VARIETAL PREFERENCE AND MANAGEMENT OF TOMATO FRUIT BORER, *Helicoverpa armigera* (Hubner)

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Registration No. 00458
Session: July-December, 2005

A THESIS

Submitted to
Sher-e-Bangla Agricultural University, Dhaka

In the partial fulfillment of the requirements
For the degree of

MASTER OF SCIENCE (MS)
IN
ENTOMOLOGY

SEMESTER: JANUARY-JUNE, 2007

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This is to certify that the thesis entitled, **"VARIETAL PREFERENCE AND MANAGEMENT OF TOMATO FRUIT BORER, *Helicoverpa armigera* (Hubner)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (M. S.) IN ENTOMOLOGY,** embodies the result of a piece of bona fide research work carried out by **MONOWARA YESMIN** bearing Roll No. 00458, Registration No. 00458 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 been duly acknowledged.

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Place: Dhaka, Bangladesh

ACKNOWLEDGEMENT

The author first wants to express her enormous sense of gratitude to the Almighty Allah for His countless blessing, love, support, protection, guidance, wisdom and assent to successfully complete her M.S. degree.

The author like to express her deepest sense of gratitude sincere appreciation to her venerable supervisor Md. Razzab Ali, Associate Professor, Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh, for his continued guidance, support, encouragement and invaluable suggestions throughout the study period and successfully completing the research work and in the preparation of the manuscript.

The author also wishes to express her sincere thanks, earnest obligation and profound gratitude are due to honourable co-supervisor Md. Mizanur Rahman, Associate Professor, Department of Entomology, Sher-e-Bangla Agricultural University (SAU), Dhaka , Bangladesh, for planning painstaking and scholastic guidance, inestimable help, valuable suggestions, and gratuitous labour in conducting and successfully completing the research work and in the preparation of the thesis.

The author also humbly expressing her grateful appreciation and thanks to Professor Jahanara Begum, Chairman, Department of Entomology, SAU and well wishers who prayed for her success.

The author is highly grateful to other teachers of the Department of Entomology, SAU for their kind co-operation and helps during the study period of MS program. Thanks are extended to Nirmal Das, Assistant Co-ordinator, WAVE Foundation, Dhaka, for his sincere co-operation in analyzing data.

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

Finally, she feels heartiest indebtedness to her beloved parents, husband for their patient inspirations, sacrifices, blessing and never ending encouragement.

June, 2007 The author

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VARIETAL PREFERENCE AND MANAGEMENT OF TOMATO FRUIT BORER, *Helicoverpa armigera* (Hubner)

BY

MONOWARA YESMIN

ABSTRACT

Two set of experiment were conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October 2006 to March 2007 to screen out some selected tomato varieties/ genotypes for resistance against tomato fruit borer, *Helicoverpa armigera* (Hubner) and to evaluate the efficacy of some management practices applied against tomato fruit borer.

Considering the field screening of different tomato varieties for resistance against tomato fruit borer, among nine tomato varieties evaluated against tomato fruit borer, the variety BARI-2 (Ratan) and BARI-8 were the susceptible variety to tomato fruit borer and the variety BARI-3, BARI-7, BARI-9, BINA-3 and BINA-4 were the moderately resistant, whereas BINA-1 and BINA-2 were the highly resistant. And the trend of resistance to tomato fruit borer is BINA-1 > BINA-2 > BINA-4 > BINA-3 > BARI-9 > BARI-7 > BARI-3 > BARI-8 > BARI-2 (Ratan). The highest yield loss (15.17%) was recorded for the variety BARI-2 (Ratan) and the lowest yield loss (6.46%) was recorded for the variety BINA-2 followed by BINA-1 (7.06%). The highest yield (74.49 t/ha) was recorded for the variety BINA-1 followed by BINA-2 (73.24 t/ha) and BARI-2/Ratan (73.00 t/ha) and the lowest yield (54.98 t/ha) was recorded in the variety BARI-7 followed by BARI-3 (61.69 t/ha), BINA-4 (62.42) and BARI-8 varieties.

Considering the effects of different management practices applied against tomato fruit borer at early, mid and late fruiting stages, the level of infestation followed more or less similar trend for both by number and weight of tomato, where the treatment T_6 (comprising Neem oil @ 3 ml/L of water sprayed at 7 days interval + plants supported by bamboo stick) performed maximum number and weight of healthy fruit/plant and minimum number and weight of infested fruit as well as lowest percent fruit infestation in number and weight whereas in T_8 (Untreated control treatment) the

situation is totally overturned in this trial. The tomato fruit yield increases due to decrease the percent fruit infestation by tomato fruit borer, also with the increase of the plant height and number of branch per plant.

In considering the economic analysis of the different treatments in controlling tomato fruit borer, the highest benefit cost ratio (3.53) was recorded in the treatment T_6 (consisting of Neem oil @ 3 ml/litre of water sprayed at 7 days interval + plants supported with bamboo stick). On the other hand, the minimum benefit cost ratio (1.31) was recorded in treatment T_4. But no management cost was required for T_8 treatment (untreated control).

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular and important vegetable grown in Bangladesh during rabi season as well as in many countries around the world (Ahmad, 1976). It belongs to the family Solanaceae. The crop ranks next to potato and sweet potato in the world vegetable production (FAO, 1997),and the top of the list of canned vegetables (Chowdhury, 1979). Tomato is reported to have originated in tropical America (Salunkhe *et al.,* 1986). It is adapted to a wide diversity of climates ranging from the tropical to the Arctic Circle. However, in spite of its broad adaptation, production is concentrated in a few area and rather dry area (Cuortero and Fernandez, 1999). The leading tomato producing countries of the world area China, United States of America, India, Egypt, Turkey, Iran, Italy, Maxico, Brazil and Indonesia (FAO,1999) In Bangladesh, tomato is grown during rabi season. It is cultivated in almost all home gardens and also in the field due to its adaptability to wide range of soil and climate (Ahmad, 1976; Bose and Som, 1990). It is a nutritious and delicious vegetable used in salads, soups, and processed into stable products like ketchup, sauce, marmalade, chutney and juice paste, powder and other products (Ahmed, 1976; Thompson and Kelly, 1983). Nutritive value of the fruit is an important quality in tomato. Its food value is very rich because it contains higher amount of vitamin A, B and C including calcium and carotene (Bose and Som, 1990). In Bangladesh, recent statistics shows that the yield of tomato is not satisfactory enough in comparison to other tomato growing countries of the world (Aditya *et al.,* 1997). Bangladesh grew tomato in 47960 Acres of land in the year 2006-2007 with a total production of 136935 M.T. approximately showing an average yield of 2855kg/acre (BBS, 2007). The low yield of tomato in Bangladesh, however, is not an indication of low yielding potentiality of this crop, but of the fact that the low yield may be attributed to a number of reasons viz unavailability of quality seeds of improved varieties, fertilizer management, disease and insect infestation and proper irrigation facilities.

Among the different limiting factors for production, tomato is very much susceptible to insect attack from seedling to fruiting stage. All parts of the plant including leaves, stems, flowers and fruits are subjected to attack. The crop is attacked by different species of insects in Bangladesh. Among them, tomato fruit borer, *Helicoverpa armigera* (Hubber) (previous knows as *Heliothis armigera* Hubner) is one of the serious pest. This has been reported to cause damage to extent of about 50-60 percent fruits (Singh and Singh, 1977). Data revealed that damage by this pest might be up to 85-93% (Tewari, 1985). Due to severe infestation, fruit as well as seed maturation hampered greatly and the viability of the seeds are reduced (Dhamo *et al*,. 1984). Tomato fruit borer is highly polyphagous insect pest and perhaps the most serious pest of Indian Agriculture (Patel and Koshiya, 1997). The pest appears throughout the year on different crops. Depending upon the cropping pattern of different regions, pest population shift from one crop to another multiplying in number and building up population, which may cause considerable damage to those crops. Some times the attack of insect pest also varied from variety to variety. Besides tomato, it also attack cotton, tobacco, sorghum, various legumes, okra and other horticultural crops (Jiirgen *et al*., 1977). It is widely distributed not only in the Indian sub continent but also in the whole tropic. This pest is not common in desert and very humid region (Singh, 1978). The pest is active throughout the year at places having moderate climate but its activity is adversely affected by severe cold. A study revealed that it is very active during the rabi season. The damage by *Helicoverpa armigera* (Hubner) starts soon after fruiting periods of the crop and the newly hatched larvae bore into the fruit and feed inside. As a result, the fruits become unfit for human consumption (Khanam, 2000).

Host plant resistance is also one of the preferred methods for minimizing such damage caused by tomato fruit borer because it does not require the complete elimination of the pest to be effective. Many developing countries are now being used resistant varieties for combating the crop infestation with the aim of increasing food/vegetable production. If, we use resistant variety(s) of tomato, this crop will remain free from fruit borer and its total production will be increased without poisoning danger to environment as well as human health. In India, Gajendra, *et al* (1998) reported that among twenty four tomato cultivars, Pusa Early Dwarf, Akra Vikas and Pusa Gaurva were less susceptible to *Helicoverpa armigera*. Thakur *et al*. (1998) also reported that among a number of tomato varieties/hybrids for resistance to *Helicoverpa armigera* in India, S-12 was the most resistant (0.66% of fruits infested), while HS-110 was the most susceptible (14% of fruits infested). But in Bangladesh, only a few works have been conducted in relation to screening tomato varieties against tomato fruit borer. Khanam (2000) reported that the lines V-29 and V-282 were found moderately resistant and susceptible respectively to tomato fruit borer. Again BARI-10, Manik, Ratan, V-3, V-8, V-14, V-40, V-52, V-56, V-80, V-90, V-167, V-187, V-231, V-250, V-258, V-259, V-280, V-321, V-332, V-374, V-378, V-382, V-387, V-422, V-423, V-433 and V-453 were found highly susceptible to tomato fruit borer.

Though the tomato fruit borer is major in status, the management of this pest through non-chemical tactics including cultural, mechanical, biological and host plant resistance etc. undertaken by the researcher throughout the world is limited. The research work on non-chemical control measures of the tomato fruit borer is scanty. So, the use of chemical insecticide is regarded to be most useful measure to combat this pest. Generally the farmers of Bangladesh control this pest by the application of chemical insecticides. Among them, cultural control comprising collection and destruction of infested fruits is a safe and cheap control technique. It was found that the larva of this insect can be control successfully by this methods following every alternate day during marble size tomato to before unripe period. Reports revealed that about 75% control is possible only by this method. But it could be possible to get better result by mechanical method + spraying of botanical pesticides (Nazim *et al.*, 2002).

Generally the farmers of Bangladesh control this pest by the application of chemical insecticides because the use of chemical insecticide is regarded to be most useful measure to combat this pest. In Bangladesh, it was reported that cypermethrin, deltamethrin, fenvalerate and quinalphos @ 1.5ml/L of water gave the better result in controlling tomato fruit borer (Alam, 2004). Of several insecticides compared against *H. armigera*, quinalphos at 0.05% was the most effective (Tewari, 1985). Dilbagh *et al.* (1990) reported in India that fenvalerate, permethrin and cypermethrin applied at 50 g a.i./ha, or decamethrin [deltamethrin] applied at 20 g a.i./ha gave equal or better control of the noctuid *Heliothis armigera [Helicoverpa armigera]* than carbaryl or endosulfan applied at 1000 and 700 g a.i./ha, respectively. Yields were higher when synthetic pyrethroids were used. Attri *et al.*, (1978) reported that carbaryl was the most effective compound against *Helicoverpa armigera* and was significantly superior to malathion and phenthoate. Residues analysis of phenthoate showed that in the absence of at tolerance limit for this compound, a waiting period of 14 days should be observed for tomatoes, which is impractical since they have to be picked every 2-3 days.

But, the application of chemical insecticides has got many limitation and undesirable side effects (Luckmann and Metcalf, 1975; Husain, 1993). Indiscriminate use of synthetic chemicals for controlling the insect pests of crop plants resulted hazardous effects causing serious problems including, pest outbreak, pest resurgence and environmental pollution. Moreover, the farmers of Bangladesh are very poor and they have limited access to buy insecticides and the spraying equipment (Husain, 1984).

To overcome these problems, the Ecologist, Entomologist and Zoologist gave great importance on IPM programme. The use of resistant variety is the first step of IPM, so we should try to develop resistant variety of any crop including tomato.

Now a day, botanical pesticide, especially neem oil is very new and unexploited approach in this context and becoming popular day by day. Karim (1994) reported from weekly spray application of the extract of neem seed kernel and found effective against *Helicoverpa armigera*. Kulat *et al.* (2001) reported in India that the crop treated with the leaf extract of *Nicotione tabacum* and seed extract of *Pongamia glabra* (5%) and indiara (1%) and neem seed kernel extract (5%) exhibited low level of population built up compared to control against *Helicoverpa armigera* infesting chickpea. But only a few works has been done to determine the efficacy of neem oil in controlling tomato fruit borer infesting tomato.

Therefore, the present study was under taken to find out the resistant or tolerant variety(s) against this pest and to test the approach comprising non-chemical and or chemical methods containing selected insecticide and or botanical and evaluated their performance in combating this pest with economic analysis with the following objectives:

OBJECTIVES

1. To evaluate the promising tomato varieties/ genotypes for resistance against tomato fruit borer, *Helicoverpa armigera* (Hubner)
2. To evaluate the level of infestation by tomato fruit borer infesting tomato
3. To evaluate the efficacy of some management practices against tomato fruit borer.

CHAPTER II

REVIEW OF LITERATURE

Tomato fruit borer is the most important insect pest of tomato in Bangladesh. Studies on different aspects of the tomato fruit borer, *Helicoverpa armigera* (Hubner) and abundance of this pest have been done elsewhere but a few of them is related to the present study. Literature relating to varietal screening or finding of resistant or tolerant varieties/genotypes against this pest are scanty in our country. However, the available literature relevant to this study including the target pest, its host preference and management are presented under the following sub heading. Until now, a few report is available on the evaluation of tomato varieties/genotypes for resistant to tomato fruit borer in Bangladesh.

2.1. GENERAL REVIEW OF TOMATO FRUIT BORER, *Helicoverpa armigera*, (HUBNER)

2.1.1. NOMENCLATURE

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

2.1.2. ORIGIN AND DISTRIBUTION

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

2.1.3. HOST RANGE OF TOMATO FRUIT BORER

A wide range of host crop plants occurs including cotton, tobacco, maize, sorghum, pennisetum, sunflower, various legumes, citrus, okra and other horticultural crops.

Wild plants considered important include species of Euphorbiaceae, Amaranthaceae, Malvaceae, Solanaceae, Compositae, Portutacaceae, Convolvulaceae but many other plant families are reported to be the host (Jiirgen *et al*,. 1977).

2.1.4. LIFE HISTORY OF TOMATO FRUIT BORER

2.1.4.1. Egg

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

2.1.4.2. Larva

The fully grown larva (Plate 1) 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.

2.1.4.3. Pupa

The light brown pupa is about 22 mm in length, living in the soil (Plate 2).

2.1.4.4. Adult

Stout bodied moth has a wing span of 40 mm. general color varies from dull yellow or olive grey to brown with little distinctive marking (Plate 3). The moths become sexually mature 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 eggs shell before feeding on the plant.

Plate 1: Tomato fruit borer larva on leaf (upper), larva feeds on tomato (lower)

Plate 2: Pupa of tomato fruit borer in pupal champer (partially opened soil clod)

Plate 3. Adult tomato fruit borer, *Helicoverpa armigera*

2.1.5. STATUS AND NATURE OF DAMAGE OF TOMATO FRUIT BORER

Tomato fruit borer, *Helicoverpa armigera* (Hub.) is one of the serious pests attacking tomato. The pest causes damage to the extent of about 50-60 percent fruit (Singh and Singh, 1977). Data revealed that damage by this pest might be up to 85-93% (Tewari, 1985). Due to severe infestation, fruit as well as seed maturation hampered greatly and the viability of the seeds is reduced and quality seed is degraded (Dhamo *et al.*, 1984). Pinto *et al.* (1997) observed high infestations of the noctuid, *Helicoverpa armigera* on field-cultivated tomatoes (cultivars Interpel and Universal Mec) in the hilly area of Madonie, Palermo province, Sicily, in the summer of 1996. The infestations caused serious damage, resulting in a reduced, and at times, inadequate commercial return.

The larvae of this pest bore circular holes and thrust only a part of their body inside the fruit and eat the contents. If the fruit is bigger in size, it is only partly damaged by the caterpillar but later it is invariably invaded by fungi, bacteria and spoiled completely. A small-darkened partially healed hole at the base of the fruit pedicle is evident. The inside of the fruit has a watery cavity that contains frass and decay. Tomatoes ripen early but not usually consumable and marketable (Husain *et al.*, 1998).

