ECOFRIENDLY MANAGEMENT OF *Bemisia tabaci* AND *Helicoverpa armigera* Hubner IN TOMATO

A THESIS

BY

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This is to certify that the thesis entitled, "**ECOFRIENDLY MANAGEMENT OF *Bemisia tabaci* AND *Helicoverpa armigera* Hubner IN TOMATO**" 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 (MS) IN ENTOMOLOGY,** embodies the result of a piece of bona fide research work carried out by **MOTAHAR HOSSAIN** bearing Registration No. 09-03383 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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ECOFRIENDLY MANAGEMENT OF *Bemisia tabaci* AND *Helicoverpa armigera* Hubner IN TOMATO

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ABSTRACT

An experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2014 to March, 2015 to evaluate some management practices applied against *Bemisia tabaci* and *Helicoverpa armigera*, two major insect pests of tomato. The treatments were T1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick (STPBS); T2 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval + STPBS; T3 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval + STPBS; T4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval + STPBS; T5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T6 : Spraying of Sweet apple leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + STPBS; T8 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval + STPBS; T9 : Untreated control without any support of the tomato plants. The highest number of whitefly (34.00) was found in T_9 but the lowest (11.33) was found in T_7 followed by T_8 (12.33), T_2 (13.67) and T_3 (14.33). Considering the application of different treatments the highest TYLCV (11.91%, 33.33% and 50.00%) was found in T_9 and the lowest TYLCV (9.523%, 14.29% and 19.05%) was found in T_7 treatment at vegetative, flowering and reproductive stages, respectively. Considering the application of different treatments against tomato fruit borer during different fruiting stages of the cropping season, at early, mid and late fruiting stages, the highest fruit infestation (16.74%, 14.28% and 13.42%, respectively) and weight (14.59%, 12.63% and 12.04%, respectively) were recorded in T_9 treatment while the lowest (2.27%, 2.89% and 2.96%, respectively) and weight (1.97%, 2.56% and 2.66%, respectively) were recorded in T_7 treatment. Considering the different treatment effects on tomato fruit yield applied against whitefly and tomato fruit borer, the highest fruit yield both in number and weight are more or less similar in T_7, T_8 and T_3. Conversely, lowest fruit yield both in number and weight was recorded in treatment T_9.

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most widely grown vegetables in the world. It is grown on more than 5 million ha with a production nearly 129 million tons including Bangladesh (Srinivasan, 2010). It is cultivated in almost all home gardens and also in the field for its adaptability to wide range of soil and climate in Bangladesh. It ranks next to potato and sweet potato in respect of vegetable production in the world (Hossain *et al*., 2010). It ranks fourth in respect of production and third in respect of area in Bangladesh (BBS, 2006). At present 6.85% area is under tomato cultivation both in winter and summer. The total production of tomato in Bangladesh was about 232000 tons from 24700 hectares of land with an average yield of 9.39 t ha^{-1} (BBS, 2011). The yield of the tomato in Bangladesh is very low as compared to those of some advanced countries (Sharfuddin and Siddique, 1985). Tomato contains a number of nutritive elements almost double compared to fruit apple and shows superiority with regard to food values (Barman, 2007). 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). It contains high levels of a vitamins A and C, as well as the carotenoid phytochemical lycopene (Milind *et al*., 2011).

Among the different limiting factors for production, tomato is very much susceptible to insect attack from seedling to fruiting stage. The key constraint to tomato production relate to tomato leaf curl virus transmitted by whitefly, *Bemisia tabaci* Genn. Other key constraints to tomato production relate to fruit borer, *Helicoverpa armigera* (Alam *et al.*, 2011). All plant parts including leaves, stems, flowers, and fruits are subjected to attack. Whitefly causes damage to the tomato crop either by direct feeding on the phloem sap and excretion of honeydew, and or by indirect transmission of virus diseases (Byrne *et al*., 1990). The whitefly acts as a mechanical vector of tomato yellow leaf curl virus (TYLCV) in tomato. Over 70 plant viruses are transmitted by whitefly (Duffas, 1987). Tomato production is seriously hampered by TYLCV. Yield loss caused by TYLCV is reported to be 63-95% (Gupta, 2000).

Tomato fruit borer is highly polyphagous insect pest and perhaps the most serious pest of tomato. The larvae of this pest make circular hole 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. In Bangladesh, *Helicoverpa armigera* is becoming an alarming pest in different vegetable crops. It was reported that infestation range of *H. armigera* on tomato was up to 46.85 per cent at Jessore (Alam *et al*., 2007). Tewari (1985) reported that the damage caused by this pest might be up to 85-93%.

Generally, the farmers of Bangladesh control the insect pest of tomato by the application of chemical insecticides because of quick effect. But indiscriminate use of synthetic chemicals for controlling the insect pests of crop plants resulted hazardous effects causing serious problem including pest outbreak, pest resurgence, residual toxicity and environmental pollution. Moreover, the farmers of Bangladesh are very poor and they have limited access to buy insecticides and the spraying equipments (Husain, 1984).

Facing these problems, Scientists all over the world are being motivated to adopt the technique of IPM. IPM give importance on botanicals as it is regarded safe for environment. Botanical pesticide, especially neem oil is very new approach in this context and becoming popular day by day. Karim (1994) reported that 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 *Nicotiana tabacum* and seed extract of *Pongamia glabra* (5%), indiara (1%) and neem seed kernel extract (5%) exhibited low level of pest population build up. These are not hazardous for environment, human health and beneficial insects and also cheaper. But only a few works has been conducted to determine the efficacy of botanicals to control insect pests of tomato. Therefore, the present study was undertaken to test the approach comprising chemical insecticides and botanicals to evaluate their performance in combating the pest of tomato with following objectives:

OBJECTIVES:

i. To assess the level of infestation caused by whitefly and tomato fruit borer in tomato.

ii. To find out the efficacy of botanicals as compared with insecticides in controlling whitefly and tomato fruit borer in tomato.

CHAPTER II
REVIEW OF LITERATURE

Among many factors responsible for low yields of tomato, insect pests are major ones that have been reported to attack tomato at all stages of crop growth. Among insect pests, the damage caused by fruit borer, *Helicoverpa armigera* Hubner and tomato whitefly, *Bemisia tabaci* surpass the loss caused by all other insect pests together. Tomato being a commercial vegetable crop, the farmers have a tendency to indiscriminately use insecticides to control this destructive pest. Consequently it has led to many problems like build up of insecticide resistance, pest resurgence replacement of natural enemies and insecticide residue in the tomato fruits (Karabhantanal and Awaknavar, 2012).

2.1.1. GENERAL REVIEW OF WHITEFLY

2.1.1.1. NOMENCLATURE

The whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae) is a very complex species consists of at least 24 biotypes in tropical and sub-tropical region around the world (Ahmed *et al*., 2009). *Bemisia tabaci* is a genetically different groups of insect that morphologically indistinguishable (Boykin *et al*., 2007). Two predominantly aggressive biotypes, known as B and Q, are distributed everywhere around the world (Martinez-Carrillo and Brown, 2007) whereas, in Bangladesh yet B and/ or Q biotype are absent but indigenous biotype BW1 and BW2 recorded recently (Jahan, 2012). The *B. tabaci* is not genetically consistent. Based on mitochondrial DNA markers, the *B. tabaci* complex can be placed into five major groups according to their geographical origin: (1) New World (US, Mexico, Puerto Rico), (2) Southeast Asia (Thailand, Malaysia), (3) Mediterranean basin (Southwest Europe, North Africa, Middle East), (4) Indian subcontinent (Bangladesh, India, Myanmar, Nepal and Pakistan), (5) Equatorial Africa (Cameroon, Mozambique, Uganda, and Zambia) (Frohlich *et al*., 1999).

2.1.1.2. ORIGIN AND DISTRIBUTION

Bemisia tabaci was described over 100 years ago and has since become one of the most important pests worldwide in subtropical and tropical agriculture as well as in greenhouse production systems. It adapts easily to new host plants and geographical regions and has now been reported from all global continents except the Antarctica. In the last decade, international transport of plant material and people have contributed to geographical spread of this pests. *Bemisia tabaci* has been recorded from more than 600 plant species (Oliveira, 2001).

2.1.1.3. HOST RANGE

Bemisia tabaci is highly polyphagous. Although the genus *Bemisia* has a wide range of host plants (more than 500 species from 74 plant families), not all of them support large populations of whiteflies. Plants that do support large numbers of B biotype whiteflies include cotton, cabbage, cucumber, squash, melon, watermelon, tomato, eggplant, sesame, soybean, okra, bean, peanut, and many ornamentals, including poinsettia, hibiscus, lantana, verbena, garden mum and gerber daisies, to name a few (Lapidot, 2002).

2.1.1.4. LIFE HISTORY

2.1.1.4.1. Egg

Adult whitefly females usually lay between 200 and 400 eggs. Eggs are pyriform or ovoid and possess a pedicel that is a peglike extension of the chorion.

2.1.1.4.2. Nymph

The eggs hatch, and the young whiteflies gradually increase in size through four nymphal stages called instars. The first nymphal stage (crawler) is rarely visible even with a hand lens.The crawler move around for several hours before settling to begin feeding. Later nymphal stages are immobile, oval, and flattened, with greatly reduced legs and antennae, like small scale insects.

2.1.1.4.3 Adult

Adult whiteflies are about 1⁄10 to 1⁄16 inch long and have four broad, delicate wings and are covered with a white powdery wax. The wings of *Bemisia tabaci* are held tent-like above the body and slightly apart, so that the yellow tinged body is more apparent. Adult females tend to lay eggs randomly, either singly or in scattered groups, usually on the under-surface of leaves, whereas the glasshouse whitefly usually lays its eggs in a semi-circle.

2.1.1.5. NATURE OF DAMAGE

Whiteflies suck phloem sap and large populations can cause leaves to yellow, appear dry, or to fall off of plants. Due to the excretion of honeydew plant leaves can become sticky and covered with a black sooty mould. The honeydew attracts ants, which interfere with the activities of natural enemies that may control whiteflies and other pests. Feeding by the immature whiteflies can cause plant distortion, silvering of leaves and possibly serious losses in some vegetable crops. This devastating global insect pest caused damage directly by sucking the plant sap from phloem, indirectly by excreting honeydews that produce sooty mould, and by spreading 111 plant virus diseases. Among the plant viruses, Tomato Yellow Leaf curl Virus (TYLCV) is most important (Mughra *et al*., 2008).

2.1.1.6. SEASONAL ABUNDENCE

Bemisia tabaci appeared during 5 to 11 November 2012 with peak between 26 February, 2013 to 4 March, 2013 in India. Its population reached the highest in the 26th February to 4th March 2013 (Rishikesh, 2015).

Many researchers reported adult longevity, fecundity, and pre-imaginal developmental and survival rates. Finally, pre-imaginal survival of *Bemisia tabaci* varies inversely with relative humidity; it may be 2-80% in the range of 31-90% relative humidity.

