd	3.40 de	9.09 c	45.60 cd
T_4	27.70 e	4.40 ab	13.74 b	19.28 e
T_5	36.40 bc	3.13 def	7.96 cd	52.04 bcd
T_6	43.20 a	2.60 f	5.69 d	65.96 a
T_7	32.83 cd	3.53 cd	9.75 c	42.34 d
T_8	41.33 ab	2.73 ef	6.23 d	63.45 ab
T_9	24.83 e	5.07 a	17.00 a	--
LSD	**4.86**	**0.69**	**2.19**	**11.14**
CV (%)	**8.23**	**11.26**	**12.76**	**13.71**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

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

T_1 = Vertical Support

T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_4 = Horizontal Support

T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_9 = Untreated Control

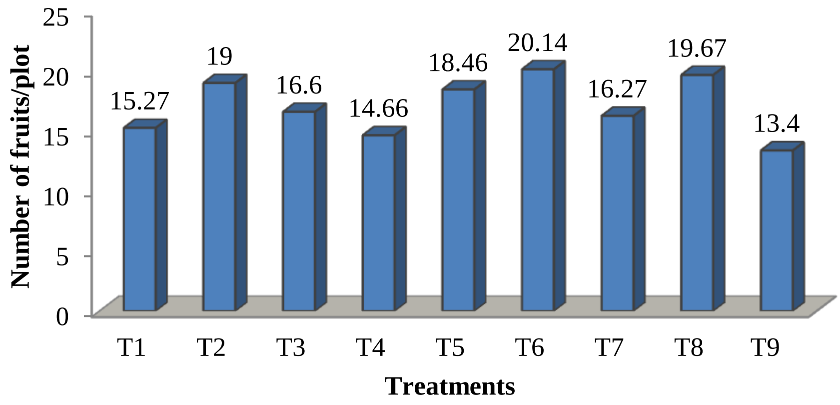


Figure 1. Total number of fruits/plot treated with different control practices at early fruiting stage

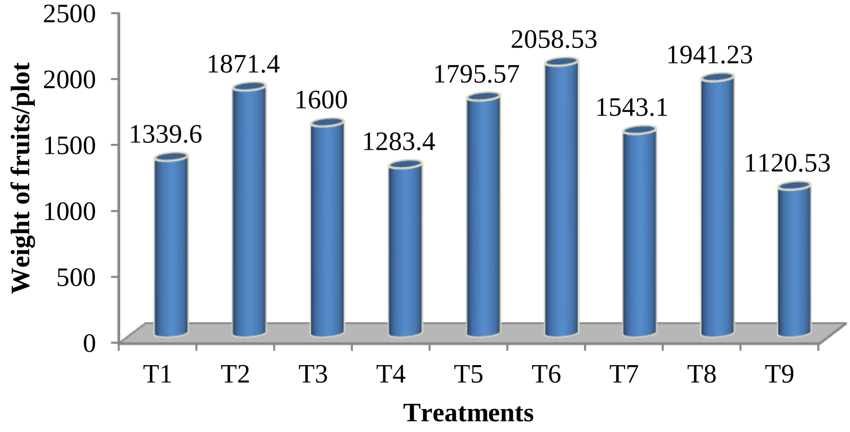


Figure 2. Total weight of fruits/plot treated with different control practices at early fruiting stage

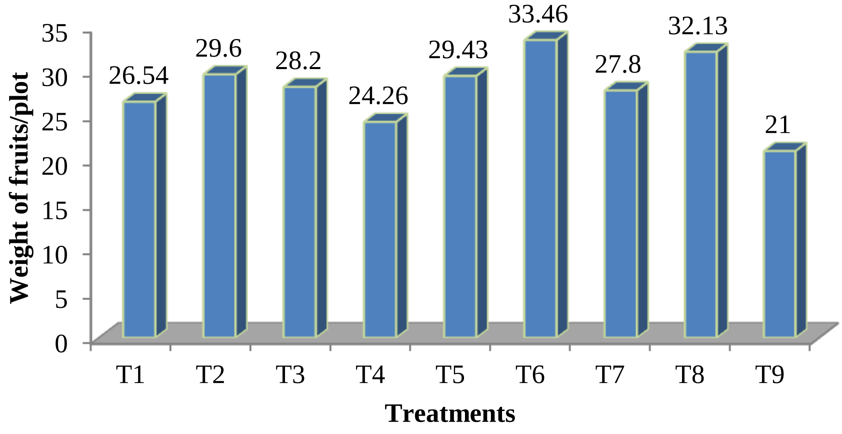


Figure 3. Total number of fruits/plot treated with different control practices at mid fruiting stage

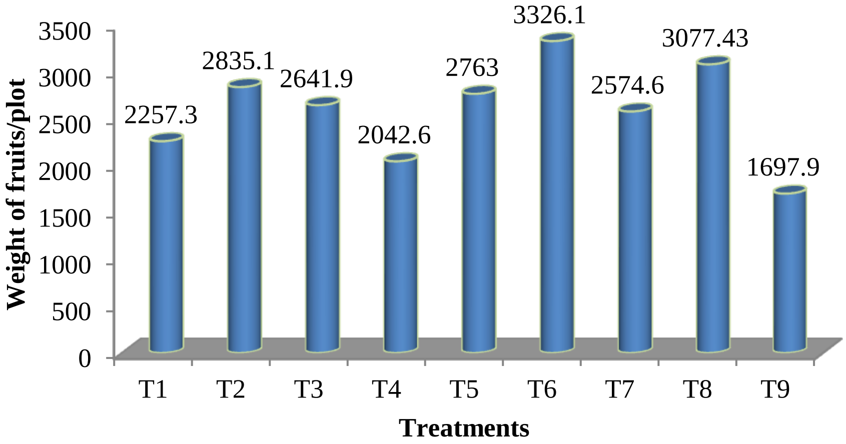


Figure 4. Total weight of fruits/plot treated with different control practices at mid fruiting stage

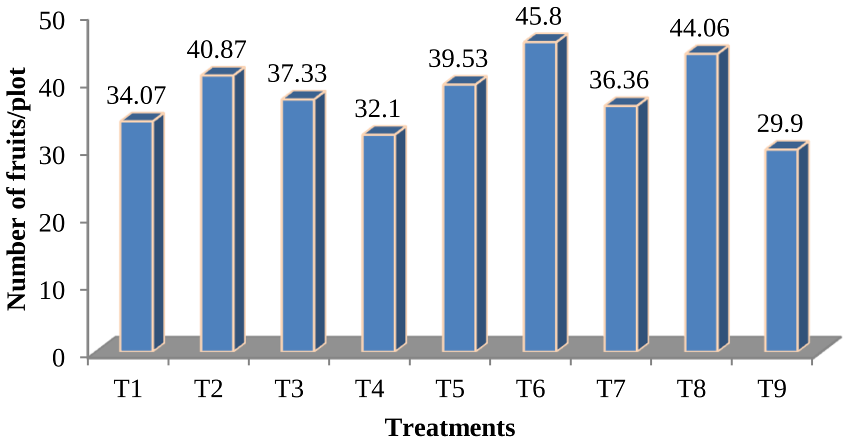


Figure 5. Total number of fruits/plot treated with different control practices at late fruiting stage

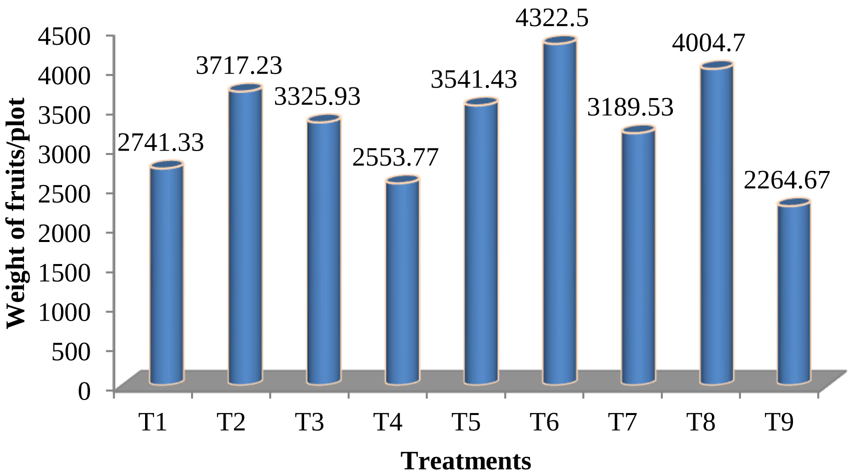


Figure 6. Total weight of fruits/plot treated with different control practices at late fruiting stage