2.1.6. SEASONAL ABUNDENCE

The seasonal history of tomato fruit borer, *H. armigera* varies considerably due to different climatic conditions throughout the year. A study revealed that the population of *H. armigera* began to increase from the mid January and peaked during the last week of February. The population of this pest was positively correlated with average temperature, mean relative humidity and total rainfall. Parihar and Singh (1986) in India showed that the larval population of *H. armigera* on tomato was low until the first week of February and increased rapidly there after, reaching a peak in the last week of march. In the last week of April, population declined to 4 larvae/10 plants, percentage 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.

Patel and Kotikal (1997) worked on seasonal abundance of *H. armigera* during kharif season; the pest started its activity in groundnut from first week of July. There after, the pest moves to cotton crop from last week of July and started to build up its population during the month of August to mid September. Simultaneously, the pest infestation was also noticed in Sunflower and pearl millet during this period but the population was very low in sunflower. However, in pearl millet, it was at peak during September. In rabi season, pest 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.

Gupta *et al.* (1984) studied in 1982-83 on the effect of infestations with larvae of *Helicoverpa armigera* on tomato yields. Infestations were heaviest (17.88%) in March- April and lightest in January- February. The avoidable yield loss was highest in March-April (37.79%) followed by January-February (36.36%) and October-November (22.39%). In crops harvested in October-November, January-February and March-April, 18.90, 18.00 and 21.64% of the total number of fruits, respectively, were infested. The average weight of infested fruit was 39.56- 40.32g and that of healthy fruit 50.18-61.43g. Infestations were heavier in the first 4 pickings. In fruit harvested in March-April, infestation was 49.70% at the first picking and 4.25% at the 7^{th}. The data indicated that control measure should be taken at the flowering stage.

Pandey *et al.* (1997) conducted a series of experiments in 1993-96 in the Western Hills, Nepal, to understand the pest dynamics and to develop integrated pest management (IPM) technologies against tomato fruit borer *Helicoverpa armigera*. Monitoring of *H. armigera* for several seasons across the agro-ecological zones indicated that March-April is the peak activity period of the moth. The period coincides with the flowering/fruiting season of tomato and the pest causes severe yield losses. Tomato cv Roma and local landraces collected from Kholakhet, Parbat, were found to be less preferred for egg laying by this pest.

2.2. VARIETAL RESISTANCE

Gajendra *et al.* (1998) screened out twenty four tomato cultivars against *Helicoverpa armigera* during the spring of 1995/96 in Madhya Pradesh, India. The results revealed that cultivars Pusa Early Dwarf, Akra Vikas and Pusa Gaurva which have highly hairy peduncles were less susceptible to the pest damage than those with less hair on the peduncles. Negative correlation between ascorbic acid content of the fruit and fruit damage by the pest was observed.

Thakur *et al.* (1998) conducted a number of tomato varieties/hybrids for resistance to *Helicoverpa armigera* in the Chamba district of Himachal Pradesh, India. From the results it was found that the variety, S-12 was the most resistant (0.66% of fruits infested), while HS-110 was the most susceptible (14% of fruits infested).

Sivaprakasam (1996) carried out laboratory and field experiments on the ovipositional preference of *Helicoverpa armigera* on 9 tomato cultivars revealed that more laid on the under surface of leaves than on the petiole, inter nodal stem and calyx. More eggs were deposited on hairy than glabrous cultivars. Least number of eggs was deposited on cv. Paiyur-1. This was related to low trichome density and long calyx.

Singn (1994) carried out field studies in Ludhiana, Punjab, India, during 1986-87 and 1991-92 to evaluate the resistance of tomato varieties to *Helicoverpa armigera*. Among the most resistant varieties were cvs Punjab Chhuhara, US 2, J 14-1-12, Pant Bahar, Azad T-2, Pusa Selection 1 and Pusa Selection 4. Cvs KS 6 and Selection 18 were the most susceptible to pest damage. Among the hybrids, cultivars KT 4 and Pusa Hybrid 4 were the most resistant.

Kakar *et al.* (1990) evaluated seventy genotypes and cultivars to tomato, one stamenless variety, one variety of *Lycopersicon esculentum* and 31 crosses between promising and commercial cultivars against the noctuid *Helicoverpa armigera* in India. Leaves and fruit of the genotype 122775 and the cross Rick x Solan Gol were not attacked.

Abhishek *et al.* (1993) assessed twelve tomato cultivars for field performance in Satpura, India and recorded resistance to damage by fruit borer, *H. armigera* during Kharif season. Pusa Rubi (3.2%) suffered the least fruit damage and Karnataka, Mangla and Art-1 had significant fruit damage (9.9, 8.6 and 8.2% respectively) due to *H. armigera*. The cultivar Rashmi produced the highest total (20.92 t/ha) and highest healthy fruit yield (17.95 t/ha).

Mishra *et al.* (1996) carried out a field trial for the screening of 35 tomato varieties for resistance to fruit borer, *H. armigera* during the summer season, 1986. Fruit damage in different varieties varied considerably. Variety 'Angurlata' was graded as "highly resistant" recording lowest fruit damage (1.94%) and required maximum days for first fruit set. Variety AC 310 was graded as "highly susceptible" recording maximum fruit damage (19.5%) and minimum days for first fruit set. A highly significant negative correlation between the earliness and per cent fruit damage was observed with most of the varieties except three varieties where bigger fruit size might be for higher susceptibility to fruit borer.

In Bangladesh, Husain *et al.* (1998) evaluated four varieties/strains of tomato against fruit borer (*H. armigera*) in Mymensingh. The lowest borer attack found in the variety Manik, and Ratan was moderately susceptible.

Khanam (2000) evaluated thirty varieties/lines for resistance against tomato fruit borer, *Helicoverpa armigera* (Hub.) in Mymensingh, Bangladesh and reported that the lines V-29 and V-282 were found moderately resistant and susceptible respectively to tomato fruit borer. Again BARI-10, Manik, Ratan, V-3, V-8, V-14, V-40, V-52, V-56, V-80, V-90, V-167, V-187, V-231, V-250, V-258, V-259, V-280, V-321, V-332, V-374, V-378, V-382, V-387, V-422, V-423, V-433 and V-453 were found highly susceptible to tomato fruit borer.

Bashar (2005) screened four varieties/lines of tomato (*Lycopersicon esculentum* Mill) at BINA sub-station, Rangpur, Bangladesh for their resistance against tomato fruit borer, *Helicoverpa armigera (*Hub.) during the period from November 2004 to February 2005. On the basis of fruit infestation BARI-7 was found susceptible and TM-135 and TM-130 were moderately tolerant.

Sharma *et al.* (1990) evaluated four tomato cultivars grown during rabi, 1989 for the effect of *H. armigera* on the number and weight of fruit. The smallest mean percentage reduction in number and yield was observed for Kanchan 3 (16.31 and 10.45%, respectively).

Brar *et al.* (1995) screened different species of *Lycopersicon* against *Helicoverpa armigera* in the field in the Indian Punjab, during 1992-93. *L. hirsutum, L. pimpinellifolium, L. peruvianum and L. chimeliwshii* proved highly resistant. Accessions LA 2992, LA 2449 and LA 2531(A) of *L. esculentum* were the most promising. Most of the accessions of *L. chilense, L. parviflorum* and *L. esculentum* were susceptible.

2.3. MANAGEMENT OF TOMATO FRUIT BORER

2.3.1. CULTURAL CONTROL

Cultural control measures are important in minimizing injuries and protesting the crop and should be considered in any integrated control program. Sometimes a slight population reduction brought about by cultural practices delays build up to damaging level. The following cultural practices are to be taken against tomato fruit borer.

These are mainly sanitation, rotation, tillage, pruning and defoliation and time of planting.

Sundeep and Kaur (2000) conducted an experiment on the economics of controlling *H. armigera* through suitable cultivars (Punjab Kesri, Punjab Chhuhara, Punjab Tropic and Hybrid Naveen) and cultural practices in tomato for two years (1993-94) at Punjab Agricultural University, Ludhiana, Punjab, India. The cumulative fruit damage and fruit yield were invariably lower in the late transplanted crop. The fruit damage was significantly lower in early maturing and small fruited cultivars Punjab Kesri followed by hybrid Naveen. The fruit yields were however, significantly higher in longer duration and medium fruited hybrid Naveen followed by the variety Punjab Kesri. The returns were highest in early transplanted Naveen followed by late transplanted Naveen and early transplanted Punjab Kesri

Patil *et al* (1997) studied to assess the effects of intercropping various vegetables with tomatoes on the infestation of tomato fruit borer (TFB), *Helicoverpa armigera* in Karnataka, India, during the kharif season of 1995. No insecticides were used during the course of the experiment. The greatest infestation of TFB (5.6%) was noticed in tomatoes intercropped with snap beans (*Phaseolus vulgaris*). The lowest infestation (3.4%) was observed in tomatoes intercropped with radishes (*Raphanus sativus*). The TFB infestation levels in tomatoes grown alone, tomatoes intercropped with coriander and onion was 4.5%, 4.2% and 4.7%, respectively. The greatest reduction in marketable yields of tomatoes was observed in tomatoes intercropped with snap beans followed by tomatoes intercropped with onions. The greatest marketable yields were observed in tomatoes intercropped with radishes. Total TFB infestation ranged from 17.0% in treatments where radishes were grown as an intercrop, to 28.2% in plots where snap beans were grown intercropped with tomatoes.

2.3.2. MECHANICAL CONTROL

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

2.3.3. BIOLOGICAL CONTROL

2.3.3.1. USE OF PARASITOID AGAINST TOMATO FRUIT BORER

Gupta *et al.* (1998) conducted field studies during April to June in 1994-95 on suppression of *Helicoverpa armigera* using *Trichogramma pretiosum* on tomato at Solan, Himachal Pradesh, revealed that four releases each consisting of 50 000 parasitized *Corcyra* eggs at 10 day intervals in 1994, provided 58.3, 93.4, 27.8 and 37.5% parasitization, respectively, as against 22.2-35% in the control. Five such releases (with mean male-biased sex ratio of 6.8:1), made in 1995 at weekly interval, provided 40-45% parasitization (no parasitization in the control) when egg density was 0.7/plant. *Bacillus thuringiensis* var. *kurstaki* (B.t.) at 1 or 1.5 kg formulated material/ha was effective in reducing the larval survival to 37% over the pretreatment count after 96 h of spray. Spray of B.t. at 1 kg/ha a week after the release and 3 rounds of each treatment resulted in the egg parasitization of 27.1-35.8% against 0 in the control. Average larval count/80 plants reduced from 50.7 to 6.7 while in the control it was between 35.3 and 46.7. Thus, combined use of egg parasitoids and *B. thuringiensis* was more effective in suppression of *H. armigera* on tomatoes.

Urmila *et al.* (1996) recorded eggs of *Trichogramma achaeae* from *Achaea janata* collected from tomatoes *(Lycopersicon esculentum)* in Anand, Gujarat, India, in 1994. The pests were also parasitized by *T. chilonis*.

Krishnamoorthy and Mani (1996) studied biological control of *Helicoverpa armigera*, infesting tomato attempted using two species of egg parasitoids, *Trichogramma brasiliensis [T. brasiliense]* and *T. pretiosum*, under conditions prevailing in Bangalore, Karnataka, India. Inundative field releases of these parasitoids were made at weekly intervals from flower initiation. A total of 2.5, and 2.5 and 5.0 lakh [1 lakh=100 000] adults/ha were made in 5-6 releases with *T. brasiliense* and *T. pretiosum*, resp. Both species of egg parasitoids at 2.5 lakh adults/ha could effectively control the population of *H. armigera*. The borer damage in the biocontrol field was 8.92 and 7.27%, resp., compared with 23.06 and 13.72% in the control when *T. brasiliense* and *T. pretiosum* were released. Release of *T. pretiosum* at 5 lakh adults/ha reduced the borer damage to 1.09% as compared with 8.92% in the control indicating the potential of these parasitoids.

Rawat and Pawar (1993) conducted field studies in tomato fields in Himachal Pradesh, India, during 1991-92 to study the effectiveness of 2 exotic egg parasitoids, *Trichogramma brasiliensis [T. brasiliense]* and *T. pretiosum*, and the egg-larval parasitoid, *Chelonus blackburni* for the control of *Helicoverpa armigera*. Mass releases of these natural enemies seemed to be effective under the agroclimatic conditions prevailing in Himachal Pradesh. The mean percentage reduction the larval population of *H. armigera* was 55.9 after releasing the parasitoids, but increased by 14.3% in fields where parasitoids were not released.

Meierrose *et al.* (1991) monitored egg densities of *Helicoverpa armigera* on tomatoes in Portugal. Parasitism rates by *Trichogramma* spp. and *Telenomus* sp. were determined with and without supplementary mass releases of *Trichogramma* spp. Several species of natural enemies were recorded. Three to 4 successive generations of *H. armigera* were not controlled by natural occurring egg parasitoids, but large fruit losses could be prevented by augmentation.

Kakar *et al.* (1990) tested 5 species of *Trichogramma* in the laboratory for their ability to parasitize *Helicoverpa armigera*. *T. exiguum* caused the highest parasitism (100%), followed by *T. brasiliense* (98%), *T. chilonis* and *T. perkinsi* (90%) and *T. minutum* (70%). *T. exiguum* and *T. minutum* completed their life cycle in 6-19 days, producing 120-150 adults, but no adult parasitoids emerged in the other species. Percentage parasitism caused by all 5 species released against the pest on tomato in the field in Himachal Pradesh, India, was 100.

2.3.3.2. MICROBIAL CONTROL

Gajendra *et al.* (1999) conducted field study in Madhya Pradesh, India during the rabi season of 1995-96 on the management of tomato fruit borer, (*Helicoverpa armigera*) on tomato cv. Pusa rabi fruits. Treatments comprised: *Heliothis* nuclear polyhedrosis virus (HNPV), Dipel (*Bacillus thuringiensis* sub sp. *kurstaki*) and/or endosulfan at 0.035 and 0.07%. HNPV + 0.07% endosulfan (15 days after spraying; DAS), HNPV + 0.035 endosulfan (7 DAS), HNPV + 0.07% endosulfan (7 DAS) and two sprays of 0.07% endosulfan at 15 days interval proved to be the best treatments as they recorded the lowest percent fruit damage and the highest yields (465.78, 435.06, 432.43 q/ha respectively). Dipel was ineffective.

Pokharkar and Chaudhary (2001) conducted field experiments during the spring seasons of 1992 and 1993, in Hisar, Haryana, India, to evaluate the efficacy of *H. armigera* nuclear polyhedrosis virus (HaNPV) and 8 synthetic insecticides at recommended concentrations applied alone, and combinations of HaNPV with half the dosages of these insecticides against fruit borer, *H. armigera* on tomato. The treatments comprised HaNPV 250 larval equivalent (LE)/ha, 0.07% endosulfan, 0.05% quinalphos, 0.05% monocrotophos, 0.15% carbaryl, 0.0075% cypermethrin, 0.01% fenvalerate, 0.002% deltamethrin, 0.008% fluvalinate, HaNPV 250 LE/ha combined with half the doses of these insecticides and untreated control. The synthetic pyrethroids, i.e. cypermethrin, fenvalerate and deltamethrin, were found superior over the conventional insecticides. Combined application of HaNPV 250 LE/ha with half the doses of these pyrethroids was comparable with their recommended doses in reducing the larval population and fruit damage, and increasing the yield. However, carbaryl and endosulfan applied alone and half of their dosages combined with HaNPV were better than monocrotophos and quinalphos and combinations of HaNPV with half the doses of these insecticides.

Praveen and Dhandapani (2001) studied the tomato fruits treated with biopesticides, *Bacillus thuringiensis* subsp. kurstaki (B.t.; at 0.25 and 5 g/litre), nuclear polyhedrosis virus (NPV; at 0.75 and 0.5 x 109 POB/litre) and neem *[Azadirachta indica]* formulation (Econeem at 0.5 ml/litre), were fed to the fruit borer *H. armigera*. The effect of these biopesticides on the food consumption, growth rate, digestion and food utilization of the insect pest was determined. The lowest consumption was observed in insects fed with Bt. Growth rate was highest in insects fed with fruits treated with NPV, while the lowest was observed in insects fed with B.t.-treated fruits. The approximate digestibility was highest in fruits treated with B.t. at 0.5 g/litre, and lowest in those treated with NPV at 0.5 x 109 POB/litre. Insects fed with B.t.-treated fruits had the highest gross efficiency or efficiency of conversion of ingested food (26.14 and 22.35% at 0.25 and 0.5 g/litre, respectively), while the lowest (16.33%) was in those fed with NPV- and neem-treated fruits. Net efficiency or efficiency of conversion of digested food was highest in the NPV and neem treatments, and lowest in the B.t. treatments.

Mehetre & Salunkhe (1998) conducted a field trial at Pune during 1995 to investigate the effects on *H. armigera* control on tomatoes of treatment with *T. pretiosum*, the nuclear polyhedrosis virus (NPV) or endosulfan (0.05%). On the basis of number and percentage of damaged fruits, all treatments were superior to the untreated control. Mean percentage of infested fruits for the 3 treatments was 19.3, 22.8 and 7.2, respectively, compared with 43.9 for the untreated control.