2.1.2. VARIETAL RESISTANCE

Rahman *et al.* (2006) evaluated the performance of eight tomato varieties namely BARI-T1 (Manik), BARI-T2 (Ratan), BARI-T4, BARI-T5, BARI-T6 (Apurba), BARI-T7 (Chaity), BARI-T1 and BARI-T2 in respect to prevalence and spread of TYLCV (Tomato Yellow Leaf curl Virus) in relation to whitefly population buildup in the field. Data were collected on the three growth stages of the plant namely early (transplanting to first flowering) mid (first flowering to first harvesting) and late (first harvesting to last harvesting). The virus prevalence percentage in eight tomato varieties varied depending on early, mid and late stage of infection as well as tomato varieties. It ranged from 42 to 69%. There was a poor and insignificant quadratic polynomial relationship ($y = -0.0059x^2 + 0.2826x - 1.5378$ & $R^2 = 0.0962$) between temperature and whitefly population build up in tomato field. The relationship between relative humidity and whitefly population build up in the field was found significant but negatively correlated ($y = -0.0321x^2 + 4.5518x - 159.44$ ($R^2 = 0.6769$). The increase of whitefly population in the field was positively correlated with the spread of TYLCV in the tomato field ($y = -0.0002x^2 + 0.0297x + 1.0626$ &

R2 = 0.663). The highest and the lowest prevalence of TYLCV was recorded in BARI-T_6 and BARI-T_1, respectively. In all the varieties, virus prevalence was found higher at mid stage followed by late and early stage of infection.

Maruthi *et al.* (2005) investigated the molecular diversity of tomato leaf curl viruses (ToLCVs), from the two main tomato growing areas of Jessore and Joydebpur, Bangladesh. An isolate of the bipartite tomato leaf curl New Delhi virus-Severe (ToLCNDV-Svr) was associated with the severe symptom phenotype from Jessore (ToLCNDV-Svr [Jes]). A previously undescribed monopartite virus, designated tomato leaf curl Joydebpur virus-Mild (ToLCJV-Mld), was sequenced from plants showing mild symptoms. ToLCNDV-Svr [Jes] was most closely related to ToLCNDV-[Lucknow] at 95.7% nucleotide (nt) identity and tomato leaf curl Gujarat virus-[Varanasi] at 90.6% nt identity, based on DNA-A and -B component sequences. Four tomato cultivars (TLB111, TLB130, TLB133, and TLB182) resistant/ tolerant to South Indian ToLCV were screened against the Bangladesh ToLCVs in 2003-04. Although challenged by diverse viruses and potentially mixed infections, disease incidence remained low (6 to 45%) in the resistant cultivars compared with local cultivars (68 to 100%).

Yang *et al.* (2004) conducted an experiment to generate engineered resistance against TYLCV. Eight different constructs of the TYLCV replication-associated protein (Rep) and C4 gene sequences were tested in transformed tomato inbred lines. Resistance was observed in plants that contained one of the following transgenes: 2/5Rep (81 nucleotides [nt] of the intergenic region [IR] plus 426 nt of the 5' end of the TYLCV Rep gene), Delta2/5Rep (85 nt of the IR plus 595 nt of the 5' end of the TYLCV Rep gene in the antisense orientation), and RepDelta2/5Rep (81 nt of the IR, the entire Rep gene, and 41 nt 3' to the end of the Rep gene fused to Delta2/5Rep).

Suarez *et al.* (2008) determined major chemical components, sugars, mineral composition, organic acids, lycopene, total phenols and hydroxycinnamic acids in six tomato cultivars and the result showed that three of them (Boludo, Dorothy and Tyna) resistant, and the other three (Daniela, Dominique and Thomas), non-resistant against TYLCV. The Daniela cultivar showed the greatest difference with respect to the others, mostly due to the higher content of soluble solids. The major significant differences between the mean values according to the cultivar and resistance against the TYLCV were observed for total soluble solids, pH, ascorbic acid, total phenols and hydroxycinnamic acids.

2.1.3. MANAGEMENT

2.1.3.1. CULTURAL CONTROL

Abd-Rabou and Simmons (2012) experimented on several cultural techniques in three vegetable crops in the Egyptian agricultural system to develop a strategy to manage this pest and associated viruses. Cultural practices of mulching with white polyethylene, intercropping with maize (*Zea mays* L.), and crop rotation with maize resulted in reduce whitefly populations and incidence of TYLCV viruses in tomato.

Yaobin *et al.* (2012) reported that yellow sticky traps significantly suppressed the population increase of adult and immature whiteflies in the greenhouse. The whitefly densities in the greenhouse with traps were significantly lower than the greenhouse without traps. In the field, traps did not have a significant impact on the population dynamics of adult and immature whiteflies. The densities in fields with traps were very similar to fields without traps. These results suggested that yellow sticky traps can be used as an effective method for the control of whiteflies in the greenhouse, but not in the field.

2.1.3.2. MECHANICAL CONTROL

Removal of leaves or plants heavily infested with the nonmobile nymphal and pupal stages may reduce populations to levels that natural enemies can contain. Water sprays (syringing) may also be useful in dislodging adults. Watering can also reduce the hot, dry dusty conditions that favored whiteflies and inhibit their natural enemies.

2.1.3.3. USE OF PARASITOID

Parasitoids are primarily important biocontrol agents to manage whiteflies. They parasitize on whitefly nymphs to produce their new generations and also feed the nymphs to improve their fitness. *Encarsia* and *Eretmocerus* are the fundamental parasitoids genera among the widespread fauna of the *Bemisia tabaci*.

Arno *et al.* (2010) reported 15 *Encarsia* spp. parasitoids and 10 *Eretmocerus* spp. of *Bemisia tabaci*.

Mansaray and Sundufu (2010) revealed that premature hosts are usually preferred by parasitoids for feeding, whereas some researchers revealed that the mature nymphs are preferred, though host size did not affect on the host feeding.

Greenberg *et al.* (2008) examined that *Er. melanoscutus* Zolnerowich and Rose and *En. pergandiella* Howard females parasitized the most on the third instar nymphs and the lowest on the first instar nymphs of *Bemisia tabaci*.

Xiao *et al.* (2011) reported that *En. sophia* has strong parasitization capacity on *Bemisia tabaci*. Adult parasitoids gain nutrients from the host through feeding insight it, but this process destroys oviposition opportunity on host.

Zang and Liu (2009) reported that almost all parasitoids kill whitefly nymphs either by piercing the nymph with ovipositor following egg oviposition or by piercing the nymph and sucking the body fluids through labium. The efficacy of the parasitoid performance for controlling whiteflies might be increased by food deprivation for an optimal period prior to release.

Zang and Liu (2009) reported that *En. sophia* feeds and parasitizes more *Bemisia tabaci* nymphs during their whole lifespan if the adult parasitoids keep on without food for 6 hours prior to release and they live considerably longer than the parasitoids of no food deprivation.

Gelman *et al.* (2005) stated the physiological and biochemical relations between parasitoids and whiteflies. They assumed that the parasitoids inject and/or generate bio-chemicals inside their hosts that interfere with the immune system of the host. They also observed that parasitoids maneuver host maturity according to their own needs. Besides, parasitoids must synchronize their own development with that of their hosts, even though if their eggs were laid in fourth instar nymphs.

Roermund *et al.* (1997) studied the biological control strategies of greenhouse whitefly with the parasitoid *Encarsia formosawere* by a simulation model of the parasitoid–host interaction in a crop. Whiteflies were suppressed rather than regulated by the parasitoids at extremely low densities (<0.3 unparasitized pupae per plant), but did not become extinct. The percentage of black pupae fluctuated between 40 and 70%. According to the model, the parasitoid adults reached high densities of 7.4 per plant, but due to the low whitefly density not more than 1% of the parasitoids were searching on infested leaflets.

Alomar *et al.* (2006) evaluated the effectiveness of releases of the omnivorous predator, *Macrolophus caliginosus* Wagner (Heteroptera: Miridae) in the control of *Bemisia tabaci* Gennadius (Homoptera, Aleyrodidae) on greenhouse melon. Two greenhouse trials were performed, one in spring and another in summer. Adults of *M. caliginosus* were released at two release rates (two and six per plant) in an initial infestation of 10 adult whitefly per plant. The high release rate did control the whitefly populations. Results of the lower release ratio did not work in the second trial, presumably due to excessive pruning of the crop that may have affected predator establishment.

2.1.3.4. MICROBIAL CONTROL

Shefali *et al.* (2012) screened out fifty rhizobacterial isolates against Tomato Leaf Curl Virus (ToLCV) disease under glasshouse conditions. Application of rhizobacteria based bioformulations to seed, soil and foliage significantly reduced the disease severity of ToLCV from 28.58 to 85.72% with *Pseudomonas* sp 206 (4) and *Pseudomonas* sp. B-15. Treatment with fluorescent *Pseudomonas* 206(4) recorded maximum plant height, total biomass and chlorophyll content.

Shefali *et al.* (2014) reported that application of *Pseudomonas* spp. in combination with chitosan reduced the severity of Tomato Leaf Curl Virus (ToLCV) diseased plants by 75–100% at 45 days after inoculation (DAI). Application of chitosan or the bacterial inoculant alone was not very effective. The study has indicated that the application of rhizobacterial mixture + chitosan effectively reduced the disease severity of ToLCV and vector population through ISR as evidenced by lower viral titre and higher production of defense molecules.

Marcic *et al.* (2011) tested the effects of commercial products of entomopathogenic fungus, *Beauveria bassiana* (Naturalis: 0.1%, 0.2% and 0.3%), azadirachtin (NeemAzal T/S: 1% and 2%) and oxymatrin (KingBo: 0.1% and 0.2%) in the control of greenhouse whitefly on tomato. The effects of the bioinsecticides, applied twice at five-day interval, were compared to effects of abamectin (Abastate EW; 0.075%) and thiamethoxam (Actara 25-WG; 0.05%). Tested bioinsecticides reduced the number of larvae by 82-97% (Naturalis), 90-99% (NeemAzal T/S) and 90-96% (KingBo), with the efficacy of >96% according to Henderson-Tilton, in the assessment 16 days after treatment. In the same assessment, achieved percentages in adults reduction and efficacy amounted 24-89% and 67-95% (Naturalis), 85-93% and 93-97% (NeemAzal T/S), 86-96%and 94-98% (KingBo). Percentages of abundance reduction and efficacy after treatment with Abastate EW were 31% and 88% (larvae) and 64% and 84% (adults), while after treatment with Actara 25-WG they amounted 96% and 99% (larvae) and 83% and 92% (adults). The results showed that NeemAzal T/S, Naturalis and KingBo can be an efficient alternative to current insecticides in control of *T. vaporariorum* populations.

2.1.3.5. BOTANICAL CONTROL

Al-mazra'awi and Ateyyat (2009) evaluated the toxicity and repellent activities of aqueous extracts of nine medicinal plants on different life stages of the sweet potato whitefly, *Bemisia tabaci*. Extracts of *Ruta chalepensis, Peganum harmala* and *Alkanna strigosa* were effective in reducing the numbers of *Bemisia tabaci* immatures similar to the reduction observed in the imidacloprid treatment. These three extracts were not detrimental on parasitoid, *Eretmocerus mundus*. In addition, the plant extracts *Urtica pilulifera* and *T. capita* were repellent to *Bemisia tabaci* adults. These results indicated that the extracts from the plants *R. chalepensis, P. harmala* and *A. strigosa* could act as a potential management source for natural product for *Bemisia tabaci*.

Chavan *et al.* (2015) reported that spraying of NSKE 5% @ 2 kg/ha, neem oil @ 2.5 lit/ha and azadirachtin 3000 ppm @ 2.5 lit/ha was most effective against whitefly and leaf miner of 20 days after transplanting.

Abou-Fakhr Hammad *et al.* (2001) experienced that extracts of callus and different age classes of *Melia azadirachta* leaves and fruits have repellent activity of 58.9±67.7% and significantly decrease the oviposition rate of the insect without affecting the adult whitefly emergence in comparison with the control.