4.2.4 Fruit infestation by weight at late fruiting stage

Statistically significant variation was recorded by weight of healthy and infested fruit, percent infestation at early fruiting stage using integrated pest management practices for controlling tomato fruit borer (Appendix VIII).The highest weight of healthy fruit per plot (4115.50 g) was recorded from the treatment T_6 which was statistically identical with T_8 (3782.30 g). On the other hand the lowest (1876.40 g) weight of healthy fruit was recorded from the untreated control (T_9) which was statistically similar with T_4 (2217.70 g) and T_1 (2424.40 g) treatments (Table 7). The lowest weight of infested fruit (207.00 g) was recorded from the treatment T_6 which was followed by the treatment T_8 (222.40 g), T_2 (240.93 g) and T_5 (248.33 g) respectively while the highest weight of infested fruit (388.27 g) was recorded from untreated control followed by T_4 (336.07 g) treatments. The lowest percent of infested fruit by weight (4.79%) was recorded from the treatment T_6 which was followed by the treatment T_8 (5.59%), T_2 (6.48%) and T_5 (7.09%) respectively. On the other hand the highest percent of infested fruit by weight (17.18%) was recorded from untreated control.

Fruit infestation reduction over control by weight was calculated as the highest (71.83%) from the treatment T_6 followed by T_8 (67.57%) and T_2 (62.02%) respectively (Table 7) and the lowest percent reduction over control was obtained from the treatment T_3 (23.49%) and T_1 (31.99%). From the findings it is revealed that T_6 had to potential to produce the highest number of healthy fruit and the lowest number of infested fruit and the lowest percent of fruit infestation by weight was also evident.

Table 7. Effect of different control practices on fruit infestation by weight at late fruiting stage

Treatments	Tomato fruit by weight (g)			
	Healthy	Infested fruit	% infestation	%infestation decrease over control
T_1	2424.40 de	316.93 bc	11.70 b	31.99 d
T_2	3476.30 bc	240.93 d	6.48 cd	62.02 abc
T_3	3057.00 c	268.93 cd	8.16 c	23.49 d
T_4	2217.70 e	336.07 ab	13.14 b	51.98 c
T_5	3293.10 bc	248.33 d	7.09 cd	57.77 bc
T_6	4115.50 a	207.00 d	4.79 d	71.83 a
T_7	2917.00 cd	272.53 cd	8.48 c	50.17 c
T_8	3782.30 ab	222.40 d	5.59 d	67.57 ab
T_9	1876.40 e	388.27 a	17.18 a	--
LSD	**529.20**	**60.53**	**2.29**	**12.20**
CV (%)	**10.13**	**12.58**	**14.44**	**13.38**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

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

T_1 = Vertical Support

T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_4 = Horizontal Support

T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_9 = Untreated Control

4.3 Fruit bearing status of tomato

4.3.1 Tomato fruits by number

As shown in Table 8 the highest number of fruit per plot (99.40) was recorded from the treatment T_6 which was followed (95.86) by the treatment T_8. The next highest fruit per plant was recorded from T_2 (89.47) treated plots which was followed by T_5 (87.42) treated ones. The lowest (64.30) number of total fruit was recorded from untreated control which was followed (71.02) by T_4 treated plots. The highest number of healthy fruit per plant (93.40) was recorded from the treatment T_6 which was statistically identical (89.33) to those of T_8 treated plots. On the other hand the lowest (51.70) number of healthy fruit was recorded from untreated control which was statistically similar (59.96) to those T_4 treated plots. The lowest number of infested fruits/plot (6.00) was recorded from T_6 treatments followed by T_8 (6.53) treatments. The second lowest number of infested fruits/plot was recorded in T_2 (7.40) having no significance difference with T_5 (7.79) treatments. The highest number of infested fruits/plot was recorded from T_9 (12.60), which was showing significant difference with other treatments.

The lowest percent of infestation in fruit by number (6.12%) was recorded from the treatment T_6 and this was statistically similar (6.97%) to those of the treatment T_8. In T_2 (8.51%) treatment the percent infestation was also lower which was followed by T_5 (9.22%). On the other hand the highest percent of infestation (20.42%) was recorded from untreated control which showed significance difference with other treatments. Fruit infestation decrease over control in number was calculated to be the highest (69.71%) in the treatment T_6 followed by T_8 (65.62%) treatments. The lowest (20.71%) was recorded from the treatment T_4. From the findings it was revealed that treatment the treatment T_6 produced the highest number of healthy fruits and the lowest number of infested fruit, as well as the lowest percent of fruit infestation by number, whereas in control treatment the situation was reverse.

Table 8. Effect of different control practices in controlling tomato fruit borer in terms of fruits per plot in number during total cultivation period of October 2016 to April 2017

Treatments	Tomato fruit/plot by number				
	Total	Healthy	Infested	% infestation	%infestation decrease over control
T_1	75.88 ef	65.21 ef	10.67 b	14.65 b	28.27 d
T_2	89.47 bc	82.07 bc	7.40 d	8.51 de	58.12 b
T_3	82.13 cde	73.39 cde	8.74 c	11.22 c	45.26 c
T_4	71.02 fg	59.96 fg	11.06 b	16.18 b	20.71 e
T_5	87.42 bcd	79.63 cd	7.79 d	9.22 d	54.76 b
T_6	99.40 a	93.40 a	6.00 e	6.12 f	69.71 a
T_7	80.43 de	71.30 de	9.13 c	11.99 c	41.55 c
T_8	95.86 ab	89.33 ab	6.53 e	6.97 ef	65.62 a
T_9	64.30 g	51.70 g	12.60 a	20.42 a	--
LSD	**8.17**	**8.61**	**0.79**	**1.74**	**4.32**
CV (%)	**5.70**	**6.72**	**5.19**	**8.83**	**5.14**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

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

T_1 = Vertical Support

T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_4 = Horizontal Support

T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_9 = Untreated Control

4.3.2 Tomato fruit by weight

Statistically significant variation was recorded by weight of total, healthy and infested fruit, percent infestation controlling using integrated pest management practices against tomato fruit borer. The highest weight of total fruit per plot (9707.13 g) was recorded from the treatment T_6 which was followed (9023.36 g) with the treatment T_8 (Table 9). On the other hand, the lowest (5083.10 g) weight of fruit per plot was recorded from untreated control which was followed (5879.77 g) by the treatment T_4. The highest weight of healthy fruit per plot (9211.00 g) was calculated from the treatment T_6 and these was followed (8470.90 g) to that of the treatment T_8 (Table 9). On the other hand, the lowest (4073.00 g) weight of healthy fruit was recorded from untreated control T_9 which was followed by the treatment T_4 (4995.40 g).

The lowest percent of infested fruit by weight (5.17%) was calculated from the treatment T_6 which was followed (6.25%) by the T_8 treated plots. On the other hand the highest percent of infested fruit by weight (20.57%) was recorded from untreated control which was showed significant difference with other treatments. Percent infestation was also higher in T_4 (15.54%) and T_1 (13.75%) treatments. Fruit infestation reduction over control by weight was calculated the highest (74.62%) infestation reduction over control was calculated from the treatment T_6 and the lowest (24.42%) was recorded from T_4 treated plots. From the findings it is revealed that the treatment T_6 produced the highest number of healthy fruit and the lowest infested fruit as well as the lowest percent of fruit infestation by weight whereas in control treatment the results is reverse.