Gopalakrishnan *et al* (1998) conducted in on-farm field experiments at 5 sites in Karnataka with tomatoes, spraying with a formulation of nuclear polyhedrosis virus against *Helicoverpa armigera* significantly decreased larval count and increased fruit yield.

Sivaprakasam (1998) conducted in a field trial in tomatoes in July-December 1992 in Tamil Nadu, India, a treatment combining nuclear polyhedrosis virus (250 lethal equivalents/hectare) and endosulfan (260 g/ha) application produced better results in terms of reducing the population density of *Helicoverpa armigera* larvae, reducing damage to flowers and fruits and increasing yields, compared with treatments of endosulfan (520 g/ha or 4%) and nuclear polyhedrosis viruses alone, neem seed kernel or 2% neem oil.

Reddy *et al.* (1997) evaluated the effectiveness of *Bacillus thuringiensis* and a nuclear polyhedrosis virus for control of *Helicoverpa armigera*. The LC50 value for *Bacillus thuringiensis* var. *kurstaki* against 3rd-instar larvae of *H. armigera* was found to be 230 ppm. Spraying the tomato crop with 1000 ppm of the commercial formulation of *B. thuringiensis*, Delfin, gave 90% mortality whereas a crude extract of nuclear polyhedrosis virus of *H. armigera* at 1500 larval equivalents/ha resulted in only 40% mortality of 3rd-instar larvae of the pest.

Mohan *et al.* (1996) isolated an occluded baculovirus from *Helicoverpa armigera*. Morphological studies and electrophoretic analysis of the viral polypeptides identified the baculovirus to be a nuclear polyhedrosis virus (NPV). The NPV was infectious to all instars (excepting the 5th) of *H. armigera*. The virus was evaluated for controlling *H. armigera* on tomatoes in field studies conducted in India using a split-plot design. Three concentrations of NPV (300, 200, and 100 LE/ha, main-plot treatments) each at 3 spray intervals (sub-plot treatments) were evaluated. Application of NPV @ 300 LE/ha gave the lowest percentage of damaged fruits and the highest yield of marketable tomatoes. However, damages in response to the various spray intervals were not significantly different from each other. A spray programme involving 4 sprays of NPV @ 300 LE/ha, applied at an interval of 8 days, beginning from the sighting of 2 eggs or larvae, or during peak flowering, is recommended for the field management of *H. armigera* on tomato.

Padmanaban *et al.* (2002) evaluated a native isolate of *H. armigera* nucleopolyhedrosis virus (HaNPV), PAU1, for its efficacy against *H. armigera* on tomato (cv. Punjab Kesari) crops in a trial conducted in Punjab, India from November

2000 to April 2001. The efficacy of two and three weekly sprays of HaNPV at 250 and 375 LE/ha was compared with that of 1 kg carbaryl 50 WP/ha. Five days after the second spray, all the NPV treatments were at par with the standard and harboured significantly lower larval populations (2.16-3.15 larvae per 10 plants) than the control (7.5 larvae per 10 plants). Five days after the third spray, a larval population of 0.83 larvae per 10 plants was recorded upon three sprays of HaNPV at 375 LE/ha, and it was at par with two and three sprays of carbaryl with 0.83 and 0.50 larvae per 10 plants. Data from four pickings revealed that the three sprays with the higher dosage of HaNPV, which yielded 121.2 q/ha, were at par with three sprays of the standard insecticide, which yielded 121.5 q/ha.

2.3.4. BOTANICAL CONTROL

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

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

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

Sundarajan & Kumuthakalavalli (2000) tested Petroleum ether extracts of the leaves of *Gnidia glauca* Gilg., *Leucas aspera* Link., and *Toddalia asiatica* Lam. against sixth instar larvae of *Helicoverpa armigera* (Hubner.) at 0.2, 0.4, 0.6, 0.8 and 1.0% by applying to bhendi (okra) slices. After 24 hr, percentage mortality, EC50 and EC90 were calculated. Total mortality was recorded in the treatment with 0.8% of the extract of *G. glauca*. Of the three leaf extracts used, *G. glauca* showed an EC50 of 0.31%.

Lopez *et al.* (1998) assayed short-term choice and no-choice feeding used to assess the antifeedant activity of *T. havanensis* fruit extracts (at 5000 ppm) against 5th-instar *H. armigera* larvae. The acetonic extract gave the highest activity and was further fractionated by silica gel column chromatography. Of the 7 fractions isolated, 5 were identified as the limonoids azadirone, trichilinone acetate, 14,15-deoxyhavanensin-1,7-diacetate, 14,15-deoxyhavanensine-3,7-diacetate and a mixture of havanensin-1,7-diacetate and havanensin-3,7-diacetate. Choice and no-choice feeding assays of each fraction at 1000 ppm, showed that the mixture of havanensin-1,7-diacetate and havanensin-3,7-diacetate had the highest antifeedant activity against *H. armigera* larvae. Azadirone and trichilinone acetate were also antifeedants. No antifeedant activity was found in the remaining fractions. It is suggested that all of the limonoids with antifeedant activity have a similar mode of action, which is probably toxic.

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

2.3.5. INSECTICIDAL CONTROL

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

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

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

Attri *et al.* (1978) carried out a study to evaluate the effectiveness of spray residues of phenthoate, where when applied against *Helicoverpa armigera* (Hb.) on tomato and compared with carbaryl and malathion. The results showed that carbaryl was the most effective compound and was significantly superior to malathion and phenthoate. Residues analysis of phenthoate showed that in the absence of a tolerance limit for this compound, a waiting period of 14 days should be observed for tomatoes, which is impractical since they have to be picked every 2-3 days.

Patel *et al.* (1991) conducted field studies in Gujarat, India, during the rabi seasons of 1987-88 and 1989-90 to determine an effective and economical insecticide formulation to control the noctuid *Helicoverpa armigera* on tomatoes, endosulfan (0.07%) spray gave the highest cost-benefit ratio (1:52.6) followed by endosulfan (2%) dust (1:4.9). Results are also given for monocrotophos, quinalphos and malathion.

Jitender *et al.* (1999) conducted an experiment on the estimation of avoidable yield loss due to fruit borer, *Helicoverpa armigera* in tomato (cv. Roma) planted at three dates (first week each of April, May and June), during 1993 and 1994, in Kullu valley, Himachal Pradesh, India, showed that in crop transplanted in the first week of April yield loss to the extent of 105.29, 76.02 and 57.02% could be avoided by giving three sprays of acephate (0.05%), fenvalerate (0.01%) and endosulfan (0.05%), respectively. In crop transplanted in the first week of May yield loss of 32.64, 28.04 and 18.50% could be avoided as a result of sprays of respective insecticides. Whereas in June-transplanted crop, 2 sprays each of acephate, fenvalerate and endosulfan helped in avoiding 25.03, 13.91 and 11.76% yield loss, respectively. Irrespective of dates of transplanting, the average yield loss to the extent of 49.27, 36.54 and 26.59% could be avoided by sprays of acephate, fenvalerate and endosulfan. The average net return per rupee invested worked out to be Rs 14 for acephate, Rs 13.18 for fenvalerate and Rs 7.80 for endosulfan sprays.

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

Walunj *et al.* (1999) conducted field trials at Ahemadnagar, Maharashtra, India, in 1997-98 to asses the efficacy of profenofos at 0.5kg/ha, profenofos + cypermethrin at 0.33-0.44kg, lufenuron at 0.33kg, dichlorvos at 0.76kg and cypermethrin at 0.05kg for control of *Helicoverpa armigera* in tomatoes cv. Namdhari Hybrid 815. Products were applied 5 times at 15 day intervals. The results indicated that fruit damage was reduced in all treatments. Lowest infestations and highest yields of marketable fruits (7.388t/ha) were recorded with the 0.44kg profenofos + cypermethrin treatment.

Dilbagh *et al.* (1990) conducted field trials in Punjab, India and revealed that fenvalerate, permethrin and cypermethrin applied at 50g a.i./ha, or decamethrin [deltamethrin] applied at 20g a.i./ha gave equal or better control of the noctuid *Helicoverpa armigera* than carbaryl or endosulfan applied at 1000 and 700g a.i./ha, respectively. Yields were higher when synthetic pyrethroids were used.

Ogunwolu (1989) studied the effects of damage caused by *Helicoverpa armigera* on yields of tomato transplanted at different times in Nigeria in 1985-86 by treatment with some insecticides against this pest. Fruit damage was highly but negatively correlated with the number, weight and yield of harvested fruits. Fruit damage was significantly reduced and yield increased by spraying, showing that serious damage was caused by *H. armigera*. Cypermethrin suppressed fruit damage by 70.4 and 52.2% in 1985 and 1986 and increased yield by 115.0 and 67.6%, respectively.

Mehta *et al* (2000) carried out an experiment on the management of tomato fruit borer, *Heliocoverpa armigera* (Hubner) with nine insecticidal treatments for 3 season during 1995-1997 at Palampur (Himachal Pradesh, India). Over all effectiveness expressed as reduction in borer damaged tomato fruits and increase in fruit yield indicated the superiority of deltamethrin alone or in combination all through the experimentation. Application of deltamethrin resulted in lowest fruit damage (4.27%)

followed by cypermethrin (8.98) and acephate (9.16%). Among the biopesticides tested, B.t. treated plots had lowest fruit infestation (10.68%) as compared to HaNPV (11.95%) and azadirachtin (14.68%). A mixture of deltamethrin + B.t. application reveled a fruit damage of 5.58 percent while untreated control had 24.2 percent fruit damage. The mean fruit yield was highest in deltamethrin + B.t. treated plots followed by deltamethrin, acephate and cypermethrin.

2.3.6. INTEGRATED PEST MMANAGEMENT (IPM)

Brar *et al* (2003) carried out a study to determine the efficacy of *Trichogramma pretiosum* (5 releases weekly at 50000 per ha), *H. armigera* nuclear polyhedrosis virus (Ha NPV; 2,3 or5 sprays at 7-, 10 or 15-day intervals at 1.5 x 1012 polyhedral occlusion bodies per ha) and /or endosulfan (3 sprays at 15 day intervals at 700 g/ha) for the management of tomato fruit borer (*H. armigera*) in Punjab, India, during 1999-2002. In all study years, egg parasitism was high (36.32-61.00%) in plots where *T. pretiosum* was released. The mean egg parasitism was highest in the plot treated with *T. pretiosum* alone (49.33). The mean egg parasitism was 7.45 and 14.85% in the endosulfan-treated and control plots respectively. Fruit damage was highest during 1999-2000. Among all treatments, treatment with *T. pretiosum* + HaNPV + endosulfan resulted in the lowest fruit damage (13.07%) and the highest mean yield (243.86 q/ha). The control treatment had the borer incidence and fruit damage, and the lowest yield 163.31q/ha) among all treatments. The yield in endosulfan alone was 209.31q/ha, which was significantly superior to three HaNPV sprays (184.15q/ha). It is concluded that the treatment combination *T. pretiosum* + HaNPV + endosulfan was most effective for *H. armigera* control.

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

Sundararajan (2001) carried out toxicological studies to evaluate the effect of leaf methanolic extracts of 5 indigenous plant materials namely, *Abutilon indicum, Achyranthes aspera, Ailanthus excelsa, Alstonia venenata and Azima tetracantha* against *Helicoverpa armigera*. Twenty healthy larvae collected from a tomato field were released into plastic containers containing tomato leaves treated with each of the plant extracts. The larval mortality was recorded 48 h after the release. Larval mortality on tomato leaves treated with *Azima tetracantha, Achyranthes aspera, Abutilon indicm, Ailanthus excelsa and Alstonia venenata* averaged 51, 58, 62, 67 and 73%, respectively.

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

Karabhantanal *et al* (2005) carried out an investigation during 2001 and 2002 during kharif seasons in Karnataka, India, to evaluate different Integrated Pest management (IPM) modules against tomato fruit borer, *Helicoverpa armigera*. The results revealed that the IPM module consisting of trap crop (15 row of tomato: 1 row marigold) + *Trichoghamma pretiosum* (45000%/ ha)-NSKE (5%)- HaNPV (250LE/ha) - endosulfan 35 EC (1250ml/ha) was significantly superior over the rest of the modules tested in restricting the larval population (100% after the fourth spray). As a result of which, the lowest fruit damage (11.87%), highest marketable fruit yield (224.56q/ha) and additional net profit (Rs. 22915/ha was observed in this module, but was comparable with the recommended package of practice and IPM module consisting of *Nomuraea rilevi* (2.0 x1011 conidia/ha) NSKE (5%) HaNPV (250LE/ha)– endosulfan 35EC (1250ml/ha).

Sivaprakasam (1998) conducted field studies in Tamil Nadu, India, during July-December 1992 and revealed that nuclear polyhedrosis virus + endosulfan (260 g) and endosulfan (520 g) sprays gave an effective level of control of *Helicoverpa armigera* infesting the PKM1 variety of tomato.

Pokharkar *et al.* (1999) conducted an experiment during the spring seasons of 1992 and 1993 in Hisar, Haryana, India, to study the effectiveness of nuclear polyhedrosis virus alone and in combination with endosulfan in the integrated control of *Helicoverpa armigera* on tomato *(Lycopersicon esculentum)*. Three sprays of endosulfan 0.07% at 10-day-intervals starting from 50% flowering of the crop proved to be effective. Application of *Helicoverpa armigera* nuclear polyhedrosis 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, 57.49 kg/plot (4 mX5 m) mean total yield and 53.64 kg/plot mean marketable yield, and it was as effective as the *Helicoverpa armigera* nuclear polyhedrosis virus at the 500 LE/ha dose. Sequential application with the first spray of 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 applications of endosulfan 0.07% applied alone.

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

Ganguli *et al.* (1997) carried out field trials in winter 1994-95 at Raipur, Madhya Pradesh, India, to study the effectiveness of NPV (250 LE (larval equivalents)/ha) applied at time of pest appearance + endosulfan (0.035 or 0.070%, 7 or 15 days after NPV) against *Helicoverpa armigera* incidence and yield of tomato cv. Pusa Ruby. Other treatments included 2 consecutive sprays of NPV, a single spray of NPV or endosulfan, and a control (no treatment). Fruit damage at the time of first picking ranged from 20.26 to 41.34%, with the least damage occurring on plots treated with NPV followed by endosulfan. Tomato yields were significantly greater on plots treated with NPV followed 7 days later by 0.07% endosulfan (178.40 Q/ha (17.84 t/ha)) than on any other plots. It is concluded that spraying with NPV (250 LE/ha) at the time of appearance of the pest, followed 7 days later by endosulfan at 0.035 or 0.070%, will protect the tomato crop from *H. armigera.*

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

CHAPTER III

MATERIALS AND METHODS

The study comprising two sets of experiment have been conducted during October, 2006 to March 2007 at the experimental fields of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla nagar, Dhaka, Bangladesh.

Experiment 1: Screening of some selected tomato varieties/genotypes for resistance against tomato fruit borer, *Helicoverpa armigera* (Hubner).

Experiment 2: Evaluation of some management practices against tomato fruit borer, *Helicoverpa armigera* (Hubner) .

Other details of the experiments are furnished below:

Experiment 1: Screening of some selected tomato varieties/genotypes for resistance against tomato fruit borer, *Helicoverpa armigera* (Hubner)

The present study was conducted on screening of nine selected tomato varieties/genotypes against tomato fruit borer, *Helicoverpa armigera* (Hubner) at the experimental field of the SAU, Dhaka, during October 2006 to March 2007.

3.1.1. TREATMENTS

The nine varieties/genotypes of tomato, *Lycopersicon esculentum* Mill collected from different sources and used in this study are given in Table 1 and each variety of which was considered as an individual treatment.

Table 1. Name and source of tomato varieties/genotypes used under the trial

Treatment	Variety	Source of availability
T_1	BARI-2 (Ratan)	Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur, Bangladesh
T_2	BARI-3	
T_3	BARI-7 (Apurbo)	
T_4	BARI-8 (Shila)	
T_5	BARI-9 (Lalima)	
T_6	BINA-1	Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, Bangladesh
T_7	BANA-2	
T_8	BANA-3	
T_9	BINA-4	

3.1.2. LOCATION OF THE EXPERIMENTAL FIELD

The experiments were conducted in the experimental farm of SAU, Dhaka situated at latitude 23.46 N and longitude 90.23E with an elevation of 8.45 meter the sea level. Laboratory studies were done in the laboratory of Entomology department, SAU. Required materials and methodology are described below under the following sub heading.

3.1.3. CLIMATE OF THE EXPERIMENTAL AREA

The experimental area is characterized by subtropical rainfall during the month of May to September (Annon., 1988) and scattered rainfall during the rest of the year (Appendix I).