Mukhtar *et al.* (2013) conducted field studies to evaluate three management techniques on controlling whitefly (*Bemisia tabaci* Genn) in tomato fields. Field evaluation was managed for two successive growing seasons (winter 2002/03 and 2003/04). Severity and infection rate of tomato yellow leaf curl begomovirus (TYLCV) as well as tomato yield were the criteria of evaluation. The techniques used were a) Sumicidin (insecticide), b) Neem (*Azadirachta indica*) seed oil c) Neem seed extract. Disease incidence was significantly reduced in both previous seasons.

TYLCV severity degree was also significantly reduced in 2002/03 season. TYLCV incidence was reduced when using applications of Neem-seed oil followed by Neem-seed extract in both seasons. Tomato yield was highest (8.4 t/ha) during 2002/03 when using Neem oil followed by Neem extract (7.7 t/ha) and Sumicidin application (4.8 t/ha). Tomato yield was highest (9.4 t/ha) during 2003/04 season when using Neem oil application followed by Neem extract application (9.2 t/ ha) and Sumicidin (6.0 t/ha).

Kuldeep *et al.* (2009) tested eight neem based formulations against whitefly causing leaf curl disease in tomato, nimbacidine proved most promising in minimizing the leaf curl incidence (08.33 and 08.73 %) in both years followed by Neemazal, Neemgold, RD-9-Repelin, Bioneem, Neemark, Neemta-2100 and Achook. Achook was least effective (23.13 and 23.64 % leaf curl incidence), however it was significantly superior over untreated control. The highest leaf curl incidence was recorded in untreated control, which was as high as 35.12 and 36.31 % during both years.

Abou-Fakhr Hammad *et al.* (2000) performed the host preference bioassays for adults of the sweetpotato whitefly with leaves of the neem, tomato, cucumber and bean. Fruit and leaf extracts of neem were tested against adults of the sweet potato whitefly. Fruit extracts were tested against eggs, first and second instar nymphs, and pupae of the insect. Results of the host preference bioassays indicated a significantly lower number of live insects on leaves of the neem leaves of bean, cucumber, and tomato after 24 h. This indicates that *Melia azadirachta* is not a good host for the whitefly. Adults significantly more repelled from tomato plants treated with the undiluted extracts when compared to the control after 72 h. Thus *Melia azadirachta* extracts were found to be repellent to the whitefly adults, while the fruit extracts have shown a significant detrimental effect against early nymphal instars.

Kumar and Poehling (2007) tested the direct and residual toxicity of NeemAzal-T/S (azadirachtin), Success (spinosad), and Abamectin against different life stages of sweetpotato whitefly, *Bemisia tabaci* (Gennadius) (Homoptera: Aleyrodidae), under air-conditioned laboratory conditions and in a tropical net greenhouse. NeemAzal-T/S and abamectin deterred the settling of adults on tomato, *Lycopersicon esculentum* Mill (Solanaceae), plants and consequently reduced egg deposition. No such effect was detected for Success. All three pesticides influenced egg hatch. Toxicity of

NeemAzal-T/S however gradually declined under greenhouse conditions with time (5 d) postapplication.

Rehman *et al.* (2015) conducted an experiment to investigate the comparative efficacy of neem leaf extracts and lambdacyhalothrin against whitefly and jassid in okra field. They grew four okra cultivars (Sabz pari, Sada bahar, Pus a sawani, Arka and Anamika) treating with five neem oil concentrations (1, 2, 3, 4 and 5 percent) and a synthetic insecticide (Lambdacyhalothrin 2.5EC) @ 330 mL acre^{-1} to evaluate efficacy effects on targeted insects population. Distilled water was used as control. Results showed that Lambdacyhalothrin and neem oil @ 4 and 5% concentrations were equally effective in controlling jassid and had same impact on yield of okra plant.

2.1.3.6. INSECTICIDAL CONTROL

Muqit *et al.* (2006) conducted an experiment to evaluate the efficacy of different treatments like Admire 0.1%, Cymbush 0.1%, Nimbicidin 0.4%, Soybean oil 1.5% and untreated control on Tomato yellow leaf curl virus at the research farm of Bangabandhu Sheikh Mujibur Rahman Agricultural University during winter 2003-04. All the tested chemicals reduced the disease significantly. Significant (P=0.01) reduction in number of whiteflies were found on treated plants. Number of whitefly adults/plant was the lowest (1.9) in Cymbush but the highest (3.7) in untreated control. Cymbush varied significantly with all treatments. But other treatments did not vary significantly among themselves.

Gorri *et al.* (2015) evaluated the insecticide toxicity on *Bemisia tabaci*, *Tetranychus evansi, Orius insidiosus, Cycloneda sanguinea* and *Chauliognathus flavipes* in tomato plants. The following toxicity treatments were applied: T_1: control, T_2: chlorpyrifos (Pitcher) 450 EC (1.25 L.ha-1), T_3: chlorpyrifos 450 EC (Pitcher) (0.62 L.ha-1), T_4: thiamethoxam 100 WG (1.00 L.ha-1), T_5: thiamethoxam 250 WG (0.50 L.ha-1), T_6: teflubenzuron 150 CS (0.025 L.ha-1) and T_7: teflubenzuron 150 CS (0.0125 L.ha-1). For the sub-lethal effect, a tenth of the recommended concentration was used. The insecticide teflubenzuron was effective against whitefly nymphs, while chlorpyrifos and thiamethoxam were efficient against adult whiteflies.

Gosalwad *et al.* (2015) reported that the insecticide, imidacloprid 17.8 SL @ 20 g a.i/ha was most effective against whitefly and leaf miner, followed by acetamiprid 20 SP @ 15 g a.i/ha and NSKE 5% up to 25 and 45 days after transplanting.

Rajasri *et al.* (2009) conducted a field trials to evaluate the efficacy of insecticides against *Bemisia tabaci* and ToLCV incidence in tomato during summer seasons of 2008 and 2009. Among the insecticides, profenophos @ 500 g a.i/ha and thiamethoxam @ 25 g a.i/ha effectively controlled the whitefly population and reduced the ToLCV incidence and improved the yield of tomato fruits. Cost benefit ratio was 1:5 and 1:4.95 with Profenophos and thiamethoxam sprays, respecitvely.

Meena and Raju (2014) reported that for control of whitefly, fipronil 5% SC was found most effective insecticide among selected six insecticides along with control followed by profenofos 50% EC by conducting an experiment. The remaining insecticides found following order; indoxacarb 14.5% SC > NSKE 5% > spinosad 45% SC > NPV. All the treatments differed significantly from each other.

Rasdi *et al.* (2012) examined the effect of avermectin, buprofezin, white oil, lambda-cyhalothrin and cyromazine on *Trialeurodes vaporariorum* Westwood (Aleyrodidae: Homoptera) in tomato (*Lycopersicon esculentum* Mill) plants in a natural environment of the Cameron Highlands, Pahang, Malaysia. Avermectin was the most effective insecticide against the population of *T. vaporariorum*. However, it was highly toxic to the predator, *Melanomys caliginosus*. Considering relatively low mammalian toxicity of buprofezin and white oil, these two insecticides were more suitable for controlling whiteflies, particularly during fruiting period. Proper selection of effective pesticides against the pest, but less harmful to natural enemies and also good timing of their applications are essential in formulating an Integrated Pest Management (IPM) programme for whiteflies.

Mason *et al.* (2000) studied the effect of thiamethoxam, a new neonicotinoid insecticide, in preventing transmission of tomato yellow leaf curl geminivirus (TYLCV) by the whitefly *Bemisia tabaci* to tomato seedlings. Viruliferous whiteflies exposed to thiamethoxam-treated plants stopped feeding before acquiring enough virus to subsequently inoculate plants.

2.1.3.7. INTEGRATED PEST MANAGEMENT (IPM)

Kabir and Rainis (2015) studied the common use of pesticide is a major challenge in trying to accomplish sustainable agriculture. Farming systems based on integrated pest management (IPM) technologies can reduce the use of pesticides to a great extent without causing harm to the yield. Therefore, Bangladesh, like many developing countries, launched IPM technologies to reduce the adverse effects of pesticides in social, economic and environmental aspects. They made an attempt to analyze the level of IPM adoption and the intensity of IPM practices by vegetable farmers of Narsingdi district, Bangladesh. A total of 331 vegetable producers were sampled. The results revealed that less than one-third of the farmers (30 %) adopted IPM and they varied in terms of the number or type of practices. The linear regression model showed that vegetable cultivation area, farmers' age, household size, land ownership status and perception toward IPM are necessary in the adoption intensity of IPM practices.

Oji (2003) assessed the effectiveness of some cultural practices and insecticides in two field experiments, conducted over two seasons. Treatments evaluated were staked (trelling), unstaked, staked + grass cover, unstaked + grass cover, unstaked + mulch + grasscover and unstated + Mulch. In the second season the cultural practices were integrated with Malataf insecticide. Staking tomato significantly reduced whitefly infestation as well as losses caused by sunscald and fruit rotting. Staking tomatoes increased the yield of marketable tomatoes up to 95.3%. Losses caused by fungal diseases were significantly reduced in all staked plants. Integration of these cultural practices with insecticides can be a solution to all the year round production of tomatoes.

Mandal (2015) reported that the IPM technology comprising of raising healthy nursery using *Trichoderma harzianum* with FYM (@ 10 g/100 g FYM/m2), covering nursery bed with nylon net for preventing whitefly and sowing of leaf curl resistant varieties, adopting wider spacing of 90 x 60 cm, transplanting 1 row marigold as trap crop/14 row of tomato, two sprays of azadirachtin 15% (Achook @ 4.0 ml/litre) against aphids in early stages, installation of pheromone traps @ 5/ha for monitoring fruit borer adult moths, releasing *Trichogramma chilonis* @ 1.0 lakh/ha 4–5 times, spraying of Ha NPV @ 250 LE/ha 2–5 times in the evening with 2% jaggery against young larvae of fruit borer, collection and destruction of damaged fruits and leaf curl affected plants and need based application of emamection benzoate 5 WDG @ 0.25 g/litre of water for borer and mancozeb for early blight was very effective in reducing the incidence of pests and minimizing the yield losses.

Cuthbertson *et al.* (2008) studied the integration of chemical insecticides and infective juveniles of the entomopathogenic nematode *Steinernema carpocapsae* (Wesier) (Nematoda: Steinernematidae), to control second instars of the sweetpotato whitefly, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae). The effect of insecticide treatment (dry residues of spiromesifen, thiacloprid and pymetrozine and soil drench of imidacloprid) on the efficacy of the nematode against *Bemisia tabaci* was also investigated. Nematodes in combination with thiacloprid and spiromesifen gave higher *Bemisia tabaci* mortality (86.5% and 94.3% respectively) compared to using nematodes alone (75.2%) on tomato plants. There was no significant difference in *Bemisia tabaci* mortality when using the chemicals imidacloprid, pymetrozine and spiromesifen in conjunction with nematodes compared to using the chemicals alone. However, using thiacloprid in combination with the nematodes produced significantly higher *Bemisia tabaci* mortality than using the chemical alone. Management programmes for the control of *Bemisia tabaci* is discussed.