Table 9. Effect of different control practices in controlling tomato fruit borer in terms of fruits per plot in weight during the cultivation period of October 2016 to April 2017

Treatments	Tomato fruit/plot by weight (g)				
	Total	Healthy	Infested	% infestation	% infestation decrease over control
T_1	6338.23 e	5497.40 e	840.80 b	13.75 c	33.16 e
T_2	8424.74 bc	7818.60 bc	605.10 de	7.37 ef	64.01 c
T_3	7568.83 cd	6842.90 cd	724.90 c	10.07 d	51.29 d
T_4	5879.77 ef	4995.40 ef	884.40 b	15.54 b	24.42 f
T_5	8100.00 bcd	7455.10 bcd	644.90 d	8.20 e	60.05 c
T_6	9707.13 a	9211.00 a	496.10 f	5.17 g	74.62 a
T_7	7307.23 d	6576.60 d	731.60 c	10.51 d	49.12 d
T_8	9023.36 ab	8470.90 ab	552.50 e	6.25 fg	69.45 b
T_9	5083.10 f	4073.00 f	1010.00 a	20.57 a	--
LSD	**967.30**	**989.20**	**53.92**	**1.73**	**3.98**
CV (%)	**7.46**	**8.44**	**4.32**	**9.23**	**4.27**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

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

T_1 = Vertical Support
T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval
T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval
T_4 = Horizontal Support
T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval
T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval
T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval
T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval
T_9 = Untreated Control

4.3.3 Effect on yield of tomato

The effect of management practices on the yield of tomato are shown in Table 10. Significant variations were observed among the treatments in terms of yield of tomato. The highest yield (9.71 kg/plot) was recorded in T_6, which was statistically similar with T_8 (9.02 kg/plot), followed by T_2 (8.24 kg/plot) and T_5 (8.10 kg/plot). On the other hand, the lowest yield (5.08 kg/plot) was recorded in T_9, which was statistically similar with T_4 (5.88 kg/plot) treatments.

Considering the yield of tomato in ton/ha, the highest yield (32.36 ton/ha) was recorded in T_6, which was statistically identical with T_8 (30.08 ton/ha), followed by T_2 (28.08 ton/ha) and T_5 (27.00 ton/ha). On the other hand, the lowest yield (16.94 ton/ha) was recorded in T_9, which was statistically similar with T_4 (19.60 kg/plot) treatment.

Table 10. Effect of different control practices on yield of tomato

Treatments	Yield (Kg/plot)	Yield (ton/ha)	%Yield increase over control
T_1	6.34 e	21.13 e	19.51 e
T_2	8.24 bc	28.08 bc	39.77 c
T_3	7.57 cd	25.23 cd	32.54 d
T_4	5.88 ef	19.60 ef	13.63 f
T_5	8.10 bcd	27.00 bcd	37.40 c
T_6	9.71 a	32.36 a	47.38 a
T_7	7.31 d	24.36 d	30.14 d
T_8	9.02 ab	30.08 ab	43.52 b
T_9	5.08 f	16.94 f	--
LSD	**0.97**	**3.22**	**2.86**
CV (%)	**7.46**	**7.46**	**4.96**

In a column, numeric data represents the mean value of 3 replications; each replication is derived from 5 plants per treatment

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

T_1 = Vertical Support

T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_4 = Horizontal Support

T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_9 = Untreated Control

4.4 Relationship between fruit infestation and yield of tomato

4.4.1 Early fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number at early fruiting stage and yield (t/ha) of tomato during the management of fruit borer. From the study it was revealed that significant correlation was observed between the fruit infestation and yield of tomato (Figure 1). It was evident from the Figure 1 that the regression equation y = -0.893x + 37.03 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.981) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation and yield of tomato, i.e., the yield decreased with the increase of the infestation of fruit with fruit borer at early fruiting stage.

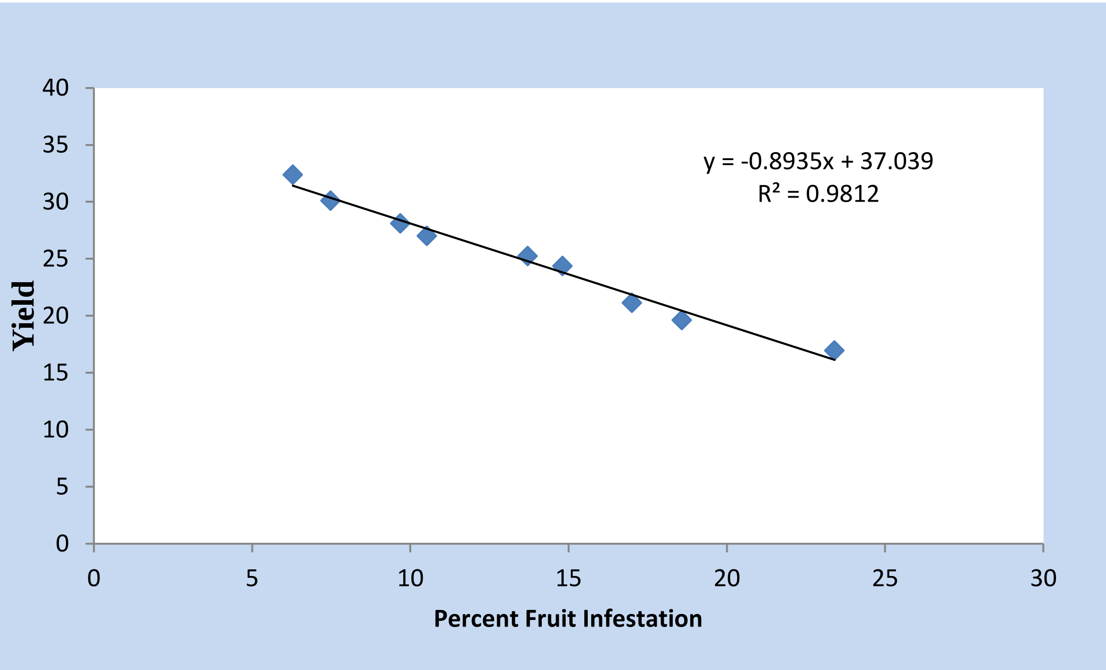


Figure 7. Relationship between percent fruit infestation by number and yield at early fruiting stage

4.4.2 Mid fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number at mid fruiting stage and yield (t/ha) of tomato during the management of fruit borer. From the study it was revealed that significant correlation was observed between the fruit infestation and yield of tomato (Figure 2). It was evident from the Figure 2 that the regression equation y = -1.037x + 37.2 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.957) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation and yield of tomato, i.e., the yield decreased with the increase of the infestation of fruit with fruit borer at mid fruiting stage.

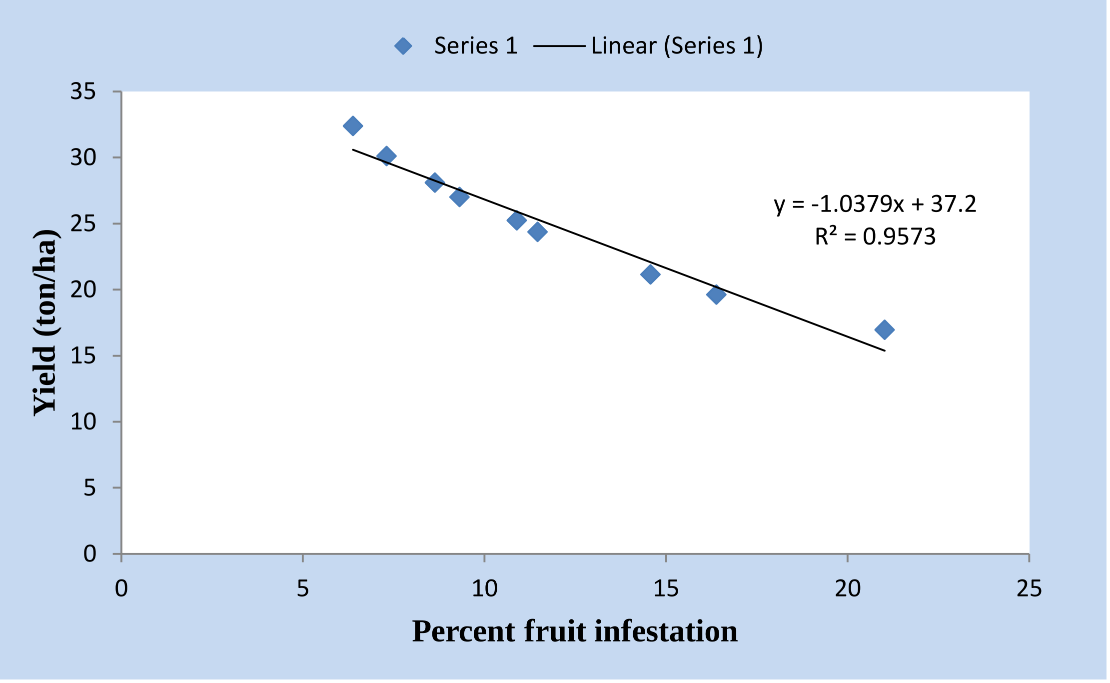


Figure 8. Relationship between percent fruit infestation by number and yield at mid fruiting stage

4.4.3 Late fruiting stage

Correlation study was done to establish the relationship between the percent fruit infestation by number at late fruiting stage and yield (t/ha) of tomato during the management of fruit borer. From the study it was revealed that significant correlation was observed between the fruit infestation and yield of tomato (Figure 3). It was evident from the Figure 3 that the regression equation y = -1.318x + 38.06 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.964) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a negative relationship between fruit infestation and yield of tomato, i.e., the yield decreased with the increase of the infestation of fruit with fruit borer at late fruiting stage.