3.1.4. SOIL OF THE EXPERIMENTAL FIELD

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

3.1.5. LAND PREPARATION

The soil was well prepared and good tilth was ensured for commercial crop production. The target land was divided into 21 equal plots (3m×1.5m) with plot to plot distance of 1.0 m and block to block distance is 1.0 m. The land of the experimental field was ploughed with a power tiller. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was ready. The field layout and design of the experiment were followed immediately after land preparation.

3.1.6. MANURE AND FERTILIZER

Recommended fertilizers were applied at the rate of 500 kg urea, 400kg triple super phosphate (TSP) and 20kg muriate of potash (MP) per hectare (Rashid, 1993) were used as source of nitrogen, phosphorus and potassium, respectively. Moreover, well-decomposed cow dung (CD) was also applied at the rate of 10 ton/ha to the field at the time of land preparation.

3.1.7. DESIGN OF EXPERIMENT AND LAYOUT

The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. The whole area of experimental field was divided into 3 blocks and each block was again divided into 9 unit plots. The size of the unit plot was 3.0 m×1.5 m. The block to block and plot-to-plot distance was 1.0 m and 1.0 m, respectively.

3.1.8. COLLECTION OF SEED, SEEDLING RAISING AND TRANSPLANTING

The seeds of nine selected tomato varieties BARI-2 (Ratan), BARI-3, BARI-7 (Apurbo), BARI-8 (Shila), BARI-9 (Lalimma), BINA-1, BINA-2, BINA-3, and BINA-4 were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur and Bangabandhu Sheikh Mujibur Rahman Agricultural University (BSMRAU), Salna, Gazipur and Bangladesh Institute of Nuclear Agriculture, Mymensingh, Bangladesh. Each of these 9 selected tomato varieties was treated as an individual treatment. Before sowing seeds, the germination test was done and 90% germination was found for all varieties. Seeds were then directly sown in the 16th October, 2006 in seedbed containing a mixture of equal proportion well decomposed cow dung and loam soil. After sowing seeds, the seedbeds were irrigated regularly. After germination, the seedlings were spayed with water by a hand sprayer. Soil was spaded 3 or 4 days for a week.

3.1.9. SEEDLING TRANSPLANTING

The 30 days old healthy seedlings of nine tomato varieties (Table 1) were transplanted on November 14^{th}, 2006 in the pits of the randomly selected each unit plot assigned for each variety in the main field. Other intercultural operations were done mentioned earlier.

3.2.10. CULTURAL PRACTICES

After transplanting, a light irrigation was given. Subsequent irrigation was applied in all the plots as and when needed. 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 height from ground level for additional support and to allow normal creeping. Weeding and mulching in the plot were done, whenever necessary.

3.1.11. DATA COLLECTION AND CALCULATION

For data collection three plants per plot were randomly selected and tagged. Data collection was started at flower initiation up to fruit harvest. The data were recorded on flower and fruit (number and weight) infestation by tomato fruit borer larvae. All the data were collected once in a week.

3.1.11.1 Percent flower infestation by number

Number of infested flower was counted from total flowers and percent flower infestation was calculated as follows:

$$\% \text{ flower infestation} = \frac{\text{Number of the infested flower}}{\text{Total number of flower}} \times 100$$

3.1.11.2. Percent fruit infestation by number

Number of infested fruit was counted from total harvested fruits and percent fruit infestation in number was calculated as follows:

$$\%\text{fruit infestation (number)} = \frac{\text{Number of the infested fruit}}{\text{Total number of fruit}} \times 100$$

3.1.11.3. Percent fruit infestation by weight

Infested fruits were weighted from total harvested fruits and percent fruit infestation was calculated as follows:

$$\%\text{fruit infestation (weight)} = \frac{\text{Weight of the infested fruit}}{\text{Weight of the total fruit}} \times 100$$

3.1.11.4. Infestation severity

Total number of fruit and the number of fruit borer infested fruits in each plot were recorded. The percentage of tomato fruit borer infestation was then graded by grading designation used by Mishra and Mishra (1996) as follows:

% fruit infestation	Grade
1-5	1 Highly resistant
5.1-10	2. Moderately resistant
10.1-15	3. Susceptible
Above 15	4. Highly susceptible

3.1.11.5. Percent yield loss

The weight of infested fruits was recorded from the total weight of the harvested fruits for each plot and the percent yield loss was calculated considering the following formula:

$$\% \text{ yield loss} = \frac{\text{Average wt. of healthy fruit per plot} - \text{Average.fruit wt.of per plot}}{\text{Average weight of healthy fruit per plot}} \times 100$$

3.1.11.6. STATISTICAL ANALYSIS

Data statistically analyzed by randomized complete block design through MSTAT-C software (Anonymous, 1989) and Duncan's multiple range test (Duncan, 1955) was used to determine the levels of significant differences among tomato varieties with regards to studied tomato fruit borer infestation.

Experiment 2: Evaluation of some management practices against tomato fruit borer

The present study on evaluation of some management practices against tomato fruit borer, *Helicoverpa armigera* (Hubner) infesting tomato was under taken and conducted at the experimental field of Sher-e-Bangla Agricultural University, Sher-e-Bangla nagar, Dhaka, during October, 2006 to March, 2007.

3.2.1. TREATMENTS

Comparative effectiveness of the following eight treatments in reducing the tomato fruit borer infestation on tomato (BARI tomato-2) was evaluated:

T_1= Handpicking tomato plants with removal of infested flowers and fruits at 7 days interval + supporting the tomato plants with bamboo stick

T_2= Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick

T_3= Spraying of Ripcord 10 EC @ 1.7 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick

T_4= Spraying of Sevin 85 WP @ 3.4g/L of water at 7 days interval + supporting the tomato plants with bamboo stick

T_5= Spraying of Malathion @ 2.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick

T_6= Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick

T_7= Only supporting the tomato plants with bamboo stick without any spray.

T_8= Untreated control without any support of the tomato plants.

3.2.2. DESCRIPTION OF THE TREATMENTS

T_1: Handpicking and removal of infested flowers and fruits and each plants of the plot was supported by bamboo stick to protect the fruits from touching the soil. Plants under this treatment were grown from normal seedling. Borer infested flowers and fruits were collected and destroyed. Clean cultivation was also practiced to keep the plot free from weeds, debris to discourage the insect population.

T_2: Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval and each plants of the plot was supported by bamboo stick to protect the fruits from touching the soil. For this treatment 5.0 ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals.

T_3: Application of Ripcord 10 EC @ 1.7 ml/L of water at 7 days interval and each plants of the plot was supported by bamboo stick to protect the fruits from touching the soil. For this treatment 8.5 ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals.

T_4: Application of Sevin 85 WP @ 3.4 gm/L of water at 7 days interval and each plants of the plot was supported by bamboo stick to protect the fruits from touching the soil. For this treatment 17 gm of insecticides per 5 liter of water was mixed sprayed at 7 days intervals.

T_5: Spraying of Malathion @ 2.0 ml/L of water at 7 days interval and each plants of the plot was supported by bamboo stick to protect the fruits from touching the soil. For this treatment 10 ml of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals.

T_6: Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval and each plants of the plot was supported by bamboo stick to protect the fruits from touching the soil. Under this treatment, neem oil were applied @ 15 ml /5L of water mixed with trix liquid detergent @ 10 ml (1%) to make the oil easy soluble in water. After proper shaking, the prepared spray was applied with a high volume knap-sack sprayer at 7 days intervals commencing from first flowering.

T_7: Only supports for proper creeping of each tomato plants were used. After 7 days of transplanting, propping of each plant per pit by two bamboo sticks (1.75m) as inverted V-shape was provided vertically on about 1.5 m high from ground level for additional support and to allow normal creeping as well as to help the plants for detouching from the soil surface. An additional one bamboo stick was used horizontally to support the all vertically used bamboo sticks for each row of the plot.

T_8: Untreated control treatment. There was no any control measure as well as any support was used in tomato plants.

3.2.3. NEEM OIL AND TRIX DETERGENT PREPARATION FOR SPRAYING

The fresh neem oil was collected from Chawkbazar, Dhaka and the trix liquid detergent was collected from the local market of Agargoan bazaar, Dhaka. All sprays were made according to the methods described earlier. For each neem oil application, 15 ml neem oil (@ 3.0 ml/L of water i.e. 0.3%) per 5 liter of water was used. The mixture within the spray machine was shacked well and sprayed on the upper and lower surface of the plants of the treatment until the drop run off from the plant. Three liters spray material was required to spray in three plot of each replication.

3.2.4. LOCATION, CLIMATE AND SOIL OF THE EXPERIMENT

This experiment was conducted in the experimental farm of SAU, Dhaka, which climate and soil characters are mentioned in the earlier experiment.

3.2.5. LAND PREPARATION, MANURING AND FERTILIZATION

The soil was well prepared with good tilth and recommended fertilizers were applied for commercial tomato production as mentioned in the earlier experiment.

3.2.6. DESIGN AND LAYOUT OF THE EXPERIMENT

The experiment was laid out in a Randomized Complete Block Design (RCBD) with 3 replications. The whole area of experimental field was divided into 3 blocks and each block was again divided into equal 8 unit plots. The size of the unit plot was 3.0 m×1.5 m. The block to block and plot-to-plot distance was 1.0 m for each.

3.2.7. SEEDLING RAISING, TRANSPLANTING AND CULTURAL PRACTICES

Seeds of variety BARI 2 (Ratan) were directly sown on the 16th October, 2006 in the seedbed and after then proper managements were done as mentioned in the earlier experiment. Then, 30 days old healthy seedlings were transplanted in thee main field as mentioned in the earlier experiment and proper intercultural operations were done for proper growth of the plants.

3.2.8. DATA COLLECTION AND CALCULATION

The effectiveness of each treatment in reducing the tomato fruit borer infestation was evaluated on the basis of some pre-selected parameters. The following parameters were considered during data collection.

3.2.9. NUMBER AND WEIGHT OF THE HEALTHY AND INFESTED FRUITS

Data were collected on the number of healthy and infested fruits per randomly selected 3 tagged plants and plot harvested at early, mid and late fruiting stages of the crop and weighted separately for each treatment. Marketable fruits were harvested usually at twice a week.

3.2.10. CALCULATION OF THE RECORDED DATA

3.2.10.1. Percent fruit infestation by number

Infested fruits were counted from total harvested and the percent fruit infestation was calculated using the following formula:

$$\text{\% fruit infestation (number)} = \frac{\text{Number of the infested fruit}}{\text{Total number of fruit}} \times 100$$

3.2.10.2. Percent fruit infestation by weight

Weight of the infested fruits was recorded from total weight of the harvested fruits and the percent fruit infestation by weight was calculated using the following formula:

$$\text{\% fruit infestation (weight)} = \frac{\text{Weight of the infested fruit}}{\text{Weight of the total fruit}} \times 100$$

3.2.10.3. Percent reduction of fruit infestation over control

The number and weight of infested and total fruit for each treated plot and untreated control plot were recorded and the percent reduction of fruit infestation in number and weight was calculated using the following formula:

$$\text{Percent infestation reduction over control} = \frac{X_2 - X_1}{X_2} \times 100$$

Where, X_1 = the mean value of the treated plot

X_2 = the mean value of the untreated plot

3.2.10.4. APPARATUS AND INSTRUMENTS USED

Sample was collected from field in polythene bags, iron cases and petridishes as where needed. Weighting balance was used for taking weight of healthy and infested fruits.

CHAPTER IV

RESULTS AND DISCUSSION

Experiment 1: Screening of some selected tomato varieties/genotypes for resistance against tomato fruit borer, *Helicoverpa armigera* (Hubner).

The present experiment was conducted to screen out the nine selected tomato varieties/genotypes for resistance against tomato fruit borer, *Helicoverpa armigera* (Hubner). The results have been presented and discussed, and possible interpretations have been given under the following sub-headings:

4.1.1 Fruit borer infestation by number

Different tomato varieties showed statistically significant differences in respect of percent fruit infestation in number infested by tomato fruit borer at early, mid and late fruiting stage under the present trial. The infestation for tomato fruit borer for different tomato varieties is presented in Table 2. At early fruiting stage, the highest percent fruit infestation by number (8.49%) was recorded in the variety BARI-8, which was statistically similar (8.46%) with the variety BARI-2 followed by variety BARI-9 (6.77%) and BARI-3 (6.75%). On the other hand, the lowest percent fruit infestation by number (3.27%) was recorded in BINA-2, which was statistically identical with the variety BINA-1 (3.29%), followed by the variety BARI-7 (5.54%), BINA-3 (5.26%) and BINA-4 (5.06%). Again at mid fruiting stage, the highest percent fruit infestation by number (12.82%) was recorded in the variety BARI-8, which was statistically similar with the variety BARI-2 (12.26%), followed by the variety BARI-9 (10.22%) and BARI-3 (9.06%) and the lowest percent fruit infestation in number was recorded in BINA-2 (4.92%), which was statistically identical with the variety BINA-1 (5.05%) followed by the variety BINA-3 (7.14%), BARI-7 (6.99%) and BINA-4 (5.83%). Finally, the highest percent fruit infestation by number (17.75%) was recorded in the variety BARI-2 at late fruiting stage, which was statistically similar with the variety BARI-8 (16.47%), followed by the variety BARI-9 (14.55%) and BARI-3 (11.86%) and the lowest percent fruit infestation by number was recorded in BINA-1 (6.24%), which was statistically identical with the variety

BINA-2 (6.42%), BINA-2 (6.42%), BINA-4 (7.65%) and BARI-7 (7.83%). Among varieties, the mean percent fruit infestation by number was calculated and the significant differences were also observed among nine tomato varieties. In an average, the highest percent fruit borer infestation by number (12.82%) was observed in the variety BARI-2, which was statistically identical with the variety BARI-8 (12.59%) and the lowest percent fruit infestation by number (4.86%) was recorded in the variety BINA-1, which was statistically similar with the variety BINA-2 (4.87%) (Table 2). From these findings it is revealed that among all nine tomato varieties/genotypes, the tomato fruit borer infestation was lower in the early fruiting stage and the higher fruit infestation was observed at the late fruiting stage. Similar findings were also observed by Khanam (2000), Sharma *et al.* (1990), Mishra and Mishra (1996).

Table 2. Percentage of tomato fruit borer infestation by number at different fruiting stages

Variety	Percentage of tomato fruit borer infestation by number at					Level of resistance
	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean	Ranked order	
BARI-2	8.46 a	12.26 a	17.75 a	12.82 a	1	S
BARI-3	6.75 b	9.06 b	11.86 c	9.22 c	4	MR
BARI-7	5.54 c	6.99 c	7.83 de	6.79 d	6	MR
BARI-8	8.49 a	12.82 a	16.47 a	12.59 a	2	S
BARI-9	6.77 b	10.22 b	14.55 b	10.51 b	3	S
BINA-1	3.29 d	5.05 d	6.24 e	4.86 e	8	HR
BINA-2	3.27 d	4.92 d	6.42 e	4.87 e	9	HR
BINA-3	5.26 c	7.14 c	9.47 d	7.29 d	5	MR
BINA-4	5.06 c	5.83 c	7.65 de	6.18 d	7	MR
$LSD_{(0.05)}$	0.652	1.889	1.889	1.092	--	--
CV (%)	6.19	12.88	9.80	7.37	--	--

Highly resistant (HR): 1-5% fruit infestation; Moderately resistant (MR): 5.1-10% fruit infestation and Susceptible (S): 10.1-15% fruit infestation (Mishra and Mishra, 1996)

Figures in a column accompanied by similar letter(s) do not differ significantly at 0.05 level of probability as per DMRT

As per grading designation, among the nine tomato varieties evaluated against tomato fruit borer, the varieties BARI-2, BARI-8 and BARI-9 were found as susceptible to tomato fruit borer and the varieties BARI-3, BARI-7, BINA-3 and BINA-4 were found as moderately resistant, whereas BINA-1 and BINA-2 were found as highly resistant varieties when infestation level was calculated in number under the present trial (Table 2). Similar findings were observed by Mishra *et al.* (1996), Husain *et al.* (1998). Khanam (2000) was also found similar findings and she stated that among thirty tomato varieties/lines none was found resistant to tomato fruit borer; the lines V-29 and V-282 were found moderately resistant; the line V-232 was susceptible and other 27 varieties/lines including BARI-3 (Manik), BARI-2 (Ratan) BARI-10 were found highly susceptible to tomato fruit borer.