Barati *et al.* (2013) assessed the effects of extracts of two medicinal plant species: *Allium sativum* (Linn) and *Calotropis procera* (Aiton), and a formulation containing azadirachtin on *Bemisia tabaci* grown on greenhouse tomato plants. The effects were compared to that of pymetrozine, a synthetic insecticide. Bioassays were carried out in a greenhouse under controlled conditions of 27 ± 2°C, R.H. of 55 ± 5% and 16:8h (L:D) photo period. All treatments significantly affected the survivorship and fertility of SLW female adults, reducing the net reproduction rate, mean generation time and intrinsic rate of increase of this insect.The net reproductive rate [R_0] values for the populations treated with garlic extract, milkweed extract, pymetrozine, azadirachtin, control for extracts (ethanol + distilled water) and control for pesticides (distilled water) were 23.58, 19.32, 10.78, 8.23, 49.66, 57.55; the intrinsic rate of increases [r_m] were 0.134, 0.139, 0.110, 0.090, 0.177, 0.178; the mean generation times [T] were 23.49, 21.23, 21.66, 23.50, 22.06, 22.69; the doubling times [DT] were 5.14,4.95, 6.27, 7.56, 3.91, 3.87, and the finite rates of increase [λ] were 1.144, 1.149, 1.116, 1.094, 1.193,1.195, respectively. Azadirachtin had the highest effect on the life table parameters of SLW. Findings indicated that, although herbal extracts were not effective as much as the chemical insecticides, they can be effective in pest control. Therefore, they are suitable choices for replacing chemical insecticides and for alternative use with azadirachtin in SLW IPM program.

Moreno-Ripoll *et al.* (2014) have found that predators *Macrolophus pygmaeus* (Rambur) and *Nesidiocoris tenuis* Reuter (Hemiptera: Miridae) and the parasitoid *Eretmocerus mundus* (Mercet) (Hymenoptera: Aphelinidae) are effective against controlling whitefly *Bemisia tabaci* populations when used as biological control agents. Although PCR analyses using *E. mundus*-specific primers showed predation on *Bemisia tabaci*-parasitized nymphs in 27 % of *M. pygmaeus* and 17 % of *N. tenuis, Bemisia tabaci* control was improved when both predators coexisted on the same plant with the parasitoid. The combined use of *E. mundus* and *M. pygmaeus*/*N. tenuis* is therefore recommended in order to improve *Bemisia tabaci* control in conservation biological control strategies.

2.2.1. GENERAL REVIEW OF TOMATO FRUIT BORER

2.2.1.1. 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 Heliothis contains several numbers of species, including *H. armigera*, which is the serious pest of tomato (Mishra *et al*., 1996)

2.2.1.2. 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).

2.2.1.3. HOST RANGE

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).

2.2.1.4. LIFE HISTORY

2.2.1.4.1. 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. The unfed females laid few viable eggs.

2.2.1.4.2. Larva

Helicoverpa armigera (Hubner) (Lepidoptera: Noctuidae) completed its larval stage in 17.325±0.326 days passing through six instars under laboratory protocol, 26±1 °C, 60-70% RH and 16 hours` daylight. The larvae moulted for 2nd instar, two days after hatching from eggs. Average stadiel periods for 2nd, 3rd, 4th, 5th, and 6th instars were 2.07, 2.15, 2.48, 3.12, 3.55 and 3.95 days, respectively. The last larval stage did not moult but contracted and shortened into grub like pre-pupal stage. The average length measured for each instar (first to sixth) was 3.4, 4.6, 9.7, 17, 28.35, 36.85 mm, respectively (Nasreen and Ghulam, 2000).

2.2.1.4.3. Pupa

The light brown pupa is about 22 mm in length, living in the soil .The average pupal period was 13.2 days for female and 15.4 days for male.

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 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.

2.2.1.5. NATURE OF DAMAGE

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, 1972). 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.

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.

2.2.1.6. SEASONAL ABUNDENCE

The seasonal history of tomato fruit borer, *Helicoverpa armigera* varies considerably due to different climatic conditions throughout the year. A study revealed that the population of *Helicoverpa armigera* began to increase from the mid January and peaked during the last week of February. The population of this pest was positively correlated with average temperature, mean relative humidity and total rainfall.

Kuldeep (2013) recorded the seasonal abundance of fruit borer, *Helicoverpa armigera* (Hubner) and found that the first appearance was in the last fortnight of December (50th and 52nd standard week), but to the lowest (0.12 and 0.10 larvae/m row) irrespective of the year of study. The initial population gradually increased and remained confined to vegetative growth but it rapidly increased during fruiting stage and attained its peak in 15th standard week (2nd week of April). Thereafter, the pest population declined. Rainfall and relative humidity were negatively correlated, whereas the temperature were positively correlated with the pest activity.

Kumar (2014) recorded the seasonal abundance of *Helicoverpa armigera* Hubner in India. The fruit borer was first recorded in the last week of February. The peak activity of the pest was observed during first week of April (6.65 per plant). However, minimum temperature and evaporation exhibited significant positive correlation ($r = 0.85$ and $r = 0.90$, respectively) with larval population. It can be said that with every unit increase in minimum temperature and evaporation, there was an increase in larval population to the tune of 2.9 and 0.8 larvae per plant, respectively. Further, significant negative correlation ($r = -0.81$) was observed between morning relative humidity and *Helicoverpa armigera* larval population.

Mandloi *et al.* (2015) revealed that *Helicoverpa armigera* was major insect pests recorded on 5th, 12th and 26th November, 2012. The peak activity was recorded during 19th to 25th March 2013. The highest mean of 6.11 larval population/plant was recorded.

2.2.2. VARIETAL RESISTANCE

Khanam *et al.* (2003) conducted the screening test of thirty tomato varieties/lines to tomato fruit borer, *Helicoverpa armigera* (Hub.) infestation in relation to their morphological characteristics in different laboratories of BAU and Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh during Rabi season, November 1999 to March 2000. Among the varieties/lines, V-29 and V-282 were found moderately resistant and susceptible, respectively. Plant height, stem diameter, total number of branches/plant, total number of leaves/plant, 2nd leaf area, total leaf chlorophyll, number of leaf hair and number of fruits/plant of V-29 line were 81.74 cm, 1.45 cm, 14, 453, 19.58 sq.cm, 1.13 mg/g, 12 and 48, respectively. Again the aforementioned characters for V-282 line were 80.74 cm, 1.18 cm, 9, 396, 21.57 sq.cm, 1.24 mg/g, 17 and 30, respectively.

Ashfaq *et al.* (2012) measured and compared morphological characters and chemical composition of tomato (*Lycopersicon esculentum* Miller) leaves among nine tomato varieties (Roma VFN, NARC-1, Fs-8802, Tommy, Pant Babr, Rio Grande, Nova Mecb, Pakit and Sahil) exhibiting varying levels of host plant resistance to *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae). Hair length and hair density on lower leaf surface, as well as thickness of leaf lamina significantly correlated with larval population and fruit infestation. Leaf hair density accounted for 92.0% of the variation in fruit infestation and 77.0% of the variation in larval population. Ferrous (Fe 2+) and phosphorous content in the leaves were negatively correlated with fruit infestation and larval population; whereas, nitrogen, calcium, magnesium, manganese and zinc content were positively correlated with fruit infestation and larval population.

Selvanarayanan and Narayanasamy (2006) studied three tomato accessions (Lycopersicon spp.) selected from preliminary field and glasshouse screening of 321 accessions for factors of resistance against the fruit worm, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) in comparison with a susceptible check at Annamalainagar, Tamilnadu, India. Among the factors of resistance in these accessions, ortho-dihydroxy phenols, trichome density in the foliage and acidity of the fruits exerted a significant negative correlation on larval feeding. Non-reducing sugars in the foliage had a significant positive correlation with larval feeding.

Kumar and Kumar (2004) reported that transgenic Bt tomato plants expressing a Cry1Ab protein of *Bacillus thuringiensis* suffered significantly lower damage by *Helicoverpa armigera* than the non-transgenic control plants in the laboratory, greenhouse and field. The Bt plants caused 100% mortality of the larvae and did not support any growth and development by the latter. A complete control of the *Helicoverpa armigera* by Bt plants in the field will have to be supported by the other tactics of pest management such as bio-control agents or limited use of pesticides.

Selvanarayanan and Narayanasamy (2004) studied the antixenosis resistance to *Helicoverpa armigera* (Lepidoptera: Noctuidae) in 10 tomato accessions selected from a germplasm of 321 at Tamil Nadu, India, using free-choice and no-choice laboratory experiments. The foliage and fruits of two accessions, namely PT 4287 and Varushanadu Local were the least preferred for feeding in both tests. In the no-choice (confinement) test, Seijima Jeisei, Varushanadu Local and PT 4287 were the most preferred for oviposition, but had low egg hatch rates. In the free-choice test, these accessions were the least preferred for oviposition. The first and second instars preferred to feed on the foliage of 30- and 45-day-old plants, respectively than 60- and 75-day-old plants, whereas ovipositional preference was insignificant among the various plant ages.

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.

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.

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

2.2.3. MANAGEMENT

2.2.3.1. CULTURAL CONTROL

Cultural control measures are important in minimizing injuries and protesting the crop and should be considered in any integrated control program. 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.

Muqit and Akanda (2007) raised tomato seedlings in the netted seedbeds before transplanting in order to study the effect of netting on the incidence of Tomato yellow leaf curl virus in the field. Two types of nets, namely, fine (40 mesh) and coarse (10 mesh) and insecticidal spray with imidacloprid @ 0.1% were used in the experiment. Results showed that the disease incidence was reduced by 12 to 37% and yield was increased by 5 to 21% due to netting and pesticidal spray. Of the two types of nets, fine net (40 mesh) was more effective than coarse net (10 mesh).

Leite *et al.* (2014) tested the economic and technical feasibility of bagging tomato fruits clusters during organic production to protect them against insects and diseases. Bagging of fruit with either organza fabric or TNT reduced insect borer damage by 99.7% and disease damage by 84.7%.

Patil *et al.* (1997) studied to assess the effects of intercropping of 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 radish. Total TFB infestation ranged from

17.0% in treatments where radishes were grown as an intercrop, to 28.2% in plots where snap beans were grown intercropped with tomatoes.

2.2.3.2. 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).

2.2.3.3. USE OF PARASITOID

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.

Walker *et al.* (2010) assessed an adjustable action threshold that uses estimates of larval parasitism of *Helicoverpa armigera* (Hubner) in individual fields over three consecutive years in processing tomatoes in Hawke's Bay, New Zealand. Overall parasitism during the three seasons was 71%, confirming that the original threshold, which relies on about 50% parasitism, needed revision. The dominant parasitoid was *Cotesia kazak*, reared from 91% of all parasitized larvae over the 3 years. *Microplitis croceipes* and the self introduced polyphagous parasitoid *Meteorus pulchricornis* were reared from 4% and 5% of the parasitized larvae, respectively. In 16 of 17 fields examined, the adjustable threshold kept fruit damage at harvest below the tolerated level of 5%. The single crop with excessive damage had only 0.5% fruit damage above this level. This adjustable threshold, which varied in this study from 1-8.3 larvae per plant, has been incorporated into an updated IPM programme and contributed to a 95% reduction in insecticide use.

Sedaratian *et al.* (2014) documented the sublethal effects of *Bacillus thuringiensis* var. kurstaki (Btk) on the *Habrobracon hebetor* attacking *Helicoverpa armigera* larvae infected with Btk. The results revealed that the duration of different life stages and fecundity of *H. hebetor* was significantly affected by sublethal treatments with Btk. Sublethal concentrations of Btk could adversely affect life table parameters of *H. hebetor*. Sublethal treatments reduced the net reproductive rate (R_0). The intrinsic (r_m) and finite (λ) rates of increase were also significantly lower in parasitoid wasps reared on the treated larvae of *H. armigera* compared to control. These findings will be useful to develop appropriate strategies for assessing the risks of Btk to the parasitoids and safe deployment of both organisms in integrated pest management programs for sustainable crop production.