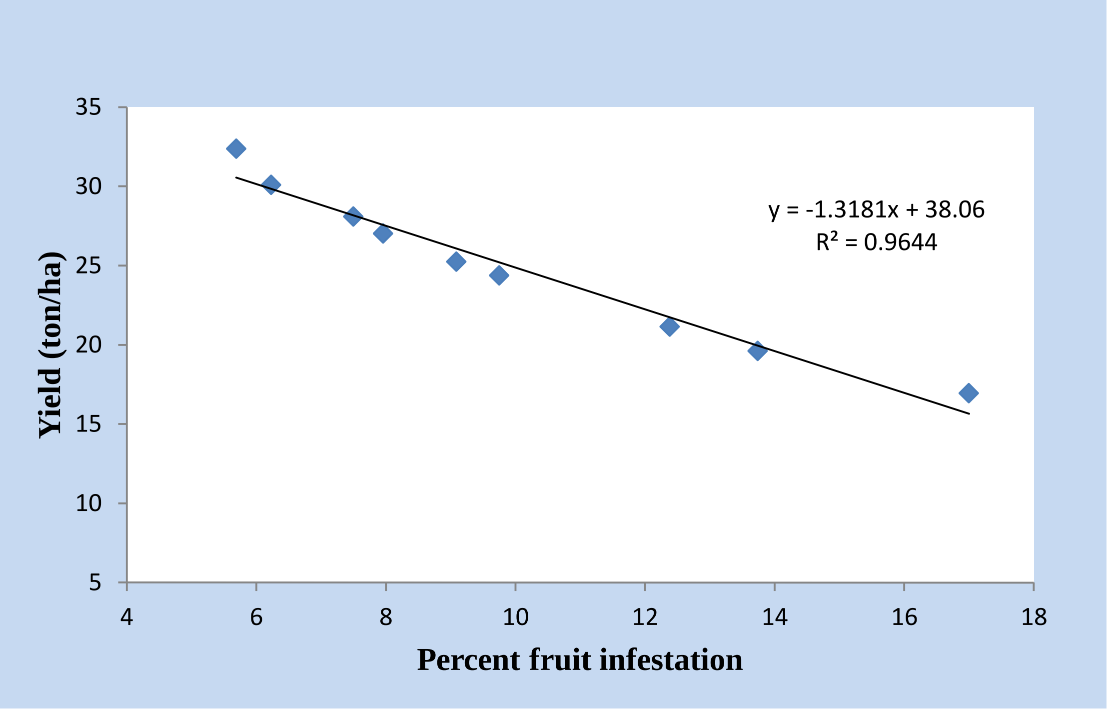


Figure 9. Relationship between percent fruit infestation by number and yield at late fruiting stage

4.4.4 Relationship between fruit weight per plot and yield

Correlation study was done to establish the relationship between the fruit weight per plot and yield (t/ha) of tomato during the management of fruit borer. From the study it was revealed that significant correlation was observed between the fruit weight per plot and yield of tomato (Figure 4). It was evident from the Figure 4 that the regression equation y = 3.359x – 0.125 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.998) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis, it was evident that there was a positive relationship between fruit weight per plot and yield of tomato, i.e., the yield increased with the increase of the fruit weight per plot.

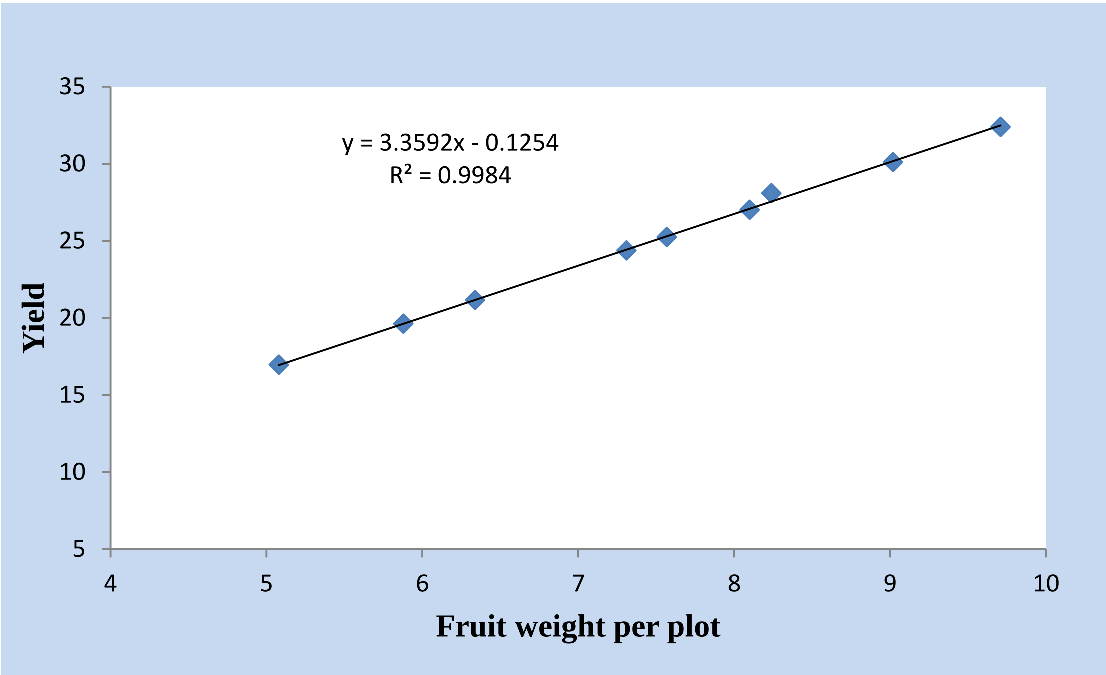


Figure 10. Relationship between fruit weight per plot and yield

4.4.5 Relationship between number of fruit per plot and yield

Correlation study was done to establish the relationship between the number of fruit per plot and yield (t/ha) of tomato during the management of fruit borer. From the study it was revealed that significant correlation was observed between the number of fruit per plot and yield of tomato (Figure 5). It was evident from the Figure 5 that the regression equation y = 0.438x – 11.37 gave a good fit to the data, and the coefficient of determination (R^2 = 0.992) showed that, fitted regression line had a significant regression co-efficient. From this regression analysis it was evident that there was a positive relationship between number of fruit per plot and the yield of tomato, i.e., the yield increased with the increase of the number of fruit per plot.