4.1.2 Fruit borer infestation by weight

The percent tomato fruit borer infestation by weight at early, mid and late fruiting stage showed statistically significant variations for different tomato varieties under the present experiment (Table 3). At early fruiting stage, the highest percent fruit infestation by weight was recorded in the variety BARI-2 (9.11%), which was statistically similar with the variety BARI-8 (8.94%) followed by the variety BARI-9 (7.41%) and BARI-3 (7.17%). On the other hand, the lowest percent fruit infestation by weight was recorded in BINA-1 (3.59%), which was statistically identical with the variety BINA-2 (3.78%), followed by BINA-4 (5.49%), BINA-3 (5.94%) and BARI-7 (6.08%). Yet again, at mid fruiting stage, the highest percent fruit infestation by weight was recorded in the variety BARI-8 (13.28%), which was statistically similar with the variety BARI-2 (12.97%), followed by the variety BARI-9 (10.77%) and BARI-3 (9.55%) and the lowest percent fruit infestation in weight was recorded in BINA-1 (5.04%), which was statistically identical with the variety BINA-2 (5.27%), BINA-4 (6.45%), BARI-7 (7.56%) and BINA-3 (7.84). At late fruiting stage, similar trend of the results of early and mid fruiting stages was observed, i.e., the highest percent fruit infestation by weight was recorded in the variety BARI-2 (17.54%) followed by the variety BARI-8 (13.16%) and the lowest percent fruit infestation was recorded in BINA-1 (5.80%), which was statistically identical with the variety BINA-2 (6.11%).

Table 3. Percentage of tomato fruit borer infestation by weight at different fruiting stages

Variety	Percentage of tomato fruit borer infestation by weight at					Level of resistance
	Early fruiting stage	Mid fruiting stage	Late fruiting stage	Mean	Ranked order	
BARI-2	9.11 a	12.97 a	17.54 a	13.21 a	1	S
BARI-3	7.17 b	9.55 bc	12.14 b	9.62 c	4	MR
BARI-7	6.08 c	7.56 cd	8.41 d	7.35 e	6	MR
BARI-8	8.94 a	13.28 a	13.16 b	11.79 b	2	S
BARI-9	7.41 b	10.77 b	10.89 c	9.69 c	3	MR
BINA-1	3.59 d	5.04 d	6.11 d	4.91 g	8	HR
BINA-2	3.78 d	5.27 d	5.80 e	4.95 g	9	HR
BINA-3	5.94 c	7.84 cd	10.80 c	8.20 d	5	MR
BINA-4	5.49 c	6.45 d	7.89 de	6.61 f	7	MR
$LSD_{(0.05)}$	0.791	1.902	1.251	0.617	--	
CV (%)	6.89	12.11	6.78	4.06	--	

Highly resistant (HR): 1-5% fruit infestation; Moderately resistant (MR): 5.1-10% fruit infestation and Susceptible (S): 10.1-15% fruit infestation (Mishra and Mishra, 1996)

Figures in a column accompanied by similar letter(s) do not differ significantly at 0.05 level of probability as per DMRT

Among the nine tomato varieties, the mean percent fruit infestation was calculated and the significant differences were also found among the varieties. In an average, the highest percent tomato fruit borer infestation by weight was recorded in the variety BARI-2 (13.21%) followed by the variety BARI-8 (11.79%) and the lowest percent fruit infestation was recorded in the variety BINA-1 (4.91%) and BINA-2 (4.95%) (Table 3). In every stages of the infestation level, more or less similar increasing trend for all nine varieties both by number and weight was observed. Similar findings were also observed by Khanam (2000), Sharma *et al.* (1990).

As per grading designation, among the nine tomato varieties evaluated against tomato fruit borer, the variety BARI-2 and BARI-8 were found as the susceptible variety to tomato fruit borer and the variety BARI-3, BARI-7, BARI-9, BINA-3 and BINA-4 were found as the moderately resistant, whereas BINA-1 and BINA-2 were found as the highly resistant varieties against tomato fruit borer when infestation level was calculated by weight under the present trial (Table 3). These findings were also supported by Mishra and Mishra (1996). Thakur *et al.* (1998) also reported the similar results in one of the experiments and also recorded 0.66% of infested fruit in resistant variety.

4.1.3 Yield and yield contributing characters and % yield loss by tomato fruit borer infestation

Significant variation was recorded in terms of number of fruit per plant, single fruit weight, fruit yield (kg/plot and ton/ha) and percent yield loss due to tomato fruit borer infestation of different tomato varieties/genotypes under the present trial represented in Table 4. In consideration of number of fruit per plant, the maximum number of fruit per plant (64.79) was recorded in the variety BINA-2, which was statistically different from all other varieties followed (31.33) by BARI-3, BARI-8, BARI-7 (29.00), BARI-9 (27.67), BARI-2 (27.33) and BINA-3 (27.33) (Table 4). On the other hand, the minimum number (23.33) of fruit per plant was recorded for variety BINA-1 followed by BINA-4 (25.67).

In terms of single fruit weight, the maximum single fruit weight was recorded for the variety BINA-1 (143.33 g), which was significantly different from all other varieties followed by the variety BARI-2 (120.00 g), which was statistically similar with BARI-9 (117.00 g), BINA-3 (118.67 g) and BINA-4 (109.33 g) and the minimum single fruit weight (50.93 g) was recorded in the variety BINA-2 followed by BARI-7 (85.33 g), which was statistically similar with BARI-3 (88.67 g) and BARI-8 (99.33 g). From the results it was found that the minimum number of fruit for each plant contributed maximum weight per single fruit.

Considering the fruit weight per plot (3 m x 1.5 m), the highest fruit weight per plot (33.52 kg) was recorded for the variety BINA-1 which was statistically identical with the variety BINA-2 and BARI-2 (32.96 kg and 32.85 kg, respectively), and the lowest fruit weight/plot (24.74 kg) was recorded in the variety BARI-7 followed by BARI-3 (27.76 ka), BINA-4 (28.09 ka) and BARI-8 (29.24 kg) varieties (Table 4). As a result, the trend of the results is BINA-1>BINA-2>BARI-2>BINA-3>BARI-9>BARI-8 >BINA-4>BARI-3>BARI-7 (Table 4).

Table 4. Yield and yield contributing character and % yield loss by tomato fruit borer infestation

Variety	Number of fruit per plant	Single fruit weight (g)	Weight of fruit/plant (kg)	Yield (kg/plot)	Yield (t/ha)	Yield loss (%)
BARI-2	27.33 b	120.00 b	3.29 a	32.85 a	73.00 a	15.17 a
BARI-3	31.33 b	88.67 c	2.78 bc	27.76 bc	61.69 bc	10.64 c
BARI-7	29.00 b	85.33 c	2.47 c	24.74 c	54.98 c	7.94 de
BARI-8	31.33 b	93.33 c	2.92 abc	29.24 abc	64.98 abc	13.33 b
BARI-9	27.67 b	117.00 b	3.22 ab	32.23 ab	71.62 ab	10.71 c
BINA-1	23.33 c	143.33 a	3.35 a	33.52 a	74.49 a	7.06 ef
BINA-2	64.79 d	50.93 d	3.30 a	32.96 a	73.24 a	6.46 f
BINA-3	27.33 b	118.67 b	3.23 ab	32.35 ab	71.89 ab	8.93 d
BINA-4	25.67 bc	109.33 b	2.81 bc	28.09 bc	62.42 bc	7.09 ef
$LSD_{(0.05)}$	3.153	11.96	0.424	4.222	17.59	6.75
CV (%)	4.15	6.29	8.02	8.02	6.51	4.98

Figures in a column accompanied by similar letter(s) do not differ significantly at 0.05 level of probability as per DMRT

The highest yield (74.49 t/ha) was recorded for the variety BINA-1 which was statistically similar with the variety BINA-2 (73.24 t/ha) and BARI-2 (73.00 t/ha) followed by BINA-3 (71.89 t/h) and BARI-9 (71.62 t/h). On the other hand, the lowest yield (54.98 t/ha) was recorded in the variety BARI-7, which was statistically different from all other varieties tested under the trial followed by BARI-3 (61.69 t/ha), BINA-4 (62.42) and BARI-8 varieties (Table 4) and similar trend of results observed that was found in terms of fruit weight (kg/plot).

The yield loss due to tomato fruit borer infestation was also calculated for different tomato varieties depicted in Table 4. The highest (15.17%) yield loss was recorded for the variety BARI-2, which was statistically different from all other tomato varieties followed by BARI-8 (13.33%), BARI-9 (10.71%) and BARI-3 (10.64%). On the other hand, the lowest yield loss (6.46%) was recorded for the variety BINA-2, which was statistically similar with the yield loss of varieties BINA-1 (7.06%) and BINA-4 (7.09%) followed by the variety BARI-7 (7.94%) and BINA-3 (8.93%). As a result, the trend of the results in terms of yield loss is BARI-2 > BARI-8 > BARI-9> BARI-3 > BINA-3> BARI-7 > BINA-4 > BINA-1 > BINA-2 (Table 4). Mishra and Mishra (1996), Sharma *et al.* (1990) also reported similar results earlier in their experiment.

4.1.4 Relationship between number of fruits/plant and yield/ha

Correlation study was done to established a relationship between number of fruits/plant and yield (t/ha). From the study it was revealed that significant correlations existed between the characters (Figure 1). The regression equation $y = -2.2636x + 170.11$ gave a good fit to the data and the value of the co-efficient of determination ($R^2 = 0.2061$). From this it can be concluded that number of fruits was not positively related to the yield.

4.1.5 Relationship between single fruit weight and yield/ha

When the data on single fruit weight and yield per hectare were regressed a positive relationship was obtained between these two characters. Here the equation $y = 0.5957x - 41.229$ gave a good fit to the data, and the value of the co-efficient of determination ($R^2 = 0.7332$) showed that the fitted regression line had a significant regression coefficient. The increase in yield per hectare due to the increase of single fruit weight was justifiable (Figure 2).

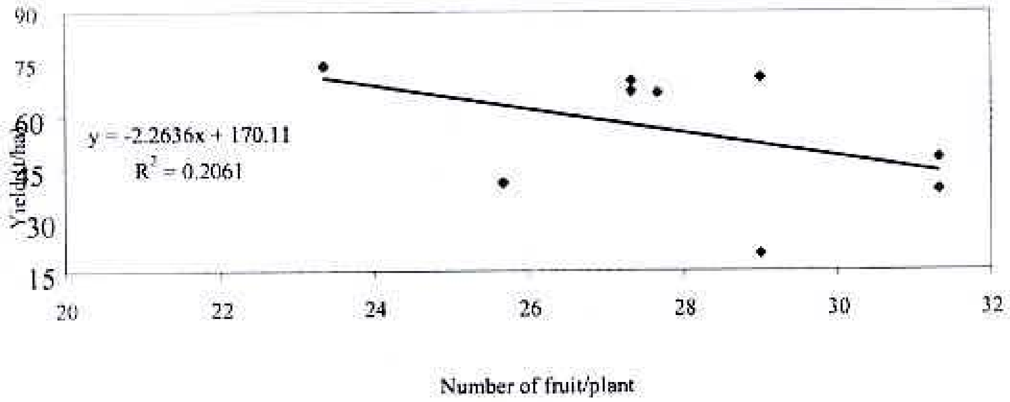

Figure 1. Relationship between number of fruit/plant and yield of tomato

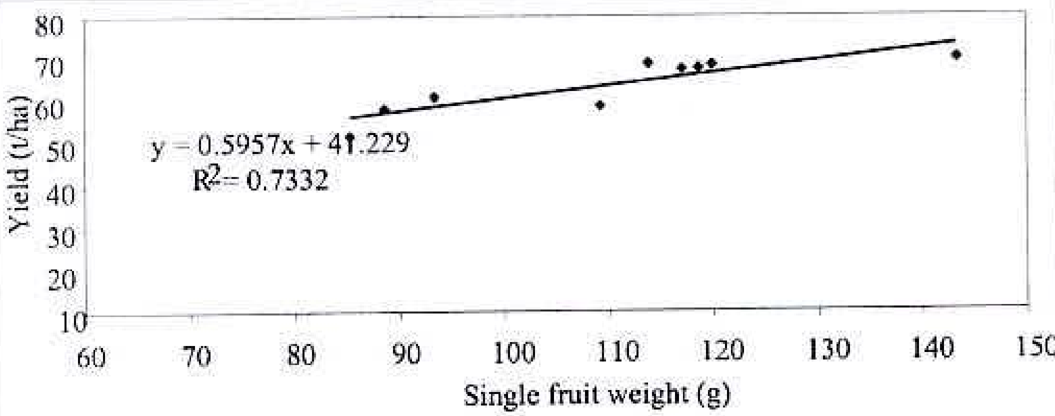

Figure 2. Relationship between single fruit weight and yield of tomato

Experiment 2: Evaluation of some management practices against tomato fruit borer, *Helicoverpa armigera* (Hubner)

The present experiment was conducted to evaluate some management practices applied against tomato fruit borer, *Helicoverpa armigera* (Hubner) on winter tomato (BARI-2/Ratan). The results have been presented and discussed, and possible interpretations have been given under the following sub-headings:

4.2.1 Effect of management practices on fruit bearing status at early fruiting stage

4.2.1.1 Effect on number of tomato fruit

Statistically significant variation was recorded by number of total fruit per plant, number infested fruit per plant and percent fruit infestation by number at early fruiting stage in controlling tomato fruit borer for different control measures under the present trial presented in Table 5. Highest number of fruit per plant (10.24) was recorded in T_6 treatment comprising Neem oil @ 3 ml/litre of water sprayed at 7 days interval + plants supported by bamboo stick, which was significantly different from all other treatments followed by T_3 treatment (9.83) comprising Ripcord 10 EC @ 1.7 ml/litre of water sprayed at 7 days interval where plants supported by bamboo stick, T_5 treatment (9.83) comprising Malathion @ 2 ml/litre of water sprayed at 7 days interval + supporting with bamboo stick and T_2 treatment (9.81) comprising Admire 200 SL @ 1 ml/L of water sprayed at 7 days interval + plants supporting with bamboo stick and T_4 treatment (9.04) comprising Sevin 85 WP @ 3.4 g/L of water sprayed at 7 days interval + plants supported by bamboo stick (Table 5). On the other hand, the lowest number (8.23) of total fruit per plant was recorded in T_8 treatment (Untreated control without support), which was statistically similar with T_7 treatment (8.53) comprising plants only supported by bamboo stick and T_1 treatment (8.63) comprising handpicking and removal of infested flowers and fruits at 7 days interval + plants supported by bamboo stick. From these results it is revealed that the trend of the number of fruit per plant was observed due to application of the different management practices against tomato fruit borer is $T_6 > T_3 > T_5 > T_2 > T_4 > T_1 > T_7 > T_8$.

The highest number of infested fruit per plant (0.73) was recorded in T_8 treatment (Untreated control) which was statistically different from all other treatments followed by T_7 (0.58) that was statistically similar with T_1 (0.58), T_5 (0.55) and T_4 (0.52) treatments. On the other hand, the lowest number of infested fruit per plant

(0.18) was recorded in T_6 treatment followed by T_2 (0.25) and T_3 (0.26) treatments (Table 5). In this case, more or less similar but inverse trend of the results found by number of total fruit per plant was observed and the trend is T_8, > T_7> T_1> T_5> T_4, > T_3> T_2 >T_6.

The highest percent fruit infestation in number (8.93%) was recorded in T_8 treatment, which was statistically different from all other treatments followed by T_7 and T_1 treatment (6.83%, 6.70%, respectively). On the other hand, the lowest percent fruit infestation by number (1.77%) was recorded in T_6 treatment (Table 5), which was significantly different from all other treatments followed by T_2, T_3 (2.56%, 2.63%, respectively) and T_5, T_4 (5.54%, 5.97%, respectively) treatments. In these cases, more or less similar trend of the results observed by number of infested fruit per plant was also found and the trend is T_8 > T_7> T_1 > T_4> T_5> > T_3> T_2 >T_6. Divokar and Pawar (1987) also reported the similar results earlier from their experiment.

In terms of percent fruit infestation reduction by number over control was also estimated and the highest value (80.18%) was estimated in T_6 treatment (comprising Neem oil @ 3 ml/L of water sprayed at 7 days interval + plants supported by bamboo stick) and the lowest value (23.52%) from T_7 treatment comprising plants only supported by bamboo stick (Table 5). From these findings it is revealed that treatment T_6 performed maximum healthy fruit and minimum infested fruit as well as lowest percent fruit infestation in number whereas in control treatment (T_8) the situation is reverse under the trial.

4.2.1.2 Effect on tomato fruit by weight

Statistically significant variation was recorded by weight (g) of total fruit and infested fruit per plant and percent fruit infestation by weight at early fruiting stage in controlling tomato fruit borer for different control measures under the present trial presented in Table 5. The highest weight of the total fruit per plant (940.74 g) was recorded in T_6 treatment consisting of Neem oil @ 3 ml/litre at 7 days interval + support with bamboo stick (Table 5). On the other hand, the lowest (776.97 g) total fruit per plant was recorded in T_8 treatment (Untreated control) treatment. These results followed more or less similar trend of results observed that was recorded in terms of total number of fruit per plant and the trend is T_6 > T_2 > T_3> T_7> T_4 > T_1> T_5> T_8.