Krishnamoorthy and Mani (1996) studied biological control of *H. armigera*, infesting tomato attempted using two species of egg parasitoids, *Trichogramma brasiliensis* 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. brasilienses* and *T. pretiosum*, respectively. 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. brasilienses* 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.

2.2.3.4. MICROBIAL CONTROL

Rahman *et al.* (2014) conducted an experiment to test the effect of two microbial insecticides HaNPV @ 0.4ml/L and Bt @ 2g/Lalong with their combination against *H. armigera* at the experimental field of Entomology Division, BARI, Gazipur during Rabi 2007-08. The lowest fruit infestation, both in number and weight, was obtained from treatment HaNPV and Bt alternate spraying (11.78%, 9.64%), followed by Bt (13.25%, 10.85%) and HaNPV (17.67%, 13.11%). The highest fruit yield (16.92 t/ha) was obtained from HaNPV and Bt alternate spraying plots followed by Bt (16.65 t/ha) and HaNPV (14.73 t/ha). In case of MBCR, the highest Marginal Benefit Cost Ratio was obtained from HaNPV and Bt alternate spraying (5.30) followed by HaNPV (4.46) and Bt (3.37).

Singh (2012) conducted a field trial during Rabi cropping seasons of 2006–07 and 2007–08 to evaluate bio-efficacy of *Bacillus thuringiensis* Berliner based formulations (Biolep, Dipel 8L, Bioasp, Biobit, Delfin, Bacticide, Halt and Spicturin). Biolep proved to be the most effective in reducing fruit infestation during both the cropping seasons.

Wakil *et al.* (2012) determined the insecticidal efficacy of formulations of *Azadirachta indica*, a Nuclear Polyhedrosis Virus (NPV), and new anthranilic diamide insecticide (chlorantraniliprole) formulations against 2nd, through 5th larval instars of *Helicoverpa armigera* collected from diverse geographical locations in the Punjab province, Pakistan. The combinations of NPV with *A. indica* and chlorantraniliprole caused higher mortality, pupation and produced an additive effect compared to their application singly in all the tested populations. The results suggested that the effectiveness of NPV and *A. indica* can be improved by the presence of chlorantraniliprole against the larvae of *H. armigera*.

Pathania *et al.* (2009) carried out a field studies during April to June 2004 and 2005 to evaluate the effectiveness of biological agents like *Bacillus thuringiensis,* nuclear polyhedrosis virus and *Trichogramma chilonis* along with insecticides to assess the impact of their integrated use on fruit damage, yield and cost benefit analysis in tomato. The lowest fruit damage (7.2 and 7.01%) and the highest yield (270.6 and 263.7 q/ha) was obtained with all insecticide module. Amongst the biopesticides, lower fruit damage (7.57 and 8.23%) was obtained in Btk. alone and *T. chilonis* HaNPV modules. However, among biopesticide modules, higher yield was obtained in Btk - HaNPV module.

Tyagi *et al.* (2010) tested the efficacy of eight treatments consisting combined use of biopesticides i.e. *Bacillus thuringiensis*, NPV and *Beauveria bassiana* with egg parasitoid, *Trichogramma pretiosum* including a chemical spray schedule and control against *Helicoverpa armigera*. Four sprays of *B. thuringiensis* @ 1 kg/ha with release of *T. pretiosum* @ 50,000 parasitoid eggs at ten days interval was proved most effective treatment in terms of reduction in fruit damage, net return and yield.

Ud Din *et al.* (2010) carried out a field efficacy test of HaNPV against *H. armigera* in tomato field. Different dosaes of HaNPV (100, 150, 200 & 250 LE/ha) and endosulfan (0.07 & 0.035%) were applied as spray. The results clearly revealed that endosulfan 0.07% and HaNPV 250 LE proved most effective treatments in terms of fruit yield. After 4 days of third spray, HaNPV 250 LE/ha caused maximum mortality (98%) followed by endosulfan 0.07% and HaNPV 200 LE having 96 and 95% mortality, respectively.

Jeyarani *et al.* (2011) investigated the possibility of integrated use of *H. armigera* nucleo polyhedron virus and the plant growth-promoting rhizobacteria *Pseudomonas fluorescens* on tomato against *H. armigera*. Lower percentage mortality (36.25%) due to NPV was noticed in tomato plants, treated with *P. fluorescens* through seed treatment (ST) + foliar application (FA). Increased levels of phenol, tannin, peroxidase, polyphenol oxidase, and phenylalanine ammonia lyase were recorded in *P. fluorescens*-treated plants than in untreated checks. Reduced consumption by *H. armigera* larvae and inactivation of baculoviruses due to defense-related enzyme induction in *P. fluorescens*-treated plants could be responsible for the reduction in NPV-induced mortality of *H. armigera* larvae.

Qayyuma *et al.* (2015) evaluated the isolates of *Beauveria bassiana* from leaf tissue of a wild tomato plant (reference WG-40) and a further two isolates of *B. bassiana* from soil (reference WG-14 and WG-19) for their ability to endophytically colonize tomatoes and subsequently infect *Helicoverpa armigera* larvae. The three isolates were inoculated on to tomato plants using root dip, injection, solid substrate and direct foliar application methods. Isolate WG-40 was the most pathogenic and achieved the highest insect mortality.

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, *H. 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.

Reddy *et al.* (1997) evaluated the effectiveness of *Bacillus thuringiensis* and a nuclear polyhedrosis virus for control of *H. armigera*. The LC50 value for *B. 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.

Padmanaban *et al.* (2002) evaluated a native isolate of *Helicoverpa armigera* Nuclear Polyhedrosis Virus (HaNPV), PAU1, for its efficacy against *Helicoverpa 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.

2.2.3.4. BOTANICAL CONTROL

Interest in biological control of insect-pests of economically important plants has been stimulated in recent years by trends in agriculture towards greater sustainability and public concern about the use of hazardous pesticides. Botanicals and microorganisms have the capability to synthesize biologically active secondary metabolites such as antibiotics, herbicides and pesticides (Gopalakrishnan, 2011). 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).

Rahman *et al.* (2014) tested the efficiency of four botanicals viz., mahogany oil, mahogany seed extract, tobacco leaf extract, neem seed kernel extract along with one synthetic chemical, cypermethrin against *Helicoverpa armigera*. The lowest fruit infestation, both by number and weight, was observed in neem seed kernel extract (27.15%, 22.29%) treated plot which was statistically similar to tobacco leaf extract (27.71%, 23.31%) treated plot and cypermethrin (28.87%, 25.44%) treated fruits.

While no significant difference was found among mahogany oil, mahogany seed extract and control treatments. Percent infestation reduction over control was the highest in neem seed kernel extract (30.08%) followed by tobacco leaf extract (28.68%). The highest yield (18.14 t/ha) and the highest MBCR (2.99) were also obtained from neem seed kernel extract treated fruits.

Gopalakrishnan (2011) evaluated the efficacy of washings of herbal vermicompost (called biowash; viz. Annona, Chrysanthemum, Datura, Jatropha, Neem, Parthenium, Pongamia, Tridax and Vitax) and plant growth promoting (PGP) bacteria [viz. *Bacillus subtilis* (BCB-19), *Bacillus megaterium* (SB-9), *Serratia mercescens* (HIB-28) and *Pseudomonas* spp. (SB-21)] and fungus (*Metarhizium anisopliae*) against *Helicoverpa armigera*. When the feed was treated with crude biowash for healthy larvae (4-day old), 42 and 86% mortality and 32 and 71% weight reduction over control was reported for *H. armigera*. When healthy larvae were treated with PGP bacteria and fungus, the mortality rate varied between 59 and 73%, with 55 and 92% weight reduction over control on *H. armigera*. It was therefore concluded that the aforementioned six botanicals and five entomopathogens has great potential in the management of *Helicoverpa armigera*.

Suradkar and Ukey (2015) reported that least fruit damage was experienced due to the treatment with endosulfan 0.05 per cent, followed by the treatment of NSE 5% alternated with Blk @ 1000 ml/ha and the treatments with other neem based materials. All treatments performed well than untreated control. The highest fruit yield of 86.49 q/ha was obtained due to the treatment with endosulfan 0.05% followed by other neem based treatments.

Kulat *et al.* (2001) conducted an experiment on extracts of some indigenous plant materials, which are claimed important as pest control properties like seed kernels of neem, *Azadiracta indica*, *Pongamia glabra*, leaves of tobacco, *Nicotiana tabacum* and indiara, a neem based herbal product, against *Helicoverpa 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 (2002) screened methanol extracts of selected plants namely *Anisomeles malabarica*, *Ocimum canum*, *O. basilicum*, *Euphorbia hirta*, *E. heterophylla*, *Vitex negundo*, *Tagetes indica* and *Parthenium hysterophorus* for their insecticidal activity against the fourth instar larvae of *Helicoverpa 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.

2.2.3.5. INSECTICIDAL CONTROL

Sandip *et al.* (2015) evaluated the efficacies and economics of some new insecticides viz., pyridalyl 10 EC (56.25, 75, 112.5 and 150 g a. i./ha), indoxacarb 14.5 SC (56.25, 75, 112.5 and 150 g a. i./ha) and chlorfenapyr 10 SC (75, 100, 150 and 200 g a.i./ha) and untreated control for the management of major lepidopteran pests of tomato at Bidhan Chandra Krishi Viswavidyalaya, Kalyani, West Bengal. Pooled results revealed that pyridalyl and indoxacarb @ 150 g a. i/ha were found to be very effective insecticides against *Helicoverpa armigera* (3.10 and 2.60% fruit damage) and with 211.21 marketable yield.

Katroju *et al.* (2014) evaluated the efficacy of insecticides viz., emamectin benzoate 5 SG @11 g a.i. ha-1, emamectin benzoate 5 SG @ 22 g a.i. ha-1, profenophos 50 EC @ 500 g a.i. ha-1, profenophos 50 EC @1000 g a.i. ha-1, spinosad 45 SC @ 100 g a.i. ha-1, bifenthrin 10 EC @ 100 g a.i. ha-1 and *Bacillus thuringiensis* @ 25 g a.i. ha-1against tomato fruit borer (*Helicoverpa armigera*). Among all the insecticides, profenophos (1000 g a.i. ha-1) was found to be the most effective one with a maximum reduction in fruit borer population (65.20%), minimum per cent of fruit damage (28.80%) and maximum yield (26.43 kg/20 m2) followed by bifenthrin @ 100 g a.i.ha-1 with reduced larval population of 64.51% and damaged fruits 32.60%.

Kumar and Indira (2014) conducted a field experiment to study the field efficacy, net profit and cost benefit ratio of certain insecticides against fruit borer, *Helicoverpa armigera* (Hubner) in tomato during Rabi season 2008. Endosulfan 35 EC recorded significantly the lowest fruit damage (22.85 per cent). Maximum fruit yield was registered by treatment endosulfan (69.50 q/ha) followed by cypermethrin (64 q/ha) and fenvalerate (61.33 q/ha) and the lowest in control (20.33 q/ha). Spraying of cypermethrin twice on tomato crop, gave maximum cost benefit ratio (1:0.98) which was obviously due to its low price as compared to other insecticides.