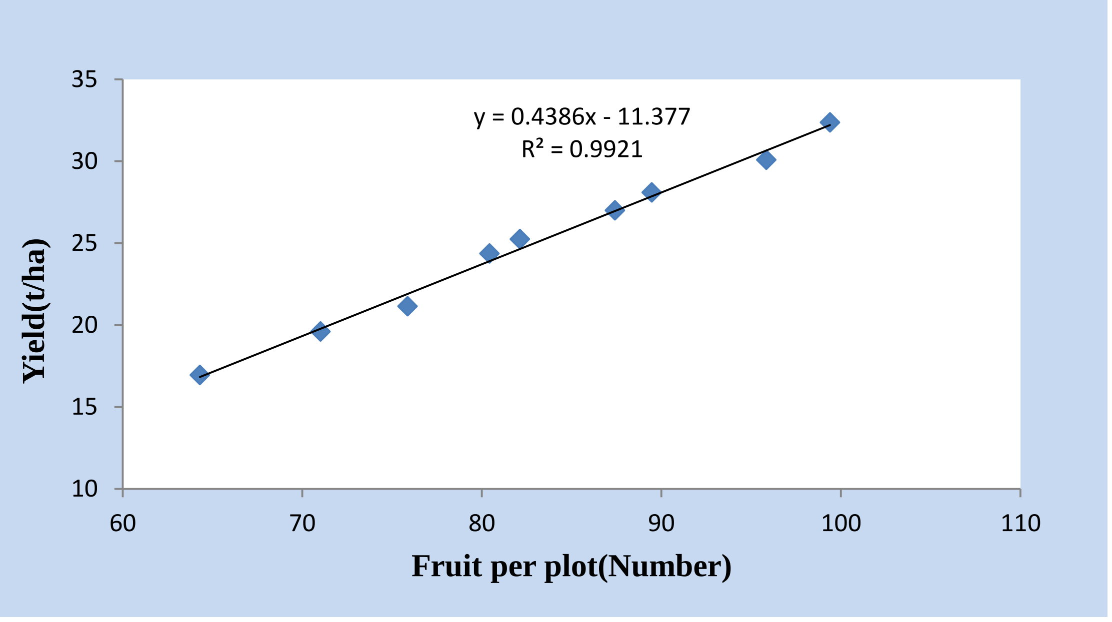


Figure 11. Relationship between fruit per plot and yield

4.5 Economic analysis of different control practices

The analysis was done in order to find out the profitable treatment based on cost and benefit of various components. Non-materials and overhead cost were recorded for all the treatments of unit plot and calculated on ha^{-1} basis (marketable yield). The price of tomato fruits at the local market rate was considered. The result of economic analysis of tomato cultivation showed that the highest gross return of Tk. 1132600 ha^{-1} was obtained in T_6 treatment and the second highest gross return was found Tk. 1052800 ha^{-1} in T_8 treatment. Among the different treatment, the minimum BCR was counted from T_4 (0.74) treatment while T_6 (Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval) gave the maximum net return Tk. 990200 where BCR was 2.79 and minimum net return Tk. 592900 from untreated control (Table 11).

Table 11. Benefit cost ratio (BCR) of tomato due to different control practices

Treatments	Cost of management (Tk)	Yield (t/ha)	Gross return (Tk)	Net return (Tk)	Adjusted net return (Tk)	Benefit cost ratio (BCR)
T_1	75790	21.13	739550	663760	70860	0.93
T_2	124200	28.08	982800	858600	265700	2.14
T_3	108750	25.23	883050	774300	181400	1.67
T_4	53430	19.60	686000	632570	39670	0.74
T_5	116250	27.00	945000	828750	235850	2.03
T_6	142400	32.36	1132600	990200	397300	2.79
T_7	99100	24.36	852600	753500	160600	1.62
T_8	129600	30.08	1052800	923200	330300	2.55
T_9	00	16.94	592900	592900	--	--

Wholesale price of tomato at that time, 1 kg = 35 Tk.

T_1 = Vertical Support

T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_4 = Horizontal Support

T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval

T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval

T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval

T_9 = Untreated Control

CHAPTER V
SUMMARY AND CONCLUSION

The study was conducted during October, 2016 to April 2017 at the central farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka to develop an IPM approach in controlling insect pests of tomato. The experiment consisted of 9 treatments such as T_1 = Vertical Support, T_2 = Vertical Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval, T_3 = Vertical Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval, T_4 = Horizontal Support, T_5 = Horizontal Support + Neem Oil @ 3 ml/L of water 5 times at 7 days interval, T_6 = Horizontal Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval, T_7 = No Support + Bishkatali @ 20 gm/L of water 3 times at 3 days interval, T_8 = No Support + Marshal 20EC @ 3 ml/L of water 5 times at 7 days interval, T_9 = Untreated Control. The experiment laid out in one factor Randomized Complete Block Design (RCBD) with three replications. Data were collected in respect of number of whitefly abundant, fruit borer infestation and their effect of yield contributing characters and yield were recorded. The data obtained for different characters were statistically analyzed to find out the significance level of the treatments.

At vegetative stage the lowest number of whitefly per plot (2.67) was recorded from the treatment T_6 plots having application of Marshal 20EC (@ 3.0ml/L of water + vertical support) at 7 days interval and the highest (22.40) number of whitefly per plot was recorded from T_9 untreated control plot. At early flowering stage the lowest number of whitefly per plot (3.20) was recorded from T_6 treated plots which was statistically similar (3.73) with that of treatment T_8 and the highest (24.07) number of white fly per plot was recorded from untreated control plot. At early fruiting stage the lowest number of whitefly per plot (3.07) was recorded from the treatment T_6 which was statistically similar (3.53) with that of treatment T_8 while the highest (23.60) number of white fly per plot was recorded from untreated control plot. At ripening stage the lowest number of whitefly per plot (2.73) was recorded from T_6 treated plots which was statistically identical (3.07) that of the treatment T_8 and the highest (22.07) number of whitefly per plot was recorded from untreated control plots (T_9).

The highest number of fruit per plot (99.40) was recorded from the treatment T_6 which was followed (95.86) by the treatment T_8. The next highest fruit per plant was recorded from T_2 (89.47) treated plots which was followed by T_5 (87.42) treated ones. The lowest (64.30) number of total fruit was recorded from untreated control which was followed (71.02) by T_4 treated plots. The highest number of healthy fruit per plant (93.40) was recorded from the treatment T_6 and the lowest (51.70) number of healthy fruit was recorded from untreated control. The lowest number of infested fruits/plot (6.00) was recorded from T_6 treatments and The highest number of infested fruits/plot was recorded from T_9 (12.60). The lowest percent of infestation in fruit by number (6.12%) was recorded from the treatment T_6 and the highest percent of infestation (20.42%) was recorded from untreated control.

The highest weight of total fruit per plot (9707.13 g) was recorded from the treatment T_6 which was followed (9023.36 g) with the treatment T_8. The lowest (5083.10 g) weight of fruit per plot was recorded from untreated control. The highest weight of healthy fruit per plot (9211.00 g) was calculated from the treatment T_6 and the lowest (4073.00 g) weight of healthy fruit was recorded from untreated control T_9. The lowest percent of infested fruit by weight (5.17%) was calculated from the treatment T_6 which was followed (6.25%) by the T_8 treated plot. On the other hand the highest percent of infested fruit by weight (20.57%) was recorded from untreated control (T_9) plot. The highest weight of fruit per hectare (32.26 t) was recorded from the T_6 treatment and the lowest (16.94 t) fruit per hectare was recorded from untreated control.

Among the different treatments Marshal 20EC @ 3ml/L of water 5 times at 7 days interval + Horizontal support was most effective than other treatments. The other treatments like Neem oil @ 3ml/L of water 5 times at 7dats interval + Vertical/Horizontal support also showed the better performance for organic production of tomato in relation to all concern parameters comparing to that Bishkatali and only horizontal/vertical support.

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

1) Similar study is needed in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.

2) More mechanical and botanical treatments against tomato insect pests may be needed to include for future study either solely or different combination to avoid total rely on insecticides.

CHAPTER VI

REFERENCES

Ahmed, N.E., Kanan, H.O., Sugimoto, Y., Ma, Y.Q. and Inanaga, S. (2001). Effect of Imidacloprid on incidence of *Tomato yellow leaf curl virus*. *Plant Disease*. **85**: 84-87.

Alam, M.Z., Ali, M., Akanda, A.M., Choudhury, D.A.M., Haque, N.M.M., Hossain, M.M. and Ohato, K. (1994). Grafting technology : An Integrated Pest Management Component for Eggplant and Tomato. Bull. Institute of Tropical Agriculture, Kyushu University. **17**: 85-91.

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.

Al-Musa, A. (1982). Incidence, economic importance and control of tomato yellow leaf curl in Jordan. *Plant Disease*. **66**: 561-563.

Anonymous, (2005). Development of a Management Approach against Whitefly *Bemisia tabaci* attacking tomato. Annual Research Report, Entomology Division. Bangladesh Agricultural Research Institute. Gazipur, Bangladesh. pp. 46-48.

Avidov, Z. (1956). Bionomics of the tobacco Whitefly (*Bemisia tabaci* Gennad.) in Israel.Ktavim (English edition). **7**(1): 25-41.