Table 5. Effect of different control measures in controlling tomato fruit borer at early harvesting stage in terms of fruit/plant by number and weight

Treatment	Tomato fruit by number				Tomato fruit by weight (g)			
	Total	Infested	% infestation	Reduction over control (%)	Total	Infested	% infestation	Reduction over control (%)
T_1	8.63 bc	0.58 b	6.70 b	24.97	812.05 cd	69.33 c	8.69 c	17.32
T_2	9.81 b	0.25 c	2.56 d	71.33	919.02 b	54.17 d	5.90 d	43.86
T_3	9.83 b	0.26 c	2.63 d	70.55	865.50 c	52.45 d	6.06 d	42.34
T_4	9.04 b	0.52 b	5.97 c	33.15	841.56 c	54.37 d	6.45 d	38.63
T_5	9.83 b	0.55 b	5.54 c	37.96	799.22 d	61.99 cd	7.76 cd	26.17
T_6	10.24 a	0.18 d	1.77 e	80.18	940.74 a	31.14 e	3.31 e	68.51
T_7	8.53 c	0.58 b	6.83 b	23.52	844.81 c	76.89 b	9.16 b	12.84
T_8	8.23 c	0.73 a	8.93 a	--	776.97 d	85.10 a	10.51 a	--

T_1 : Handpicking and removal of infested flowers and fruits at 7 days interval + tomato plants supported by bamboo stick; T_2 : Admire 200 SL @ 1 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_3 : Ripcord 10 EC @ 1.7 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_4 : Sevin 85 WP @ 3.4/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_5 : Malathion @ 2 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_6 : Neem oil @ 3ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_7 : Tomato plants only supported by bamboo stick; T_8 : Untreated control without support.

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

The highest weight of infested fruit (85.10 g) per plant was recorded in T_8 treatment and the lowest weight of infested fruit (31.14 g) was recorded in T_6 treatment (Table 5). Similarly, the highest percent fruit infestation in weight (10.51%) was recorded in T_8 treatment and the lowest percent fruit infestation in weight (3.31%) was recorded in T_6 treatment (Table 5).In these both cases, more or less similar trends of the results observed that were recorded in both number of infested fruit per plant and percent fruit infestation by number. And the trend is $T_8 > T_7 > T_1 > T_5 > T_4 > T_2 > T_3 > T_6$. Thakur *et al.* (1998), Divokar and pawar (1987), Gopal and Senquttuvan (1997) reported the similar results earlier from their experiment.

The percent fruit infestation reduction over control by weight was also estimated and the highest value (68.51%) was estimated in T_6 treatment and the lowest value (12.84%) from T_7 treatment (Table 5). From these findings it is revealed that treatment T_6 performed maximum weight of healthy fruit/plant and minimum infested fruit as well as lowest percent fruit infestation by weight whereas in control treatment the situation is totally overturned. Gupta *et al.* (1998) reported that the reduction of percent fruit infestation from 50.7 to 6.7 while in the control it was between 35.3% and 46.7% from their experiment.

4.2.2 Effect of management practices on fruit bearing status at mid fruiting stage

4.2.2.1 Tomato fruit by number

Statistically significant variation was recorded by number of total fruit per plant, number infested fruit per plant and percent fruit infestation by number at mid fruiting stage in controlling tomato fruit borer for different control measures under the present trial presented in Table 6. The highest number of fruit per plant (11.11) was recorded in T_6 treatment, which was statistically similar (10.94 and 10.12) with T_2 and T_3 treatments (Table 6). On the other hand, the lowest (8.51) number of total fruit per plant was recorded in T_8 treatment (Untreated control) followed (8.68) by T_7 treatment. As a result, more or less similar trend of the results found in early fruiting stage was also observed and the trend is $T_6 > T_2 > T_3 > T_4 > T_5 > T_1 > T_7 > T_8$

Both the highest number of infested fruit (1.04) and the highest percent fruit infestation (12.28%) was recorded in T_8 treatment which was statistically identical with T_7 treatment (1.01% and 11.36% respectively). On the other hand, the lowest number of infested fruit (0.31) and the percent fruit infestation by number (2.78%)

was recorded in T_6 treatment (Table 6). As a result, more or less similar trend of the results found in early fruiting stage was also observed and the trend is $T_8 > T_7 > T_1 > T_5 > T_4 > T_3 > T_2 > T_6$. Divokar and pawar (1987), Gopal and Senquttuvan (1997) reported the similar results earlier from their experiment.

The percent fruit infestation reduction by number over control was also estimated and the highest value (77.36%) was estimated from T_6 treatment and the lowest value (5.29%) from T_7 treatment (Table 6). From these findings it is revealed that treatment T_6 performed maximum healthy fruit and minimum infested fruit as well as lowest percent fruit infestation by number whereas in control treatment the situation is reverse under the trial in mid fruiting stage during controlling tomato fruit borer through using different management practices.

Table 6. Effect of different control measures in controlling tomato fruit borer at mid harvesting stage in terms of fruit/plant by number and weight

Treatment	Tomato fruit by number				Tomato fruit by weight (g)			
	Total	Infested	% infestation	Reduction over control (%)	Total	Infested	% infestation	Reduction over control (%)
T_1	9.05 b	0.82 b	9.10 b	25.90	818.15 d	81.75 b	10.00 b	24.70
T_2	10.94 a	0.46 c	4.19 c	65.88	970.96 b	61.66 c	6.35 e	52.18
T_3	10.12 a	0.50 c	4.98 c	59.45	947.91 b	64.59 c	6.82 de	48.64
T_4	9.79 b	0.79 b	8.11 b	33.96	765.21 e	55.18 d	7.21 d	45.71
T_5	9.73 b	0.79 b	8.16 b	33.55	757.47 e	62.73 c	8.29 c	37.58
T_6	11.11 a	0.31 d	2.78 d	77.36	1000.04 a	36.93 e	3.69 f	72.21
T_7	8.68 bc	1.01 a	11.63 a	5.29	857.24 c	91.92 a	10.79 b	18.75
T_8	8.51 c	1.04 a	12.28 a	--	722.34 e	95.87 a	13.28 a	--

TT_1 : Handpicking and removal of infested flowers and fruits at 7 days interval + tomato plants supported by bamboo stick; T_2 : Admire 200 SL @ 1 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_3 : Ripcord 10 EC @ 1.7 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_4 : Sevin 85 WP @ 3.4/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_5 : Malathion @ 2 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_6 : Neem oil @ 3ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_7 : Tomato plants only supported by bamboo stick; T_8 : Untreated control without support.

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

4.2.2.2 Effect on tomato fruit in weight

Statistically significant variation was recorded by weight (g) of total fruit and infested fruit per plant and percent fruit infestation by weight at mid fruiting stage in controlling tomato fruit borer for different control measures under the present trial presented in Table 6. The highest weight of fruit per plant (1000.04 g) was recorded in T_6 treatment followed (970.96 g) by T_2 treatment (Table 6). On the other hand the lowest weight (722.34 g) of total fruit per plant was recorded in T_8 treatment (Untreated control) treatment followed (857.24 g) by T_1 treatment. The trend of the results is more or less similar with the trend found earlier and the trend is $T_6 > T_2 > T_3 > T_7 > T_1 > T_4 > T_5 > T_8$.

Both highest weight of infested fruit (95.87 g) and highest percent fruit infestation by weight (13.28%) were recorded in T_8 treatment. On the other hand, both the lowest weight of infested fruit (36.93 g) and the lowest percent fruit infestation by weight (3.69%) were recorded in T_6 treatment (Table 6). As a result, the trend of the results is more or less similar with the trend found earlier at early fruiting stage and the trend is $T_8 > T_7 > T_1 > T_3 > T_2 > T_5 > T_4 > T_6$ and $T_8 > T_7 > T_1 > T_5 > T_4 > T_3 > T_2 > T_6$, respectively. Divokar and pawar (1987), Gopal and Senquttuvan (1997) reported the similar results earlier from their experiment.

The percent fruit infestation reduction over control by weight was also estimated and the highest value (72.21%) was estimated in T_6 treatment and the lowest value (18.75%) from T_7 treatment (Table 6). From the findings it is revealed that treatment T_6 performed maximum weight of healthy fruit/plant and minimum infested fruit as well as lowest percent fruit infestation by weight at mid fruiting stage whereas in control treatment the situation is totally overturned.

4.2.3 Effect of management practices on fruit bearing status at late fruiting stage

4.2.3.1 Effect on tomato fruit in number

Statistically significant variation was recorded by number of total fruit per plant, number infested fruit per plant and percent fruit infestation by number at late fruiting stage in controlling tomato fruit borer for different control measures under the present trial presented in Table 7. The highest number of fruit per plant (13.06) was recorded in T_6 treatment. On the other hand, the lowest (10.00) number of total fruit per plant was recorded in T_8 treatment (Untreated control) (Table 7). As a result, more or less similar trend of the results found earlier was also observed and the trend is $T_6 > T_2 > T_3 > T_7 > T_1 > T_5 > T_4 > T_8$.

Both the highest number of infested fruit (1.71) and the highest percent fruit infestation (17.12%) was recorded in T_8 treatment which was statistically identical with T_7 treatment (1.01% and 11.36% respectively). On the other hand, the lowest number of infested fruit (0.43) and the percent fruit infestation by number (3.30%) was recorded in T_6 treatment (Table 7). These results also followed more or less similar trend of the results found in earlier stages. Divokar and pawar (1987), Gopal and Senquttuvan (1997) reported the similar results earlier from their experiment.

The percent fruit infestation reduction over control by number was also estimated and the highest value (80.72%) was estimated in T_6 treatment and the lowest value (22.84%) from T_7 treatment (Table 7). From the findings it is revealed that treatment T_6 performed maximum healthy fruit and minimum infested fruit as well as lowest percent fruit infestation in number whereas in control treatment the situation is reverse under the trial.

4.2.3.2 Effect on tomato fruit by weight

The weight of total fruit, infested fruit per plant and percent fruit infestation at late fruiting stage in controlling tomato fruit borer for different control measures showed a statistically significant difference under the present trial depicted in Table 7. The highest weight of total fruit per plant (1138.85 g) was recorded in T_6 treatment followed (1125.47 g) by T_1 treatment (Table 7). On the other hand, the lowest weight (895.31 g) of total fruit per plant was recorded in T_8 treatment (Untreated control), which was followed (1063.64 g) by T_7 treatment. And the trend of the results is $T_6 > T_1 > T_5 > T_7 > T_2 > T_4 > T_3 > T_8$, which was more or less similar trend found in the earlier stages.

Both the highest weight of infested fruit (161.29 g and 160.34 g) and the highest percent fruit infestation by weight (17.96%) were recorded in T_7 & T_8 and T_8 treatments respectively. On the other hand, both the lowest weight of infested fruit (37.71 g) and the lowest percent fruit infestation by weight (3.30%) were recorded in

T_6 treatment (Table 7). As a result, more or similar trend of the results was also found like earlier fruiting stages.

Fruit infestation percentage over control by weight was estimated and the highest value (81.63%) was estimated in T_6 treatment and the lowest value (14.87%) from T_7 treatment (Table 7), which indicate the treatment T_6 performed maximum weight of healthy fruit/plant and minimum infested fruit as well as lowest percent fruit infestation by weight whereas in control treatment the situation is totally overturned in this trial.

Table 7. Effect of different control measures in controlling tomato fruit borer at late harvesting stage in terms of fruit/plant by number

Treatment	Tomato fruit by number				Tomato fruit by weight (g)			
	Total	Infested	% infestation	Reduction over control (%)	Total	Infested	% infes-tation	Reduc-tion over control (%)
T_1	10.31 b	1.19 c	11.51 b	32.77	1125.47 a	141.74 b	12.60 c	29.84
T_2	12.53 a	0.52 ef	4.18 d	75.58	1046.24 b	77.10 e	7.42 e	58.69
T_3	12.00 a	0.63 e	5.31 d	68.98	975.92 b	77.14 e	7.84 e	56.35
T_4	10.09 b	0.87 d	8.64 c	49.53	1007.76 b	95.46 d	9.48 d	47.22
T_5	10.17 b	0.91 d	9.16 c	46.50	1117.95 a	104.37 c	9.49 d	47.16
T_6	13.06 a	0.43 f	3.30 e	80.72	1138.85 a	37.71 f	3.30 f	81.63
T_7	10.91 b	1.44 b	13.21 b	22.84	1063.64 b	161.29 a	15.29 b	14.87
T_8	10.00 b	1.71 a	17.12 a	--	895.31 c	160.34 a	17.96 a	--

T_1 : Handpicking and removal of infested flowers and fruits at 7 days interval + tomato plants supported by bamboo stick; T_2 : Admire 200 SL @ 1 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_3 : Ripcord 10 EC @ 1.7 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_4 : Sevin 85 WP @ 3.4/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_5 : Malathion @ 2 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_6 : Neem oil @ 3ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_7 : Tomato plants only supported by bamboo stick; T_8 : Untreated control without support.

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

For all the fruiting stage like early, mid and late, the infestation level was following more or less similar trend for both by number and weight of tomato under the present experiment (Figure 3 and 4) for all the treatment that were used for controlling tomato fruit borer, where the treatment T_6 (comprising Neem oil @ 3 ml/L of water sprayed at 7 days interval + plants supported by bamboo stick) performed maximum number and weight of healthy fruit/plant and minimum number and weight of infested fruit as well as lowest percent fruit infestation in number and weight whereas in T_8 (Untreated control treatment) the situation is totally overturned in this trial. Gopal and Senqttuvan (1997), Kulat *et al.* (2001), Sundarajan (2001 & 2002) also reported similar results in their experiments.

From the all above findings it is also revealed that although T_7 treatment (comprising plants only supported by bamboo stick) numerically performed better results in terms of increasing yield and yield contributing characters as well as reducing the level of tomato fruit borer infestation than T_8 treatment (comprising untreated control); but there were few statistical significant differences found between the effects of T_7 and T_8 treatments.

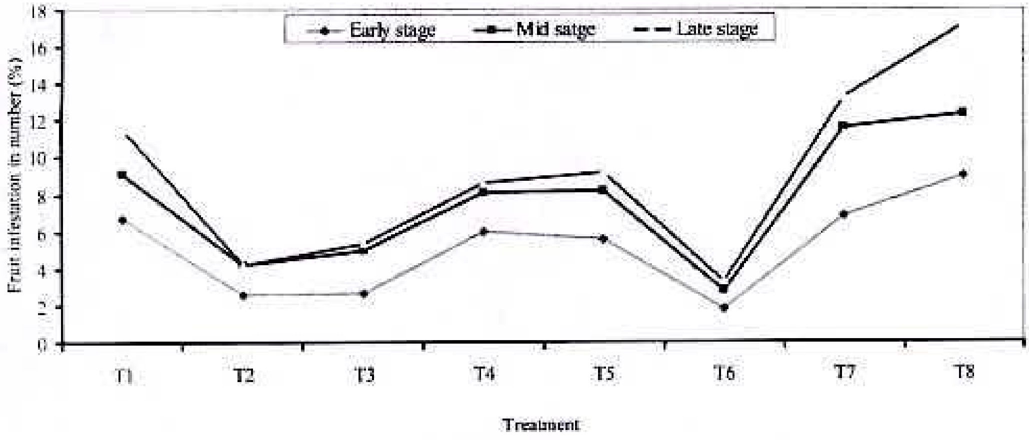

Figure 3. Effect of different control measures on percent fruit infestation in number by tomato fruit borer at different harvesting stage

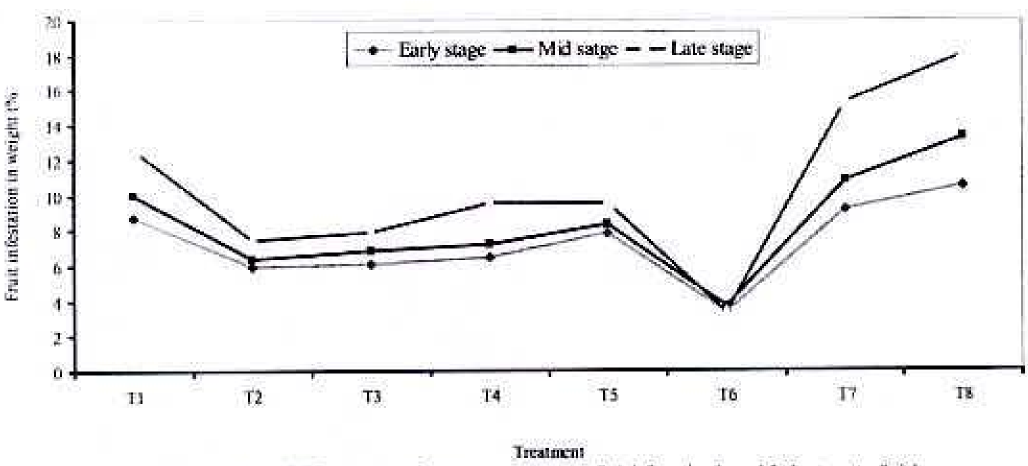

Figure 4. Effect of different control measures on percent fruit infestation in weight by tomato fruit borer at different harvesting stage

4.2.4 Effect of management practices on fruit bearing status of tomato during total cropping season

4.2.4.1 Effect on tomato fruit by number

Considering the total cropping season of tomato, statistically significant differences were recorded in terms of number of healthy and infested fruit per plant and percent fruit infestation in number during the application of different control measures applied against tomato fruit borer in this trial is presented in Table 8. The highest number of healthy fruit per plant (33.49) was recorded in T_6 treatment (Plate 4 and Plate 6) which was statistically identical (32.05) with T_2 treatment. On the other hand, the lowest (23.26) number of healthy fruit was recorded in T_8 treatment (Plate 5 and Plate 6) (Untreated control) followed (25.09) by T_7 treatment (Table 8). As a result, the trend of the results performed by different treatments is $T_6 > T_2 > T_3 > T_5 > T_4 > T_1 > T_7 > T_8$ and this trend was more or less similar with the trends observed earlier in different fruiting stages.