Dhaka *et al.* (2010) carried out a field study on the efficacy of different sequential application of some novel insecticides viz., novaluron 10 E.C., indoxacarb 14.5 S.C., bifenthrin 10 E.C., lambda cyhalothrin 5 E.C., and biopesticides viz., nucleopolyhedrovirus (NPV) of *Helicoverpa armigera*, *Bacillus thuringiensis* var. kurstaki and neemarin, against *Helicoverpa armigera* in comparison with sequential application of conventional insecticide i.e. endosulfan 35 E.C. and untreated control on tomato hybrid Pusa Ruby. Results showed that among different sequential application of insecticides, indoxacarb provided the lowest fruit infestation of 2.53 and 2.83 and highest yield 39.45 & 38.85 q/ha during both the seasons, respectively.

Saini and Raj (2008) studied on the efficacy of four insecticides, viz., Endosulfan (0.05%), lambda cyhalotrin (0.004%), cypermethrin (0.01%) and mixture of Endosulfan + Btk (0.025%+0.05%) against *Helicoverpa armigera* (Hubner). The study revealed that cypermethrin was the most effective and gave maximum reduction of borer population (1.75 per three plants) followed by endosulfan, endosulfan + Btk and Lambda cyhalothrin.

Chaudhary *et al.* (2014) reported that treatment with endosulfan @ 2ml/l (7.37%) and *Metarhizium anisopliae* Talc 5g/l (8.12%) found equally effective in recording least fruit damage. The highest yield of 532.98 q/ha was recorded in endosulfan. However, the yield in the treatment of *M. anisopliae* was comparatively less than endosulfan.

Sandeep and Subash (2014) carried out a study to evaluate the field efficacy of some systemic insecticides and microbial pesticides modules against tomato fruit borer, *Helicoverpa armigera* (Hubner) on tomato (*Lycopersicon esculenum* Mill.) at the Vegetable Research Farm, Punjab Agricultural University, Ludhiana. Spinosad 45% SC @0.5 ml L^{-1} in module M1 and Profenophos (Carina) 50 EC @1.5Lha^{-1}in module M5 a$T_1$5 days interval, and Bt (Delfin WG) @ 500 gha^{-1}in module M2 and *Beauveria bassiana* (Larvocel) @ 4g L^{-1} in module M3, Nuclear Polyhedrosis Virus (NPV) @ 350 LEha^{-1} in module M4 at 10 days interval was evaluated for fruit borer . Spinosad 45% SC significantly resulted in lower fruit borer infestation (9.68%) than other modules (M2-M5) with 13.73–29.00% fruit infestation, standard check M6 (13.87%) and control M7 (32.66%).

Gupta *et al.* (2011) studied the persistence of cypermethrin, chlorpyriphos, and profenofos in tomato and soil following application of two pre-mix formulations of insecticides viz. Roket 44EC (profenofos 40% + cypermethrin 5%) and Action-505 EC (chlorpyriphos 50% + cypermethrin 5%) at recommended (0.8–1.0 L ha − 1) and double dosage (1.6–2.0 L ha − 1). In all the treatments residues persisted beyond 7 days in tomato fruits. In soil, residues of profenofos persisted for 7–15 days, whereas residues of chlorpyrophos and cypermethrin persisted for 0–7 days only.

Duraimurugand Regupathy (2005) diagnosed the resistance to synthetic pyrethroids in the field population of American bollworm, *Helicoverpa armigera* (Hubner) from Coimbatore, Tamil Nadu, South India during 2003-2004 cropping seasons. The extent of resistance in terms of percent survival was 88.1-96.4, 87.2-94.3, 87.0-94.0, 84.3-94.2 and 80.0-91.8% for cypermethrin, fenvalerate, deltamethrin, lambda-cyhalothrin and beta-cyfluthrin, respectively.

2.2.3.6. INTEGRATED PEST MMANAGEMENT (IPM)

Chavan *et al.* (2012) conducted a field experiment to evaluate the efficacy of various pest management module against tomato fruit borer, *Helicoverpa armigera* (Hubner). The results revealed that IPM module was found most promising in reducing larval population (1.04/plant), fruit infestation (15.35%) and increasing yield (36445 kg/ha). The insecticidal module was equally effective in reducing larval population (1.09/plant), fruit infestation (16.33%) and increasing yield (34684 kg/ha) as compared to IPM module. The biological module (1.13 larvae/plant, 20.19% infested fruit, 30813 kg/ha yield) was found next to insecticidal module, whereas botanical module (1.19 larvae/plant, 17.74% infested fruit, 30350 kg/ha yield) was next to biological module. The sole non-pesticidal module remained least effective. The net ICBR obtained in IPM module was 1:9.45 which was comparable with insecticidal module (1:15.92).

Sardana *et al.* (2013) carried out a three year trials in tomato (*Lycopersicon esculentum* L.) in Daluhera, Meerut, Uttar Pradesh during 2006–09 with a view to studying the economic viability of adaptable IPM technology in a farmers participatory approach. The IPM technology comprising of raising healthy nursery using *Trichoderma harzianum* (c.f.v. 2×109) enriched FYM (@10g/100g FYM/m^2); covering nursery bed with nylon net for preventing whitefly and sowing of leaf curl resistant hybrids; adopting wider spacing of 90×60 cm, transplanting 1 marigold row/14rows of tomato as trap crop; erection of pheromone traps @ 5/ha for monitoring fruit borer adult moths; releasing *Trichogramma chilonis* @ 1.0 lakh/ha 4–5 times; spraying of HaNPV(a) 250 LE/ha 2–3 times in the evening with 2% jaggery against young larvae, collection and destruction of damaged fruits and leaf curl affected plants; and need based application of emamectin benzoate 5 WDG @ 0.25g/litre of water for borer was very effective in reducing the incidence of pest and minimizing the yield losses. The adoption of IPM technology resulted in reducing the number of chemical sprays to 6.6 from 12.1 in non-IPM fields with higher fruit yields of 17.44, 19.0 and 45.1 tonnes/ha in IPM and 14.56, 17.1 and 42.0 tonnes/ha in FP fields and with higher CBR of 1:1.98, 1:1.92 and 1:3.85 in IPM and 1:1.58, 1:1.65 and 1:3.47 in non-IPM fields.

Karabhantanal and Awaknavar (2012) conducted a field investigation to know the effecacy of integration of bioagents and Neem Seed Kernel Extract (NSKE) in the management of tomato fruit borer, *Helicoverpa armigera*. Spraying of *Nomurea rileyi* (49.79 % decrease over control) and HaNPV (73.08 % decrease over control) combined with NSKE were found significantly superior to all treatments either alone or combined with NSKE except endosulfan (80% decrease over control) in reducing the fruit damage. Further the highest yield and net profit was recorded with *N. rileyi* + NSKE and HaNPV + NSKE treatments.

Patange and Dange (2016) reported that the picking of larvae + profenophos 50 EC @ 0.5% >HaNPV @ 250 LE/ha (0.13, 0.13 and 0.07 larvae / plant at one, three and seven days after spray, respectively was found to be most effective treatment for reducing larval population of *Helicoverpa armigera* and for reducing % pod damage (20.1%) and grain damage (7.1%) caused by *Helicoverpa armigera*. Significantly maximum grain yield (1327.33 kg/ha) was recorded over control (889 kg/ha) and highest incremental cost benefit ratio (1: 5.13) was attained by profenophos 50 EC @ 0.5% and dimethoate 30 EC @ 0.03% followed by picking of larvae + HaNPV 250 LE (1: 4.84), respectively.

Brar *et al.* (2003) carried out a study to determine the efficacy of *Trichogramma pretiosum* (5 releases weekly at 50000 per ha), *Helicoverpa armigera* nuclear polyhedrosis virus (Ha NPV; 2, 3 or 5 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 (*Helicoverpa armigera*). Among all treatments, *T. pretiosum* + HaNPV + endosulfan resulted in the 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 *Helicoverpa armigera* control.

Ali *et al.* (2011) conducted a field trial at three farmer's fields to study the role of bio-agents in management of tomato fruit borer. NPV with chick pea flour 1% + Jaggery 0.5% significantly reduced the larval population of *Helicoverpa* (93.1%), the lowest fruit damage (6.9%) and higher yield (112.02 q/ha) was obtained over the control. In the treatment of NPV mixed with sandovit 0.2%, the population reduction (63.8%), the lowest fruit damage (12.6%) and maximum fruit yield (118.21 q/ha) was obtained. Endosulfan 35 EC @ 0.07 was most effective for the reduction of population (79.6%), minimum fruit damage (12.4%) and maximum fruit yield (176.4 q/ha) followed by haNPV @ 250 LE + 0.035% endosulfan 35 EC.

Mehta *et al.* (2000) carried out an experiment on the management of tomato fruit borer, *Heliocoverpa armigera* (Hubner) with nine insecticidal treatments for 3 seasons during 1995-1997 at Palampur (Himachal Pradesh, India). Application of deltamethrin resulted in lowest fruit damage (4.27%) followed by cypermethrin (8.98) and acephate (9.16%). A mixture of deltamethrin + Bt 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 + Bt treated plots followed by deltamethrin, acephate and cypermethrin.

Chavan *et al.* (2015) reported that spraying of *Bacillus thuringiensis* @ 1 kg/ha and azadirachtin 3000 ppm @ 2.5 lit/ha at 45 and 65 days after transplanting showed maximum efficacy against *Helicoverpa armigera*. Chloropyrifos 20 EC @ 1 lit/ha was most effective against fruit borer.

CHAPTER III

MATERIALS AND METHODS

The present study regarding ecofriendly management of two major insect pests of tomato whitefly (*Bemisia tabaci*) and tomato fruit borer (*Helicoverpa armigera*) has been conducted during October 2014 to March 2015 at the experimental fields of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. Laboratory studies were done in the laboratory of entomology department, Sher-e-Bangla Agricultural University. Required materials and methodology are described below under the following heading.

3.1. 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 heading.

3.2. 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.

3.3. SOIL OF THE EXPERIMENTAL FIELD

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

3.4. LAND PREPARATION

The soil was well prepared and good tilth ensured for commercial crop production. The target land was divided into 27 equal plots (2.5m×1.5m) with plot to plot distance of 0.50 m and block to block distance was 0.75 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 was followed immediately after land preparation.

3.5. MANURE AND FERTILIZER

Recommended fertilizers were applied at the rate of 500 kg urea, 400 kg triple super phosphate (TSP) and 20 kg muriate of potash (MP) per hectare 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.

3.6. 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 2.5 m×1.5 m. The block to block and plot-to-plot distance was 0.75m and 0.5m, respectively.

3.7. COLLECTION OF SEED AND RAISING SEEDLING

The seeds of selected tomato variety BARI-2 (Ratan) were collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. Before sowing seeds, the germination test was done and found 90% germination for all varieties. Seeds were then directly sown in the 28th October, 2014 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 sprayed with water by a hand sprayer. Soil was spaded 3 or 4 days for a week.

3.8. SEEDLING TRANSPLANTING

The 30 days old healthy seedlings of tomato variety (BARI Tomato-2) was transplanted on November 28th, 2014 in the main field from the seed bed. Other intercultural operations were done as when necessary.

3.9. CULTURAL PRACTICES

After transplanting, a light irrigation was given. Subsequent irrigation was applied in all the plots as and when needed. Each plant was provided by bamboo stick 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.

3.10. TREATMENTS

Comparative effectiveness of the following eight treatments in reducing the tomato whitefly infestation on tomato (BARI tomato-2 variety) were evaluated:

T_1= Spraying of neem leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick

T_2= Spraying of neem oil @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick

T_3= Spraying of neem seed kernel extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick

T_4= Spraying of garlic extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick

T_5= Spraying of thuza leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick

T_6= Spraying of sweet apple leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick

T_7= Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick.