Azab, A.K., Megahed, M.M. and EI-Mirsawi, H.D. (1971). On the biology of *Bemisia tabaci* (Gen.) (Hemiptera-Homoptera: Aleyrodidae).

Azam, K.M., Razvil, S.A., Zouba, A. and Al-Raeesi, A.A. (1997). Management of Whitefly (*Bemisia tabaci* Gennadius) and tomato leaf curl virus in tomato crops. Arab and Near East Plant Protection Newsletter. pp. 25-27.

Basu, A.N. (1995). *Bemisia tabaci* (Gennadius): Crop Pest and Principal Whitefly Vector of Plant Viruses. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi, Bombay, Calcutta, India. pp. 1-183.

BBS (Bangladesh Bureau of Statistics). (2015). Statistical Year Book of Bangladesh. Statistical Division Ministry of Planning, Govt. Peoples Republic Bangladesh, Dhaka, p. 297.

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

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.

Brown, J.K. and Bird, J. (1992). Whitefly-transmitted geminiviruses and associated disorders in the Americas and the Caribbean Basin. Plant Disease. **76**(3): 220-225.

Butani, D.and M. Jotwani. (1984). Insects in vegetables. Periodical Expert book Agency, Vivek- Vihar, Delhi (India). pp. 29.

Butler, G.D., Jr., and Henneberry, T.J. (1991). Sweet potato whitefly control: Effect of tomato cultivars and plant derived oils. Southwestern Entomologist. **16**(1): 37-43.

Byrne, D.N., Bellows, T.S. and Parrella, M.P. (1991).Whiteflies in agricultural systems. *In:* whiteflies: Their Bionomics, Pest Status and Management (D. Gerling, ed.) Intercept, Wimborne, England. pp. 227-261.

Byrne,D.N. and M.A. Houck. (1990). Morphometric identification of wing polymorphism in *Bemisia tabaci* (Homoptera: Aleyrodidae).*Annals of the Entomological Society of America.* **83**: 487-493.

Cahil, M., Byrne, F.J., Gorman, K., Denholm, I. and Devonshire, A.L. (1995). Pyrethroud and Organophosphate resistance in tobacco Whitefly, *Bemisia* *tabaci* (Homoptera: Alerodidae). *Bulletin on Entomological Research*. **85**: 181-187.

Cohen, S. and Melamed-Madjar. (1978). Prevention by soil mulching of the spread of *Tomato yellow leaf curl virus* transmitted by *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) in Israel. *Bull. Ent. Res*. **68**: 465-470.

Csizinsky, A.A., Schuster, D.J. and Kring, J.B. (1995). Color mulches influence yield and insect pest populations in tomatoes. *J. Amer. Soc. Hort. Sci*. **120**(5): 778-784.

Csizinsky, A.A., Schuster, D.J. and Kring, J.B. (1997). Evaluation of color mulches and oil spray for yield and for the control of silver leaf whitefly, *Bemisia argentifolii* (Bellows and Perring) on tomatoes. *Crop Protection*. **16**(5): 475-481.

Dhandapani, N.U. Shekhar, R. and Murugan, M. (2003). Bio-intensive pest management (BIPM) in major vegetable crops: an Indian perspective. *Food. Agric. Environ.* **1**: 333-339.

El-Serwiy, S.A., Ali, A.A., and Razoki, I.A. (1987). Effect of intercropping of some host plants with tomato on population density of tobacco whitefly, *Bemisia tabaci* (Genn.) and the incidence of tomato yellow leaf curl virus (TYLCV) in plastic houses. Journal of Agriculture and water resources Research, *Plant Production.* **6**(2): 79-81.

Ewing, K.P., Parencia, C.R. Jr. and Ivy, E.E. (1947). Cotton insects'control with benzene hexachloride, alone or in mixturewith DDT. *J. econ. ent.* **40**: 374-381.

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

Gajanana, T.M., Krishna Moorthy, P.N. Anupama, H.L. Raghunatha, R. and Prasanna Kumar, G.T. (2006). Integrated pest and disease management in tomato: an economic analysis. *Agril. Economics Res. Rev.* **19:** 269-280.

Gajendra, C., Ganguli, R.N. Kaushik, U.K, Dubey, V.K. and Chandrakar, G. (1998). Resistance to the fruit borer, *Helcoverpa armigera* in tomato. Advances in IPM for Horticultural crops. Proceedings of the First National symposium on pest Management in Horticultural crops. Environmental Implications and Thrusts, Bangalore, India. pp. 73-76.

Ganguli, R.N. and Dubey, V.K. (1998). Management of tomato fruit borer, *Helicoverpa armigera*. Hubner in Chhattisgarh region of Madhya Pradesh. *Insect Environ.* **4**(1): 25.

Gerling, D. and Horowitz, A.R. and Baumgartner, J. (1986). Autecology of *Bemisia tabaci. Agric. Ecosys. Evniron*. **17**: 5-9.

Ghosh, A., Chatterjee, M. and Roy, A. (2010). Bio-efficacy of spinosad against tomato fruit borer (*Helicoverpa armigera* Hub.) (Lepidoptera: Noctuidae) and its natural enemies. *J. Hort. Forestry*. **2**(5): 108-111.

Gomez, K.A. and Gomez, A.A. (1976). Statistical Procedure for Agricultural Research (2nd Ed.). A Willey Inter Science Publication, New York. p. 680.

Greathead, A.H. (1986). Host plants. *In: Bemisia tabaci*- a Literature Survey (M.J.W. Cock, ed.). C.A.B. international Institute of Biological Control, U.K. pp. 17-23.

Green, S.K. and Kalloo, G. (1994). Leaf curl and yellowing viruses of pepper and tomato: an overview. Technical Bulletin No. 21. Asian Vegetable Research and Development Center, Taiwan. p. 51.

Hilje, L. (2000). Use of living ground covers for managing the whitefly *Bemisia tabaci* as a geminivirus vector in tomatoes. The BCPC Conference – Pests and Disease, UK, 13-16 Nov. 2000. **1**: 167-170.

Hilje, L., Costa, H.S. and Stansly, P.A. (2001). Cultural practices for managing *Bemisia tabaci* and associated viral diseases. *Crop Protection*. **20**: 801-812.

Hirano,K., E. Budiynto and S.Winarni. (1993). Biological characteristics and forecasting outbreaks of the whitefly *Bemisia tabaci*, a vector of virus diseases in soybean fields. *Food and Fertilizer Technical bulletin*. No.135.

Horowitz, A.R., (1986). Population dynamics of *Bemisia tabaci* (Gennadius) with special emphasis on cotton fields, *Agric. Ecosys. Environ*. **17**: 37-47.

Husain, M. (1993). Controlling rice borer under Bangladesh conditions. Pestology. **8**(8): 28-30.

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

Hussain, B. and Bilal Ahmed, S. (2006). Biology and management of tomato fruit borer, Helicoverpa armigera (Hb.) using African marigold as trap crop (online available at*: http://dspaces.uok.edu.in/handle/1/262).*

Hussain, B. and Bilal, S. (2007). Efficacy of Different Insectides on Tomato Fruit Borer *Helicoverpa armigera*. *J. Entom.* **4**: 64-67.

Hussain, M.A., Trehan, K.N. (1933). Observations on the life history, bionomics and control of the whitefly of cotton (*Bemisia gossypiperda,* M and L.). *Indian J. Agric. Sci*. **3**: 710-753.

Ioannou, N. and Iordanou, N. (1987). Epidemiology of Tomato yellow leaf curl virus in relation to the population density of its whitefly vector, *Bemisia tabaci* (Genn.). Technical Bulletin 71, Agricultural Research Institute, Nicosia, Cyprus. p. 7.

Jiang, Y.X., DeBlas, C., Barrios, L. and Fereres, A. (2000). Correlation between whitefly (Homoptera: Aleyrodidae) feeding behavior and transmission of *Tomato yellow leaf curl virus*. *Annals of the Entom. Soc. America.* **93**(3): 573-579.

Jiirgen, K., Heinij, S. and Werner, K. (1977). Pests in tropical crops. *In* diseases, pests and weeds in tropical crops. Jonh Wiley and Sons, New York, Brisbane, Toronto. pp. 479-781.