The highest number of infested fruit (3.48) and percent fruit infestation (13.03%) was recorded in T_8 treatment (Plate 5 and Plate 6) followed by T_7 treatment (3.03 and 10.78%, respectively). On the other hand, the lowest number of infested fruit (0.92) and percent fruit infestation (2.67%) was recorded in T_6 treatment (Table 8, Plate 4 and Plate 6). And in both cases, more or less similar trend of the results was observed.

Plate 4: Health fruits produced in Neem oil treated plot (T_6

Plate 5: Tomato fruit borer infested fruit produced in untreated control plot (T_8)

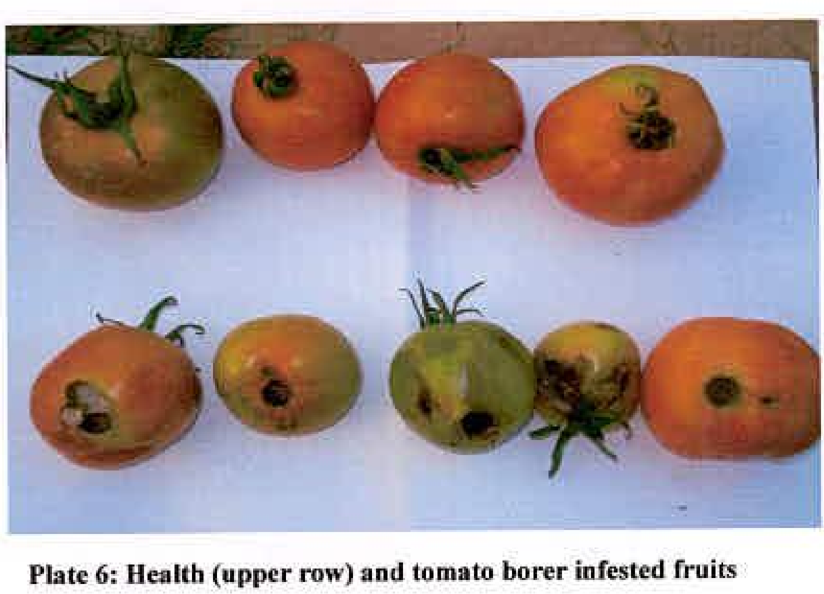

Plate 6: Health (upper row) and tomato borer infested fruits

Table 8. **Effect of different control measures in controlling tomato fruit borer in terms of fruit/plant by number during total cropping season**

Treatment	Tomato fruit/plant by number				
	Total	Healthy	Infested	% infestation	Reduction over control (%)
T_1	27.99 de	25.41 d	2.59 c	9.24 c	29.09
T_2	33.28 a	32.05 a	1.23 e	3.69 e	71.68
T_3	31.94 bc	30.55 b	1.39 d	4.38 e	66.39
T_4	28.92 cd	26.73 c	2.19 d	7.58 d	41.83
T_5	29.74 c	27.48 c	2.25 d	7.59 d	41.75
T_6	34.41 a	33.49 a	0.92 d	2.67 f	79.51
T_7	28.12 d	25.09 d	3.03 b	10.78 b	17.27
T_8	26.74	23.26 f	3.48 a	13.03 a	--

T_1 : Handpicking and removal of infested flowers and fruits at 7 days interval + tomato plants supported by bamboo stick; T_2 : Admire 200 SL @ 1 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_3 : Ripcord 10 EC @ 1.7 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_4 : Sevin 85 WP @ 3.4/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_5 : Malathion @ 2 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_6 : Neem oil @ 3ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_7 : Tomato plants only supported by bamboo stick; T_8 : Untreated control without support.

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

In T_6 treatment, the percent fruit infestation over control by number was estimated the highest value (79.51%) and the lowest value (17.27%) from T_7 treatment (Table 8). From the findings it is revealed that treatment T_6 performed maximum healthy fruit and minimum infested fruit as well as lowest percent fruit infestation by number whereas in control treatment the situation is reverse under the trial in all the growing season.

4.2.4.2 Effect on tomato fruit by weight

Statistically significant variation was also recorded in terms of weight of healthy and infested fruit per plant and percent fruit infestation by number during the application of different control measures applied against tomato fruit borer in this trial and presented in Table 9. The highest weight of healthy fruit per plant (2.97 kg) was recorded in T_6 treatment. On the other hand, the lowest weight (2.09 kg) of healthy fruit was recorded in T_8 treatment (Untreated control).As a result, the trend of the results performed by different treatments is $T_6 > T_2 > T_3 > T_5 > T_4 > T_1 > T_7 > T_8$ and this trend was more or less similar with the trends observed earlier in different fruiting stages.

The highest weight of infested fruit (0.34 kg) and percent fruit infestation (14.05%) per plant in weight were recorded in T_8 treatment. On the other hand, the lowest weight of infested fruit (0.11 kg) and percent fruit infestation (3.43%) in weight was recorded in T_6 treatment under the trial (Table 9). And in both cases, more or less similar trend of the results was observed.

In T_6 treatment, percent fruit infestation over control by weight was estimated the highest value (75.59%) and the lowest value (15.16%) from T_7 treatment (Table 9). From the findings it is revealed that treatment T_6 performed maximum healthy fruit and minimum infested fruit as well as lowest percent of fruit infestation by weight whereas in control treatment the situation is reverse under the trial in all the growing season.

Table 9. Effect of different control measures in controlling tomato fruit borer in terms of fruit/plant by weight (kg) during total cropping season

Treatment	Tomato fruit/plant by weight (kg)				
	Total	Healthy	Infested	% infestation	Reduction over control (%)
T_1	2.74 c	2.45 d	0.29 b	10.68 b	23.99
T_2	2.94 b	2.74 b	0.19 c	6.58 d	53.17
T_3	2.79 c	2.60 c	0.19 c	6.96 d	50.46
T_4	2.61 c	2.41 d	0.21 c	7.84 c	44.20
T_5	2.67 c	2.45 d	0.23 c	8.60 c	38.79
T_6	3.08 a	2.97 a	0.11 d	3.43 e	75.59
T_7	2.77 c	2.44 d	0.33 a	11.92 b	15.16
T_8	2.43 d	2.09 e	0.34 a	14.05 a	

T_1 : Handpicking and removal of infested flowers and fruits at 7 days interval + tomato plants supported by bamboo stick; T_2 : Admire 200 SL @ 1 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_3 : Ripcord 10 EC @ 1.7 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_4 : Sevin 85 WP @ 3.4/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_5 : Malathion @ 2 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_6 : Neem oil @ 3ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_7 : Tomato plants only supported by bamboo stick; T_8 : Untreated control without support.

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

4.2.5 Effect of different management practices on tomato fruit by weight per plot during the total cropping season

Considering the total cropping season, statistically significant difference was recorded in terms of weight of total fruit/plot during the application of different control measures against tomato fruit borer in this trial and presented in Table 10. The highest total fruit weight (38.49 kg) per plot was recorded in T_6 treatment followed by T_2 treatment (36.70 kg). On the other hand, the lowest fruit weight (30.37 kg) per plot was recorded in T_8 treatment followed by T_4 treatment (32.68 kg), T_5 treatment (33.43

kg), T_1 treatment (34.25 kg), T_7 treatment (34.56 kg), and T_3 treatment (34.87 kg) (Table 10). As a result, the trend of the results is $T_6 > T_2 > T_3 > T_7 > T_1 > T_5 > T_4 > T_8$. In terms of weight of healthy fruit per plot, more or less similar trend was observed found earlier in terms of total fruit weight per plot and the trend is $T_6 > T_2 > T_3 > T_1 > T_5 > T_7 > T_4 > T_8$ (Table 10).

Table 10. Effect of different control measures in controlling tomato fruit borer in terms of fruit/plot by weight (kg) during total cropping season

Treatment	Tomato fruit/plot by weight (kg)				
	Total	Healthy	Infested	% infestation	Reduction over control (%)
T_1	34.25 c	31.20 cd	3.05 b	9.78 c	55.48
T_2	36.70 b	34.50 b	2.20 c	6.38 d	70.96
T_3	34.87 c	32.85 c	2.52 c	7.79 d	64.54
T_4	32.68 c	29.65 d	3.03 c	10.22 c	53.48
T_5	33.43 c	30.85 d	2.58 c	8.36 cd	61.94
T_6	38.49 a	36.70 a	1.79 d	4.87 e	77.83
T_7	34.56 c	29.85 d	4.71 a	15.77 b	28.22
T_8	30.37 d	24.90 e	5.47 a	21.97 a	--

T_1 : Handpicking and removal of infested flowers and fruits at 7 days interval + tomato plants supported by bamboo stick; T_2 : Admire 200 SL @ 1 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_3 : Ripcord 10 EC @ 1.7 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_4 : Sevin 85 WP @ 3.4/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_5 : Malathion @ 2 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_6 : Neem oil @ 3ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_7 : Tomato plants only supported by bamboo stick; T_8 : Untreated control without support.

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

In terms of weight (kg) of infested fruit, percent fruit infestation by weight per plot and percent fruit infestation reduction by weight over control, more or less similar trends were also followed (Table 10) found earlier in different fruiting stages. From the findings it is also revealed that treatment T_6 performed maximum healthy fruit and minimum infested fruit as well as lowest percent of fruit infestation by weight whereas in control treatment the situation is reverse under the trail in all the growing season.

4.2.6 Effect of management practices on yield and yield contributing characters of Tomato applied against tomato fruit borer

Statistically significant difference was recorded in terms of plant height (cm), leaf number per plant, branch number per plant, flower bunch per plant, flower number per bunch, single fruit weight (g), yield (ton/ha) considering the different control measures applied against tomato fruit borer in this trial presented in Table 11. The maximum plant height (87.58 cm) was recorded in T_6 treatment followed (85.25 cm) by T_2 treatment. On the other hand, the minimum plant height (72.42 cm) was recorded in T_8 treatment followed (78.05 cm) by T_7 treatment.

In terms of number of leaf, branch, flower bunch per plant, and number of flower per bunch; the maximum values were recorded in T_6 treatment and the minimum values were recorded in T_8 treatment (Table 11). As a result, more or similar trends of the results were observed for all cases.

Table 11. Effect of different control measures on yield and yield contributing characters of tomato applied against tomato fruit borer

Treatment	Plant height (cm)	Number of leaf /plant	Number of branch /plant	Number of flower bunch/plant	Number of flower /bunch	Single fruit weight (g)	Yield (ton/ha)
T_1	79.42 c	412.33 d	14.02 bc	8.67 c	5.67 c	124.25 a	76.13 b
T_2	85.25 ab	421.67 b	15.08 ab	9.67 b	6.00 b	121.33 bc	81.56 a
T_3	82.63 bc	416.00 c	14.63 b	9.33 b	6.00 b	118.65 c	77.48 b
T_4	75.95 e	403.33 f	13.12 cd	8.33 cd	5.67 c	112.22 d	72.63 b
T_5	76.32 e	406.67 e	13.47 c	8.67 c	5.00 d	114.95 cd	72.40 b
T_6	87.58 a	425.33 a	13.25 a	10.33 a	6.33 a	129.00 a	85.55 a
T_7	78.05 d	410.67 d	16.38 c	9.00 c	5.00 d	109.62 e	76.82 b
T_8	72.42 f	388.33 g	12.85 d	7.67 d	4.67 d	103.33 f	67.49 c

T_1 : Handpicking and removal of infested flowers and fruits at 7 days interval + tomato plants supported by bamboo stick; T_2 : Admire 200 SL @ 1 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_3 : Ripcord 10 EC @ 1.7 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_4 : Sevin 85 WP @ 3.4/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_5 : Malathion @ 2 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_6 : Neem oil @ 3ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_7 : Tomato plants only supported by bamboo stick; T_8 : Untreated control without support.

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

In terms of single fruit weight, the highest single fruit weight (129.00 g) was recorded in T_6 treatment followed (121.33 g) by T_2 treatment. On the other hand, the lowest single fruit weight (103.33 g) was recorded in T_8 treatment followed (109.33 g) by T_7 treatment (Table 11). Probably tomato fruit borer destroyed the leaf and branches of tomato plant as well as flower bunches and the ultimate results are minimum single fruit weight found in T_8 treatment under the trial.

In terms of tomato fruit yield (ton/ha), the highest fruit yield (85.55 t/ha) was recorded in T_6 treatment. On the other hand, the lowest fruit yield (67.49 t/ha) was recorded in T_8 treatment comprising untreated control (Table 11). As a result, more or less similar trend of the results was observed found earlier in different situation for different parameters under the trial and the trend is $T_6 > T_2 > T_3 > T_7 > T_1 > T_5 > T_4 > T_8$.

From these findings it is also revealed that treatment T_6 (comprising Neem oil @ 3 ml/litre of water spayed at 7 days interval + plants supported with bamboo stick) showed best performance in increasing yield and yield contributing characters of the tomato plants whereas in treatment T_8 (comprising untreated control) the situation is reverse under the trial. It is also revealed that in respect of environmental point of view, as botanical, neem oil is safer for human health as well as environmental pollution free. These findings also supported by Gopal and Senquttuvan (1997), Kulat *et al.* (2001), Sundarajan (2001 & 2002).

4.2.7 Economic analysis

Economic analysis of different control measures applied against tomato fruit borer infesting BARI Tomato-2 variety is presented in Table 12.

In this study, the untreated control treatment (T_8) did not require any pest management cost. But the costs were involved in all treatments except T_8 for mechanical support of the plants through bamboo stick. The labor costs were involved in T_1 treatment for the removal and destruction of infested flowers and fruits from the plots under the trial. The cost for the treatment (T_6) of neem oil @ 3 ml per litre of water sprayed at 7 days interval was incurred for Neem oil, trix liquid detergent and its application. For chemical treatments, cost of chemicals and its application also involved.

Considering the control of tomato fruit borer, the highest benefit cost ratio (3.53) was calculated in the treatment T_6 comprising of Neem oil @ 3 ml/litre of water sprayed at 7 days interval + plants supported by bamboo stick followed by T_2 treatment (2.85), T_7 treatment (2.36), T_1 treatment (2.32) and T_3 treatment. On the other hand, the minimum benefit cost ratio (1.31) was recorded in treatment T_4 followed by T_5 treatment (1.49) (Table 12).

Table 12. Economic analysis for different control measures applied against tomato fruit borer

Treatments	Cost of pest Management (Tk./ha)	Yield (t/ha)		Gross return (Tk.)	Net Return (Tk.)	Adjusted net return (Tk.)	Benefit cost Ratio
		Healthy	Infested				
T_1	34,000	67.99	8.13	856,530	822,530	79,010	2.32
T_2	51,400	76.2	5.36	941,200	889,800	146,280	2.85
T_3	47,500	72.09	5.39	892,030	844,530	101,010	2.13
T_3	38,200	66.93	5.69	831,610	793,410	49,890	1.31
T_5	41,500	67.93	6.36	846,960	805,460	61,940	1.49
T_6	58,000	82.61	2.94	1006,020	948,020	20,4500	3.53
T_7	34,000	67.66	9.17	857,770	823,770	80,250	2.36
T_8	0	58.01	9.48	743,520	743,520	-	--

T_1 : Handpicking and removal of infested flowers and fruits at 7 days interval + tomato plants supported by bamboo stick; T_2 : Admire 200 SL @ 1 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_3 : Ripcord 10 EC @ 1.7 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_4 : Sevin 85 WP @ 3.4/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_5 : Malathion @ 2 ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_6 : Neem oil @ 3ml/L of water sprayed at 7 days interval + tomato plants supported by bamboo stick; T_7 : Tomato plants only supported by bamboo stick; T_8 : Untreated control without support.

Market price of tomato: Tk. 12.00/kg for healthy and Tk. 5.00/kg for infested fruit

4.2.8 Relationship between percent fruit infestation by number and yield (t/ha)

The data on percent fruit infestation by number were regressed against yield (t/ha) and a positive linear relationship was obtained between them. It was evident from the Figure 5 that the equation $y = -1.263x + 85.804$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.6986$) showed that, fitted regression line had a significant regression co-efficient. It is evident from the regression line and equation that the yield increased with decreasing the percent fruit infestation in number in different controlling methods applied against tomato fruit borer.