T_8= Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval + supporting the tomato plants with bamboo stick.

T_9= Untreated control without any support of the tomato plants.

3.11. TREATMENTs APPLICATION

T_1: Neem leaf extract @ 3.0 ml/L of water was applied 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 leaf extract was applied @ 15 ml /5L of 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_2: Neem oil @ 3.0 ml/L of water was applied 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 was 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_3: Neem seed kernel extract @ 3.0 ml/L of water was applied 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 seed kernel extract was applied @ 15 ml /5L of 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_4: Garlic extract @ 3.0 ml/L of water was applied 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, garlic extract was applied @ 15 ml /5L of 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_5: Thuza leaf extract @ 3.0 ml/L of water was applied 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, thuza leaf extract was applied @ 15 ml /5L of 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_6: Sweet apple leaf extract @ 3.0 ml/L of water was applied 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, sweet apple leaf extract was applied @ 15 ml /5L of 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: Admire 200 SL @ 1.0 ml/L of water was applied 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_8: Sevin 85WP @ 2.00 gm/L of water was applied 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 10.0 gm of insecticides per 5 liter of water was mixed and sprayed at 7 days intervals.

T_9: Untreated control treatment. No control measure was applied in tomato plants.

3.12. COLLECTION AND PREPARATION OF NEEM OIL, TRIX DETERGENT 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.

3.13. DATA COLLECTION

For data collection five plants per plot were randomly selected and tagged. Data collection was started at vegetative stage to final fruit harvest. The data were recorded on number of whitefly, TYLCV infected plant, flower and fruit (number and weight) infestation by tomato whitefly larvae. The following parameters were considered during data collection.

3.13.1. Number of whitefly and number of TYLCV infected plant

Data were collected on the number of number of whitefly and number of TYLCV infected plant randomly selected 5 tagged plants per plot harvested at 15 days interval and counted separately for each treatment of each plot.

3.13.2. Determination of the healthy and infested fruits

The number of healthy and infested fruits per randomly selected 5 tagged plants and plot harvested at early fruiting (upto 10th February), mid fruiting (11th February, 2015 to 25th February, 2015) and late fruiting (26th February to final harvest) stages of the crop and weighted separately for each treatment of each plot. Marketable fruits were harvested usually at twice a week.

3.14. CALCULATION

3.14.1. Percent TYLCV infected plant

Number of infected plant was counted from total plants per plot and percent plant infection by TYLCV was calculated as follows:

$$\text{TYLCV infected plant (\%)} = \frac{\text{Number of TYLCV infected plant}}{\text{Total number of plants per plot}} \times 100$$

3.14.2. Fruit infestation by number

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

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

3.14.3. Fruit infestation by weight

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

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

3.14.4. Reduction of fruit infestation over control

The number and weight of borer 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

3.14.5. 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 by using the following formula:

$$\text{Yield loss (\%)} = \frac{\text{Avg. wt. of healthy fruit} - \text{Avg. fruit wt. of whole plot}}{\text{Average weight of healthy fruit per plot}} \times 100$$

3.14.6. STATISTICAL ANALYSIS

Data statistically analyzed by randomized complete block design through MSTAT-C software and Duncan’s multiple range test was used to determine the levels of significant differences among different management practices with regards to study tomato whitefly and tomato fruit borer infestation.

CHAPTER IV
RESULTS AND DISCUSSION

The present experiment was conducted to evaluate some management practices applied against two major insect pests of tomato, whitefly, *Bemisia tabaci* and tomato fruit borer**,** *Helicoverpa armigera* (Hubner) on winter tomato (BARI-2/Ratan). The analysis of variance (ANOVA) of the data on fruit infestation and different yield contributing characters of different tomato varieties are given in Appendix III-VII. The results have been presented, discussed and possible interpretations have been given under the following sub-headings:

4.1. Effect of control measures in controlling whitefly

Statistically no significant variation was found in number of whitefly at 15 days after transplanting (DAT) of tomato plant in different management practices. But there was significant variation in number of whitefly at 30 DAT in different management practices. Highest number of whitefly per plant was found in T_9 (23.67) which was significantly different from all other treatments and followed by T_6 (18.67). On the other hand, the lowest number of whitefly per plant was found in T_7 (12.00) followed by T_8 (13.00), T_2 (13.33), T_3 (13.33) and T_1 (14.00) (table 1). From these results it is revealed that the trend of the number of whitefly per plant was observed due to application of the different management practices against tomato whitefly as $T_9 > T_6 > T_4 > T_5 > T_1 > T_2 > T_3 > T_8 > T_7$.

Statistically significant variation was found in number of whitefly per plant at 45 DAS in different management practices under present trial (table 1). The highest number of whitefly per plant (39.00) was found in T_9 followed by T_5 (32.33), T_4 (31.33) and T_6 (29.00). On the other hand, the lowest no of whitefly per plant was found in T_7 (20.33) followed by T_8 (20.67), T_3 (22.67), T_2 (23.00) and T_1 (24.67) (table 1). From these results it is revealed that the trend of the number of whitefly per plant at 45 DAT was observed due to application of the different management practices against tomato whitefly as $T_9 > T_5 > T_4 > T_6 > T_1 > T_2 > T_3 > T_8 > T_7$.

Statistically significant variation was found in number of whitefly per plant at 60 DAT in different management practices. Among the treatment, the highest number of whitefly per plant (34.00) was recorded in T_9 which was significantly different from all other treatments and followed by T_6 (21.33), T_5 (20.67) and T_4 (20.33). On the other hand, the lowest number of whitefly per plant was found in T_7 (11.33) followed by T_8 (12.33), T_2 (13.67), T_3 (14.33) (table 1). From these results it is revealed that the trend of the number of whitefly per plant at 60 DAT was observed due to application of the different management practices against tomato whitefly as $T_9 > T_6 > T_5 > T_4 > T_1 > T_3 > T_2 > T_8 > T_7$.

Table 1. Number of whitefly due to application of control measures on tomato

Treatments	Number of whitefly per plant					
	15 DAT	**30 DAT**	**45 DAT**	**60 DAT**	**Mean value**	**Reduction over control (%)**
T_1	7.67 a	14.00 cd	24.67 cd	16.00 c	15.58 c	40.47
T_2	7.33 a	13.33 cd	23.00 d	13.67 d	14.33 cd	45.24
T_3	7.00 a	13.33 cd	22.67 d	14.33 cd	14.33 cd	45.24
T_4	7.33 a	17.00 b	31.33 b	20.33 b	19.00 b	27.40
T_5	6.67 a	15.00 c	32.33 b	20.67 b	18.67 b	28.66
T_6	5.67 a	18.67 b	29.00 bc	21.33 b	18.67 b	28.66
T_7	7.67 a	12.00 d	20.33 d	11.33 e	12.83 d	50.97
T_8	7.33 a	13.00 cd	20.67 d	12.33 de	13.33 d	49.06
T_9	8.00 a	23.67 a	39.00 a	34.00 a	26.17 a	-
LSD value	3.555	1.935	4.548	2.151	1.742	-
CV (%)	28.58	7.19	9.73	6.81	5.92	-

[DAT = Day After Transplanting

In a column, numeric data represents the mean values of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick (STPBS); T_2 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval + STPBS; T_3 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_6 : Spraying of Sweet apple leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + STPBS; T_8 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval + STPBS; T_9 : Untreated control without any support of the tomato plants.]

Statistically significant variation was found in mean number of whitefly per plant during total cropping season in different management practices. Highest no of whitefly per plant (34.00) was found in T_9 which was significantly different from all other treatments. This was followed by T_6 (21.33), T_5 (20.67) and T_4 (20.33). On the contrary, the lowest number of whitefly per plant was found in T_7 (11.33) followed by T_8 (12.33), T_2 (13.67), T_3 (14.33) (table 1). From these results it is revealed that the trend of the number of whitefly per plant at 60 DAT was observed due to application of the different management practices against tomato whitefly as $T_9 > T_6 > T_5 > T_4 > T_1 > T_3 > T_2 > T_8 > T_7$.

4.2. Effect of control measures in controlling TYLCV infection

Statistically no significant variation was found in percentage of TYLCV infected tomato plant at vegetative stage for different control measures (Table 2). But in flowering stage significant variation was observed in percentage of TYLCV infected tomato plant for different control measures. Among the treatments, the highest percentage of TYLCV infected tomato plant (33.33) was found in $T_{9.}$ On the other hand, the lowest percentage of TYLCV infected plant (14.29) was recorded in T_7 which was statistically similar with T_8 (16.67) (Table 2). The trend of the percentage of TYLCV infected tomato plant for different control measures at flowering stage was $T_9 > T_6 > T_5 > T_1 = T_3 = T_4 > T_2 > T_8 > T_7$.

Significant variation in percentage of TYLCV infected tomato plant for different control measures were found at harvesting stage (table 2). Among the treatments, the highest percentage of TYLCV (50.00) was found in T_9 which was statistically different from all other treatments. On the other hand, the lowest percentage of TYLCV infected plant (19.05) was found in T_7 followed by T_8 (23.81), T_1 (26.19), T_2 (26.19) and T_3 (26.19). The trend of percentage of TYLCV infected tomato plant for different control measures at flowering stage was $T_9 > T_6 > T_4 > T_5 > T_1 = T_2 = T_3 > T_8 > T_7$.

Table 2. Effect of control measures in controlling TYLCV infection in tomato on BARI- 2 (Ratan) variety

Treatments	Percentage of TYLCV infected tomato plant at different stages		
	Vegetative stage	Flowering stage	Harvesting stage
T_1	11.91 a	21.43 cd	26.19 d
T_2	11.91 a	19.05 cd	26.19 d
T_3	9.523 a	21.43 cd	26.19 d
T_4	9.523 a	21.43 cd	35.71 bc
T_5	9.527 a	26.19 bc	33.33 c
T_6	14.29 a	30.95 ab	38.09 b
T_7	9.523 a	14.29 d	19.05 e
T_8	7.143 a	16.67 d	23.81 d
T_9	11.91 a	33.33 a	50.00 a
LSD value (0.05)	10.07	6.623	4.37
CV (%)	54.95	16.82	8.16

[In a column, numeric data represents the mean values of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick (STPBS); T_2 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval + STPBS; T_3 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_6 : Spraying of Sweet apple leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + STPBS; T_8 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval + STPBS; T_9 : Untreated control without any support of the tomato plants.]

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

4.3.1.1. Number of tomato fruit

Statistically significant variation was recorded in number of fruits per five plant, number of infested fruits per five plant and percent fruit infestation in number at early fruiting stage in controlling tomato fruit borer for different control measures (Table 3). The highest number of fruits per five plant (44.88) was recorded in T_7 treatment which was statistically similar with T_8 treatment (44.71) and T_3 treatment (43.33). On the other hand, the lowest number (35.5) of total fruits per five plant was recorded in T_9 treatment followed by treatment T_4 (38.85), T_5 (39.64) and T_6 (40.06). From these results it is revealed that the trend of the number of fruits per five plants was observed due to application of the different management practices against tomato fruit borer as $T_7 > T_8 > T_3 > T_1 > T_2 > T_6 > T_5 > T_4 > T_9$.