Kalb, T. (2004). Fact Sheet on *Tomato yellow leaf curl virus* (TYLCV). AVRDC Publication 04-608. http: www.avrdc.org.

Karabhantanal, S.S. and Kulkarni, K.A. (2002). Implication of tritrophic interactions in the management of the tomato fruit borer, *Helicoverpa armigera* (Hubner). *Pest management and Economic Zoology*. **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.

Khan, M.A. and Mukhopadhyay, S. (1985). Studies on the effect of some alternative control methods on the incidence of yellow vein mosain virus disease of Okra (*Abelmoschus esculentus*). *Indian J. Virol*. **1**: 69-72.

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

Kranz, J., Schmutterer, H. and Koch, W. (1977). Diseases, pests and weeds in tropical crops. John Wiley and Sons Ltd. Chichester, New York, Brisbane, Toronto. pp. 27-35.

Lopez-Avila, A. (1986). Taxonomy and biology. **In**: *Bemisia tabaci*: A Literature Survey of the Cotton Whitefly with an Annotated Bibliography (M.Z.W. Cock, ed.). C.A.B. International Institute of Biological Control, U.K. pp. 27-35.

Maleque, M.A., Kabir, K.H., Khanam, N.N., Alam, S.N. and Islam, N. (2002). Combined effect of planting date and variety of tomato on the incidence of whitefly, *Bemisia tabaci* Gennadius and virus diseases. *Banglczdesh J. Zool.* **30**(2): 159-165.

Marcano, B.R.V. (1991). Study of the biology and some behavioral aspects of the tomato fruit borer *Neoleucinodes elegantalis* (Lepidoptera: Pyralidae) in tomatoes. *Agonomia Tropical Maracay.* **41**(5-6): 257-263.

Marcano, R. and Gonzalez, E. (1993). Evaluation of insecticides for the control of the whitefly *Bemisia tabaci* (Gennadius) in tomato. *Boletin de Entomologia Venezolana.* **8**(2): 121-132.

Mason, G., Rancati, M. and Bosco, D. (2000). The effect of Thiamethoxam, a second generation neonicotinoid insecticide in preventing transmission of Tomato yellow leaf curl geminivirus (TYLCV) by the whitefly *Bemisia tabaci* (Gennadius*). Crop Protection*. **19**: 473-479.

Mehta, P.K., Rah, P.C. and Nath, P. (2000). Influence of plant and fruit characters of tomato on fruit borer infestation. *Bull of 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, 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.

Molla, M.M.H. (2000). Effect of mulching and weed control on the incidence of yellow leaf curl virus. ARC-AVRDC Training Report 2000. 205p. (http:www.arc-avrdc.org/pdf_files/ 021-Molla-18th.pdf).

Monsef, A.A. and Kashkooli, A. (1978). Die Baumvollveissfliege *Bemisia tabaci* (Genn.) in der provinz Fars und die kontrolle. Entomologie *et* phytopathologie Appliquees. **46**(1\2):66-77.

Mound, L.A. (1963). Host-correlated variation in *Bemisia tabaci* (Genn.) (Homoptera: Aleyrodidae). Proc. Royal Entomological Society, London. **38**: 171-180.

Mound, L.A. (1983). Biology and identity of whitefly vectors of plant pathogens. **In**: Plant Virus Epidemiology. The Spread and Control of Insect-Borne Viruses

(R.T. Plumb and J.M. Thresh, eds.). Blackwell Scientific Publications, U.K. pp. 305-313.

Mound, L.A. and Hasley, S.H. (1978). Whitefly of the world. A Systematic Catalogue of the Aleyrodidae (Homoptera) with Host Plant and Natural Enemy Data. British Museum (Natural History). John Willey and Sons, London. p. 340.

Musuna, A.C.Z. (1985). A technique for monitoring whitefly, *Bemisia tabaci* (Genn.), in cotton in Zimbabwe. *Agril. Ecosys. Environ*. **17**:29-35.

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 pre-imaginal instars. *Madras Agril. J.* **61**(1-2): 813.

Opena, R.T., Luo, C.G. and Yoon, J.Y. (1987). Breeding for stress tolerance under tropical conditions in tomato and heading Chinese cabbage. ASPAC-FFTC. Taipei, Taiwan (ROC). Pp.88-109 (Original not seen Appeared in CAB Pest Abstract).

Pandey, R.R., Gurung, T.B. and Gutung, G. (1997). Monitoring and management of tomato fruit worm (*Helicoverpa armigera*) and its egg parasite (*Trichogramma ishi*) inthe western hills. Working-Paper Lumle Regional Agricultural Research Center. **24**(3): 14.

Parihar, S.B.S. and Singh, B.R. (1986). Incidence of *Heliothis armigera* (Hub.) 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 (*H. armigera*) on different crop host at Junagodh (Gujarat). *Indian J. Entomol.* **59**(4): 396-401.

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

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

Pokharkar, 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.

Pruthi, H.S. and Samuel, C.K. (1942). Entomological investigation on the leaf curl disease of tobacco in Northern India. V. Biology and population of the whitefly vector (*Bemisia tabaci* Genn.) in relation to the incidence of the disease. *Indian J. Agril. Sci*. **12**: 35-57.

Rahman, M.M., Rahman, S.M.M. and Akter, A. (2011). Comparative performance of some insecticides and botanicals against chilli fruit borer (*Helicoverpa armigera*). *J. Expt. Sci.* **2**(1): 27-31.

Ramappa, H.K., Muniyappa, V. and Colvin, J. (1998). The contribution of tomato alternative host plants to *Tomato leaf curl virus* inoculum pressure in different areas of South India. *Ann. Appl. Biol*. **133**: 187-198.

Rao, N.N., Reddy, A.S. and Reddy, D.D.R. (1990). Impact of some insecticides on *Bemisia tabaci* on cotton. *J. Plant Prot. in the Tropics*. **7**(2): 77-86.

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. of Entom*. New Delhi. **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). *Shashpa*. **8**(1): 63-64.

Saha, P.K., Nath, P. and Chatterjee, M.L. (2001). Effect of intercropping and spacing of lentil and tomato on the incidence of insect pest infestation. *Annals Plant Prot. Sci*. **9**(2): 311-313.

Saha, P.K., Nath, P., Chatterjee, M.L. and Khan, M.R. (2000). Effect of intercropping and spacing of linseed with mustard and tomato on the incidence of insect pests. *Pest Mangt. Econ. Zool*. **8**(1): 85-89.

Sajjad, M. (2011). A book on “Insecticide Resistance Management in Tomato Fruit Borer by Employing Bio-Intensive IPM Strategies”. LAP Lambert Aca. Pub. ISBN-13 (978-3-8443-8248-8), ISBN-10 (3844382488), EAN: 9783844382488. pp. 1-232.

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

Sastry, K.S. 1989. Tomato leaf curl virus management by carbofuran plus oil combination. *Journal of Turkish Phytopathology*. **18**(1-2): 11-16.

Sastry, K.S.M. and Singh, S.J. (1973). Assessment of losses in tomato leaf- curl virus. Indian J. Mycol. *Plant Pathol*. **3**: 50-54.

Sathish, K. and Raguraman, S. (2007). Effect of organic amendments, botanicals and biopesticides against tomato fruit borer, *Helicoverpa armigera* (Hub.) and its parasitoid, *Trichogramma chilonis* Ishii. Effect of organic amendments, botanicals and biopesticides against tomato fruit borer, *Helicoverpa armigera* (Hub.) and its parasitoid, *Trichogramma chilonis* Ishii. *Madras Agric. J.* **94**(7-12): 232-241.

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.

Savary, P. (2000). Effect of whitefly control on *Tomato yellow leaf curl virus* incidence for fresh market tomato. ARC-AVRDC Training Report 2000. 205p. (http: www.arc-avrdc.org/_pdf_files/027-savary-18th. Pdf).

Schuster, D. and Polston, J. (1999). Whitefly management guide: *Tomato yellow leaf curl virus*. Citrus and Vegetable Summer 1999: A6-A7.

Sharaf, N.S. and Batta, Y. 1985. Effect of some factors on the relationship between the whitefly *Bemisia tabaci* Genn. (Homopt., Aleyrodidae) and the parasitoid *Eretmocerus mundus* Mercet (Hymenopt., aphelinidae). *Zeitschrift fu¨r Angewandte Entomologie*. **99**: 267-276.