4.2.9 Relationship between % fruit infestation by number and yield/ha

Correlation study was done to established a relationship between percent fruit infestation by weight and yield (t/ha). From the study it was revealed that significant correlations existed between the characters (Figure 8). The regression equation $y = -1.323x + 88.088$ gave a good fit to the data and the value of the co-efficient of determination ($R^2 = 0.6595$). From this it can be concluded that percent fruit infestation in number decrease the fruit yield of tomato under the present trial (Figure 6).

4.2.10 Relationship between plant height (cm) and yield (t/ha)

When the data on plant height (cm) and yield (t/ha) were regressed, a positive relationship was obtained between these two characters. Here the equation $y = 1.0362x - 6.0933$ gave a good fit to the data, and the value of the co-efficient of determination ($R^2 = 0.9358$) showed that the fitted regression line had a significant regression co-efficient. From these findings it may be concluded that the increase in yield (t/ha) to the increase of plant height was justifiable (Figure 7).

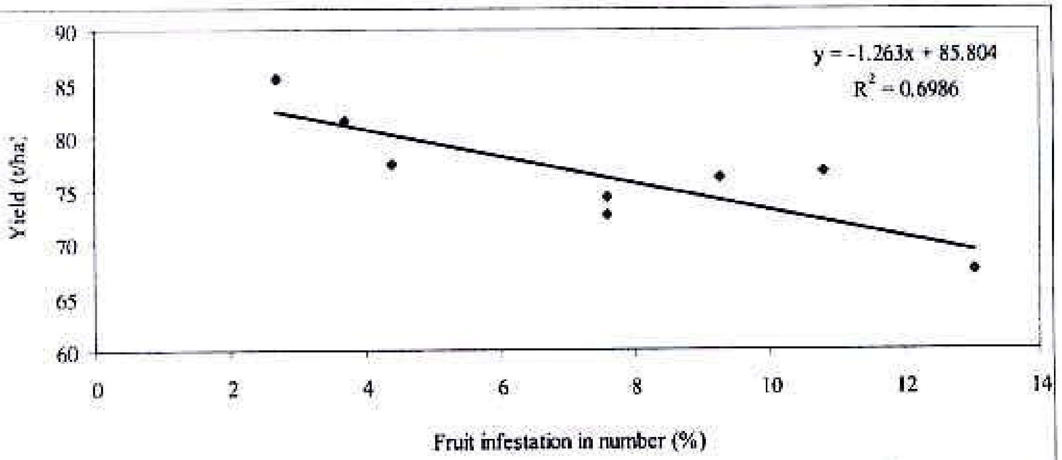

Figure 5. Relationship between percent fruit infestation in number and fruit yield of tomato

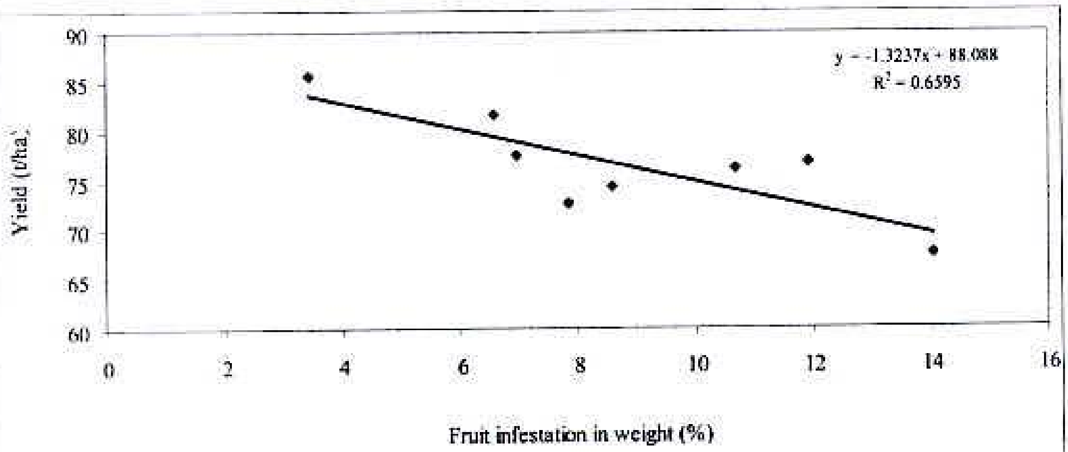

Figure 6. Relationship between percent fruit infestation in weight and fruit yield of tomato

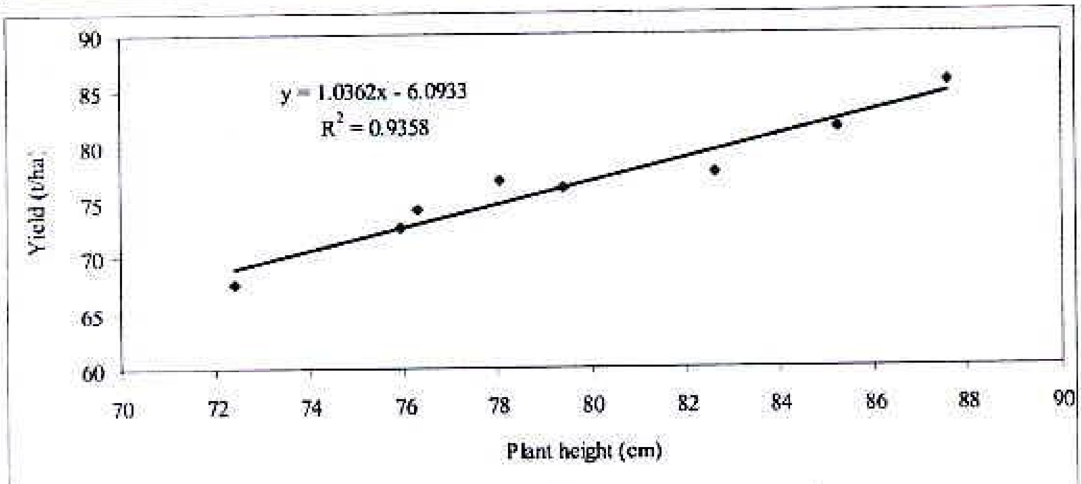

Figure 7. Relationship between plant height (cm) and fruit yield (t/ha) of tomato

4.2.11 Relationship between number of branch per plant and fruit yield (t/ha)

The data on number of branch per tomato plant were regressed against fruit yield (t/ha) and a positive linear relationship was obtained between the characters. It was evident from the Figure 8 that the equation y = 4.6089x + 11.337 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.9071) showed that, fitted regression line had a significant regression co-efficient. It is evident from the regression line and equation that the yield increases with increasing the number of branch/plant.

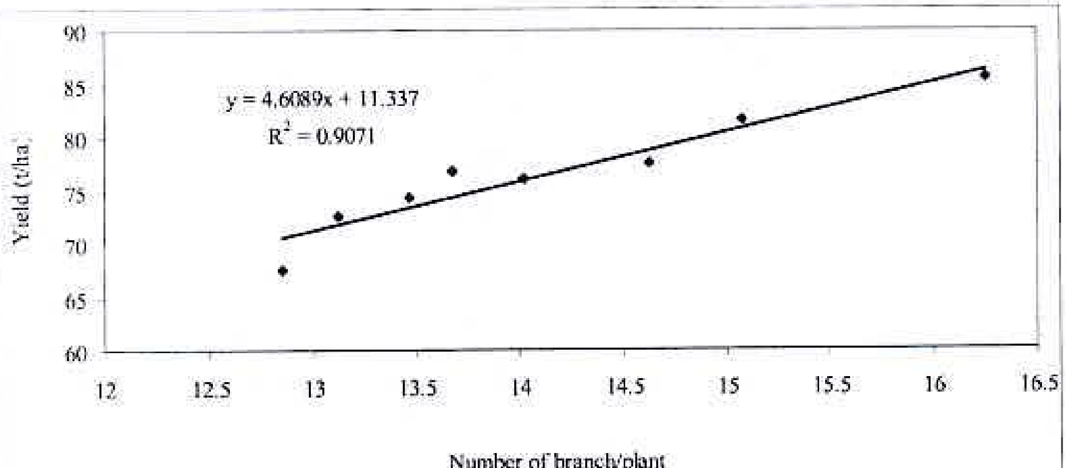

Figure 8. Relationship between number of branch/plant and fruit yield of tomato

CHAPTER V

SUMMARY AND CONCLUSION

Two set of field experiments were conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2006 to March 2007 to screen out of nine selected tomato varieties/genotypes for resistance against tomato fruit borer, *Helicoverpa armigera* (Hubner) and to evaluate some management practices applied against tomato fruit borer infesting winter tomato. First set of experiment considered the screening of nine tomato varieties/genotypes for resistance against tomato fruit borer. Second set of experiment considered the control measures consist of one cultural (removal of infested fruits and flowers), one mechanical (plants supported by bamboo stick), one botanical and other different insecticides including one untreated control as treatments. The experiment was laid out in the one factor Randomized Complete Block Design (RCBD) with three replications. Data were collected in respect of the fruit infested in number and weight basis and some yield contributing characters and yield of tomato. The data obtained for different characters were statistically analyzed to find out the significance level of the treatment. Cost Benefit ratio was also calculated to find out the optimum selection of the management treatment for attaining maximum benefit.

Considering the field screening of different tomato varieties for resistance against tomato fruit borer, in an average, the highest percent (12.82% and 12.59%) fruit infestation in number was recorded in BARI-2, BARI-8 varieties followed by BARI-9 (10.51%) and the lowest percent (4.86% and 4.87%) fruit infestation by number was recorded in the variety BINA-1 and BINA-2. On the other hand, the highest percent (13.21%) tomato fruit borer infestation by weight was recorded in the variety BARI-2 followed by the variety BARI-8 (11.79%) and the lowest percent (4.91% and 4.95%) fruit infestation was recorded in the variety BINA-1 and BINA-2.

Yield loss was calculated for different varieties. The highest yield loss (15.17%) was recorded for the variety BARI-2 followed by BARI-8 (13.33%) and BARI-3 (10.64%). On the other hand, the lowest yield loss (6.46%) was recorded for the variety BINA-2 followed by BINA-1 (7.06%) and BARI-7 (7.94%).

Among nine tomato varieties evaluated against tomato fruit borer, the variety BARI-2 and BARI-8 were the susceptible variety to tomato fruit borer and the variety BARI-3, BARI-7, BARI-9, BINA-3 and BINA-4 were the moderately resistant where as BINA-1 and BINA-2 were the highly resistant.

In consideration of number of fruit per plant, the maximum number of fruit per plant (64.79) was recorded in the variety BINA-2 followed (31.33) by BARI-3, BARI-8, BARI-7 (29.00), BARI-9 (27.67), BARI-2 (27.33) and BINA-3 (27.33). On the other hand, the minimum number (23.33) of fruit per plant was recorded for variety BINA-1 followed by BINA-4 (25.67). In terms of single fruit weight, the maximum single fruit weight was recorded for the variety BINA-1 (143.33 g) and the minimum single fruit weight (50.93 g) was recorded in the variety BINA-2. From the results it was found that the minimum number of fruit for each plant contributed maximum weight per single fruit.

The highest yield (74.49 t/ha) was recorded for the variety BINA-1 followed by BINA-2 (73.24 t/ha) and BARI-2 (73.00 t/ha), BINA-3 (71.89 t/h) and BARI-9 (71.62 t/h). On the other hand, the lowest yield (54.98 t/ha) was recorded in the variety BARI-7 followed by BARI-3 (61.69 t/ha), BINA-4 (62.42) and BARI-8 varieties.

Considering the application of different management treatments against tomato fruit borer during different fruiting stages of the cropping season, at early fruiting stage, the highest percent fruit infestation by number (8.93%) was recorded in T_8 treatment followed by T_7 and T_1 treatments and the lowest percent fruit infestation by number (1.77%) was recorded in T_6 treatment followed by T_2 and T_3. Similarly, the highest percent fruit infestation by weight (10.51%) was recorded in T_8 treatment followed by T_7 treatment (9.16%) and the lowest percent fruit infestation by weight (3.31%) was recorded in T_6 treatment. At mid fruiting stage, the highest percent fruit infestation by number (12.28%) was recorded in T_8 treatment which was statistically similar with T_7 treatment (11.63%). On the other hand, the lowest percent fruit infestation by number (2.78%) was recorded in T_6 treatment followed by T_2 and T_3 treatment (4.19% and 4.98%, respectively). Similarly the highest percent fruit infestation by weight (13.28%) was recorded in T_8 treatment followed by T_7 treatment (10.79%) and the lowest percent fruit infestation by weight (3.69%) was recorded in T_6 treatment. Considering the late fruiting stage, the highest percent fruit infestation by number (17.12%) was recorded in T_8 treatment followed by T_7 and T_1 treatment (13.21%, 11.51%, respectively) and the lowest percent fruit infestation by number (3.30%) was recorded in T_6 treatment. On the other hand, the highest percent fruit infestation by weight (17.96%) was recorded in T_8 treatment followed by T_7 treatment (15.29%) and the lowest percent fruit infestation by weight (3.30%) was recorded in T_6 treatment.

Considering the different treatment effects on tomato fruit yield applied against tomato fruit borer, the highest fruit yield (85.55 t/ha) but the lowest percent (3.43%) fruit infestation was recorded in T_6 treatment (comprising Neem oil @ 3 ml/litre of water sprayed at 7 days interval + plants supported by bamboo stick) followed (81.56 t/ha and 6.58% respectively) by T_2 treatment (comprising of Admire 200 SL @ 1 ml/litre of water sprayed at 7 days interval + plants supported by bamboo stick). On the other hand, the lowest fruit yield (67.49 t/ha) but highest percent fruit infestation (14.05%) was recorded in T_8 treatment followed by T_7 treatment (76.82 t/ha and 11.92%) (comprising plants only supported by bamboo stick). Among the different control measures, neem oil @ 3 ml/litre of water sprayed at 7 days interval + plants supported by bamboo stick performed the best result in reducing the level of tomato fruit borer infestation. From these findings it is revealed that among the different control measures, neem oil @ 3 ml/litre of water sprayed at 7 days interval + plants supported with bamboo stick (T_6) performed the best result in increasing the tomato fruit yield by reducing the level of fruit borer infestation.

In considering the different treatment effects on yield contributing characters, the maximum plant height (87.58 cm) was recorded in T_6 treatment followed (85.25 cm) by T_2 treatment and minimum plant height (72.42 cm) was recorded in T_8 treatment. The maximum weight of single fruit (129.00 g) was also recorded in T_6 treatment followed (121.33 g) by T_2 treatment and the minimum weight of single fruit (103.33 g) was recorded in T_8 treatment (Untreated control) followed (109.33 g) by T_7 treatment. The tomato fruit yield increases due to decrease the percent fruit infestation by tomato fruit borer, also with the increase of the plant height, number of branch per plant.

In considering the economic analysis of the different treatments in controlling tomato fruit borer, the highest benefit cost ratio (3.53) was recorded in the treatment T_6 (consisting of Neem oil @ 3 ml/litre of water sprayed at 7 days interval + plants supported with bamboo stick). On the other hand, the minimum benefit cost ratio

(1.31) was recorded in treatment T_4. But no management cost was required for T_8 treatment (untreated control).

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

1. The BINA-1 and BINA-2 tomato varieties may be cultivated as resistance to tomato fruit borer as well as higher yield producing varieties.
2. Neem oil @ 3 ml/L of water may be used as effective measure in reducing the level of tomato fruit borer infestation as well as safety measure in context of human health and environment.
3. Any other chemical and botanical insecticides may be used for comparative study among the chemical and botanical insecticides.
4. The treatments that were used in these experiments may be tested for another tomato variety on another locality of the country.

CHAPTER VI

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APPENDICES

Appendix I. Monthly average temperature, relative humidity and total rainfall of the experimental site during the period from September 2006 to March 2007

Month	Air temperature (^0C)		R..H. (%)	Total rainfall (mm)
	Maximum	Minimum		
September 06	26.20	24.1	73	07
October 06	26.70	21.1	89	07
November 06	24.00	20.1	87	02
December 06	21.00	20.9	64	04
January 07	20.20	21.85	74	15
February 07	20.25	18.55	71	22
March 07	22.25	19.30	75	38

Source : Dhaka Metrological Center

Appendix II. Results of mechanical and chemical analysis of soil of the experimental plot

Mechanical analysis

Constituents	Percent
Sand	33.45
Silt	60.25
Clay	6.20
Textural class	Silty loam

Chemical analysis

Soil properties	Amount
Soil pH	6.12
Organic carbon (%)	1.32
Total nitrogen (%)	0.08
Available P (ppm)	20
Exchangeable K (%)	0.2

Source: Soil Resource Development Institute (SRDI)