Sharma, D.K., Dhaliwal, M.S., Cheema, D.S. and Singh, 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 *Helicoverpa armigera* Hub. In Punjab, India. *J. Entomol.* **27**(2): 154-164.

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

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

Suwwan, M.A., Akkawi, M., Al-Musa, A.M. and Mansour, A. (1988). Total performance and incidence of tomato yellow leaf curl virus (TYLCV) as affected by type of mulch. *Sci. Hort*. **37**: 39-45.

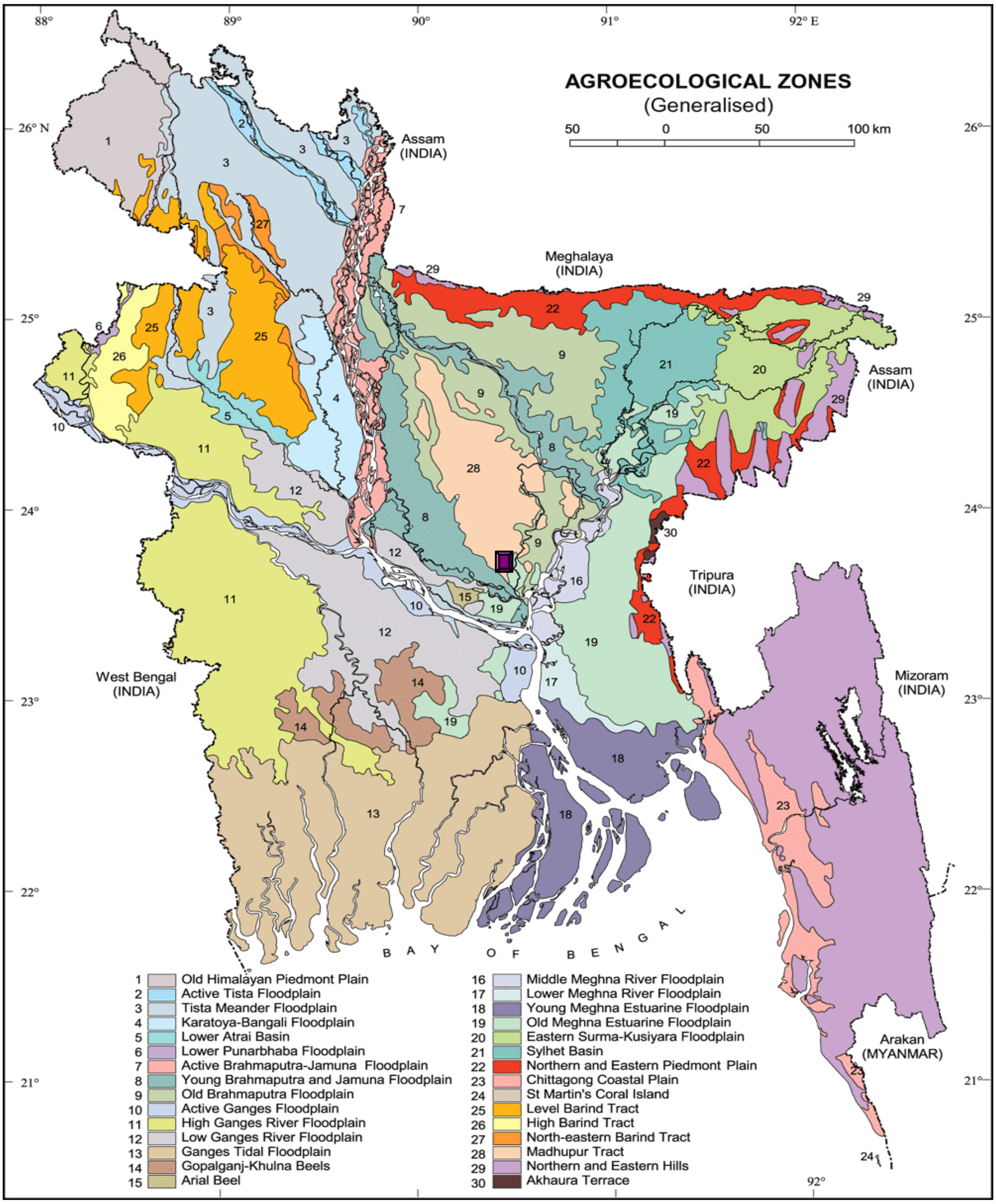
Traboulsi, R. (1994). *Bemisia tabaci*: a report on its pest status with particular reference to the Near East. *FAO Plant Protection Bulletin*. **42**(1-2): 33-58.

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

Xienqui, Y. 2000. Effect of intercropping on *Tomato yellow leaf curl virus* incidence. ARC-AVRDC Training Report 2000. p. 205. (http://www. arc-avrdc.org/pdf_ files/023-yin-18th.pdf).

APPENDICES

Appendix I. Map showing the experimental site under the study



The experimental site under study

Appendix II. Analysis of variance of the data on number of white fly per plot in tomato field as influenced by Integrated pest management practices

Source of variation	Degrees of freedom	Mean square					
		Number of whitefly per plot stage at					
		Vegetative	Flowering		Fruiting		Ripening
			Early	Late	Early	Late	
Replication	2	0.539	0.138	0.373	0.339	0.846	0.650
Treatment	8	924.66**	132.307**	174.675**	128.165**	119.078**	111.539**
Error	16	4.84	0.151	0.152	0.276	0.316	0.222

Appendix III. Analysis of variance of the data on in controlling tomato fruit borer at early fruiting stage in terms of fruits per plot in number as influenced by Integrated pest management practices

Source of variation	Degrees of freedom	Mean square		
		Tomato fruit in number		
		Healthy	Infested	% Infestation
Replication	2	3.957	0.058	3.450
Treatment	8	26.708**	1.123**	93.571**
Error	16	2.117	0.068	2.264

** significant at 1% level of probability

Appendix IV. Analysis of variance of the data on in controlling tomato fruit borer at early fruiting stage in terms of fruits weight per plot as influenced by Integrated pest management practices

Source of variation	Degrees of freedom	Mean square		
		Tomato fruit in weight		
		Healthy	Infested	% Infestation
Replication	2	47271.967	340.111	3.112
Treatment	8	414580.002**	7175.834**	101.044**
Error	16	30961.044	543.976	2.039

** significant at 1% level of probability

Appendix V. Analysis of variance of the data on in controlling tomato fruit borer at mid fruiting stage in terms of fruits per plot in number as influenced by Integrated pest management practices

Source of variation	Degrees of freedom	Mean square		
		Tomato fruit in number		
		Healthy	Infested	% Infestation
Replication	2	5.600	0.053	0.626
Treatment	8	63.078**	1.857**	67.640**
Error	16	3.996	0.115	2.307

** significant at 1% level of probability

Appendix VI. Analysis of variance of the data on in controlling tomato fruit borer at mid fruiting stage in terms of fruits weight per plot as influenced by Integrated pest management practices

Source of variation	Degrees of freedom	Mean square		
		Tomato fruit in weight		
		Healthy	Infested	% Infestation
Replication	2	29808.864	191.628	0.695
Treatment	8	973106.963**	11005.631**	77.363**
Error	16	49729.760	635.948	2.123

** significant at 1% level of probability

Appendix VII. Analysis of variance of the data on in controlling tomato fruit borer at late fruiting stage in terms of fruits per plot in number as influenced by Integrated pest management practices

Source of variation	Degrees of freedom	Mean square		
		Tomato fruit in number		
		Healthy	Infested	% Infestation
Replication	2	23.354	0.055	2.782
Treatment	8	112.644**	2.040**	42.304**
Error	16	7.934	0.161	1.605

** significant at 1% level of probability

Appendix VIII. Analysis of variance of the data on in controlling tomato fruit borer at late fruiting stage in terms of fruits weight per plot as influenced by Integrated pest management practices

Source of variation	Degrees of freedom	Mean square		
		Tomato fruit in weight		
		Healthy	Infested	% Infestation
Replication	2	39047.237	531.160	2.032
Treatment	8	1643383.759**	10329.277**	49.284**
Error	16	93473.443	1223.092	1.756

** significant at 1% level of probability