Table 3. Number of fruit infestation by tomato fruit borer due to application of treatments at early fruiting stage

Treatment	Number of fruits per 5 plants at early fruiting stage		
	Total fruits	Infested fruits	Infestation (%)
T_1	42.35 b	2.65 cd	6.25 cd
T_2	42.05 bc	2.19 d	5.21 d
T_3	43.33 ab	1.38 e	3.19 e
T_4	38.85 d	3.57 b	9.22 b
T_5	39.64 d	3.03 bc	7.64 bc
T_6	40.06 cd	3.35 bc	8.37 b
T_7	44.88 a	1.01 e	2.27 e
T_8	44.71 a	1.05 e	2.34 e
T_9	35.50 e	5.95 a	16.74 a
LSD value (0.05)	2.0	0.77	1.79
CV (%)	2.81	16.44	15.16

[In a column, numeric data represents the mean values of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick (STPBS); T_2 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval + STPBS; T_3 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_6 : Spraying of Sweet apple leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + STPBS; T_8 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval + STPBS; T_9 : Untreated control without any support of the tomato plants.]

The highest number of infested fruits per five plants (5.95) was recorded in T_9 treatment which was statistically different from all other treatments and was followed by T_4 (3.57). On the other hand, the lowest number of infested fruits per five plants (1.01) was recorded in T_7 treatment which was statistically similar with T_8 (1.05) (Table 3). In this case, more or less similar but inverse trend of the results found in number of infested fruits per 5 plants at early fruiting stage was observed and the trend is $T_9 > T_4 > T_6 > T_5 > T_1 > T_2 > T_8 > T_7$.

The highest (16.74) percent fruit infestation was recorded in T_9 treatment which was statistically different from all other treatments and followed by T_4 (9.22), T_6 (8.37) and T_5 (7.64). On the other hand, the lowest (2.27) percent fruit infestation was recorded in T_7 treatment which was statistically similar with T_8 (2.34) and T_3 (3.19) (Table 3). In this case, more or less similar trend of the results in percent fruit infestation in number at early harvesting stage was observed and the trend is $T_9 > T_4 > T_6 > T_5 > T_1 > T_2 > T_3 > T_8 > T_7$.

4.3.1.2. Weight of tomato fruit

Statistically significant variation was recorded in weight of total tomato fruits per five plant, weight of infested fruits per five plant and percent fruit infestation in weight at early fruiting stage in controlling tomato fruit borer for different control measures (table 4). The highest weight of fruits per five plants (3.50) was recorded in T_7 treatment which was statistically similar with T_8 treatment (3.48) and T_3 treatment (3.38). While, the lowest weight of fruit per five plants (2.77) was recorded in T_9 treatment followed by treatment T_4 (3.03), T_5 (3.09) and T_6 (3.12). From these results it is revealed that the trend of the weight of fruits per five plant was observed due to application of the different management practices against tomato fruit borer as $T_7 > T_8 > T_3 > T_1 > T_2 > T_6 > T_5 > T_4 > T_9$.

The highest weight of infested fruits per five plants (0.40 kg) was recorded in T_9 treatment (Untreated control) followed by T_4 (0.24 kg). But, the lowest weight of infested fruit per five plants (0.07 kg) was recorded in both T_7 and T_8 treatments which is statistically similar (Table 4). In this case, more or less similar but inverse trend of the results found in weight of infested fruit per five plants at early fruiting stage was observed and the trend is $T_9 > T_4 > T_6 > T_5 > T_1 > T_2 > T_3 > T_8 = T_7$.

Table 4. Weight of fruit infested by tomato fruit borer due to application of treatments at early fruiting stage

Treatments	Weight of tomato fruits per 5 plants			
	Total Fruits (kg)	Infested fruits (kg)	Infestation (%)	Reduction over control (%)
T_1	3.30 b	0.18 cd	5.45 cd	62.65
T_2	3.27 bc	0.15 de	4.55 d	68.81
T_3	3.38 ab	0.10 bc	2.78 e	80.95
T_4	3.03 d	0.24 b	8.04 b	44.89
T_5	3.09 d	0.21 bcd	6.67 bc	54.28
T_6	3.12 cd	0.23 bc	7.29 b	50.03
T_7	3.50 a	0.07 f	1.97 e	86.50
T_8	3.48 a	0.07 f	2.04 e	86.02
T_9	2.77 e	0.40 a	14.59 a	-
LSD value	.155	0.05	1.56	-
CV (%)	2.81	16.2	15.16	-

[In a column, numeric data represents the mean values of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick (STPBS); T_2 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval + STPBS; T_3 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_6 : Spraying of Sweet apple leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + STPBS; T_8 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval + STPBS; T_9 : Untreated control without any support of the tomato plants.]

The highest (14.59) percent fruit infestation in weight was recorded in T_9 treatment (Untreated control) followed by T_4 (8.04), T_6 (7.29) and T_5 (6.67). On the other hand, the lowest percent fruit infestation in weight (1.97) was recorded in T_7 treatment which was statistically similar with T_8 (2.04), T_3 (2.78) T_3 treatment was followed by T_2 (4.55) and T_1 (5.45) treatments (Table 4). In this case, more or less similar trend of the results in percent of fruit infestation in weight at early fruiting stage was observed and the trend is $T_9 > T_4 > T_6 > T_5 > T_1 > T_2 > T_3 > T_8 > T_7$.

In this case, percent reduction over untreated control was also estimated. The highest (86.50) percentage reduction over untreated control was found in T_7 treatment and the lowest (44.89) percentage reduction over untreated control was found in T_4 treatment (table 4).

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

4.3.2.1 Number of tomato fruit

Statistically significant variation was recorded in number of total fruits per five plants, number of infested fruits per five plants and percent fruit infestation in number at mid fruiting stage in controlling tomato fruit borer for different control measures (Table 5). The highest (55.95) number of fruits per five plants was recorded in T_7 treatment followed by T_8 treatment (44.71). On the other hand, the lowest number (46.06) of total fruits per five plants was recorded in T_9 treatment (Untreated control without support) followed by treatment T_5 (48.57) and T_6 (48.86). From these results it is revealed that the trend of the number of fruits per five plants at mid fruiting stage was observed due to application of the different management practices against tomato fruit borer as $T_7 > T_8 > T_3 > T_1 > T_2 > T_4 > T_6 > T_5 > T_9$.

Table 5. Number of fruits infested by tomato fruit borer due to application of treatments at mid fruiting stage

Treatments	Number of tomato fruits per 5 plants		
	Total Fruits	Infested Fruits	% Infestation
T_1	52.47 c	3.25 cd	6.20 cd
T_2	51.57 cd	2.79 d	5.42 d
T_3	52.86 bc	1.99 e	3.78 e
T_4	49.68 de	4.17 b	8.42 b
T_5	48.57 e	3.63 bc	7.50 bc
T_6	48.86 e	3.95 bc	8.07 b
T_7	55.95 a	1.62 e	2.89 e
T_8	54.95 ab	1.65 e	3.01 e
T_9	46.06 f	6.56 a	14.28 a
LSD value	2.12	.77	1.60
CV (%)	2.39	13.44	13.93

[In a column, numeric data represents the mean values of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick (STPBS); T_2 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval + STPBS; T_3 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_6 : Spraying of Sweet apple leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + STPBS; T_8 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval + STPBS; T_9 : Untreated control without any support of the tomato plants.]

The highest (6.56) number of infested fruits per five plants was recorded in T_9 treatment (Untreated control) which was statistically different from all other treatments. On the other hand, the lowest (1.62) number of infested fruit per five plants was recorded in T_7 treatment which was statistically similar with T_8 (1.65) and T_3 (1.99) treatments (Table 5).

The highest (14.28) percent fruit infestation was recorded in T_9 treatment (Untreated control) which was statistically different from all other treatments and was followed by T_4 (8.42), T_6 (8.07) and T_5 (7.50). On the other hand, the lowest (2.89) percent fruit infestation was recorded in T_7 treatment which was statistically similar with T_8 (3.01) and T_3 (3.78) treatments (Table 5). In this case, more or less similar trend of the results in percent fruit infestation in number at early fruiting stage was observed and the trend is $T_9 > T_4 > T_6 > T_5 > T_1 > T_2 > T_3 > T_8 > T_7$.

4.3.2.2. Weight of tomato fruit

Statistically significant variation was recorded in weight of fruits per five plants, weight of infested fruits per five plants and percent fruit infestation in weight at mid fruiting stage in controlling tomato fruit borer for different control measures (Table 6). The highest weight of fruits per five plants (4.36 kg) was recorded in T_7 treatment followed by T_8 treatment (4.28 kg). On the other hand, the lowest weight of fruit per five plants (3.60 kg) was recorded in T_9 treatment followed by treatment T_5 (3.79 kg), T_6 (3.81 kg) and T_4 (3.88 kg). From these results it is revealed that the trend of the weight of fruits per five plants was observed due to application of the different management practices against tomato fruit borer as $T_7 > T_8 > T_3 > T_1 > T_2 > T_4 > T_6 > T_5 > T_9$.

Table 6. Weight of fruit infested by tomato fruit borer due to application of treatments at mid fruiting stage

Treatments	Weight of tomato fruit per 5 plants			
	Total fruits (kg)	Infested fruits (kg)	Infestation (%)	Reduction over control (%)
T_1	4.09 c	0.22 cd	5.48 cd	51.11
T_2	4.02 cd	0.19 d	4.79 d	57.78
T_3	4.13 bc	0.14 e	3.34 e	68.89
T_4	3.88 de	0.29 b	7.45 b	35.56
T_5	3.79 e	0.25 bcd	6.63 bc	44.44
T_6	3.81 e	0.27 bc	7.14 b	40.00
T_7	4.36 a	0.11 e	2.56 e	75.56
T_8	4.28 ab	0.11 e	2.67 e	75.56
T_9	3.60 f	0.45 a	12.63 a	-
LSD value (0.05)	0.16	0.06	1.41	-
CV (%)	2.41	13.56	13.94	-

[In a column, numeric data represents the mean values of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick (STPBS); T_2 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval + STPBS; T_3 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_6 : Spraying of Sweet apple leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + STPBS; T_8 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval + STPBS; T_9 : Untreated control without any support of the tomato plants.]

The highest (12.63) percent fruit infestation in weight was recorded in T_9 treatment followed by T_4 (7.45), T_6 (7.14) and T_5 (6.63). On the other hand, the lowest percent fruit infestation in weight (2.56) was recorded in T_7 treatment which was statistically similar with T_8 (2.67) and T_3 (3.34) treatments (Table 6). In this case, more or less similar trend of the results in percent fruit infestation in weight at mid fruiting stage was observed and the trend is $T_9 > T_4 > T_6 > T_5 > T_1 > T_2 > T_3 > T_8 > T_7$.

The highest (75.56) percentage of reduction over untreated control was recorded in both T_7 and T_7 treatment and the lowest (40.00) percentage reduction over untreated control was recorded in T_4 treatment (table 6).

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

4.3.3.1 Number of tomato fruit

Statistically significant variation was recorded in number of fruits per five plants, number of infested fruits per five plants and percent fruit infestation 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 fruits per five plants (61.31) was recorded in T_7 treatment followed by T_8 (58.99), T_3 (58.81), T_2 (57.41) and T_1 (57.00). Nevertheless, the lowest number (50.34) of fruits per five plants was recorded in T_9 treatment followed by treatment T_6 (55.29), T_5 (55.36) and T_4 (55.52).

Table 7. Number of fruit infestation by tomato fruit borer due to application of treatments at late fruiting stage

Treatments	Number of tomato fruits per 5 plants		
	Total Fruits	Infested fruits	Infestation (%)
T_1	57.00 bc	3.64 cd	6.37 cd
T_2	57.41 bc	3.18 d	5.54 d
T_3	58.81 b	2.19 e	3.72 e
T_4	55.52 c	4.38 b	7.89 b
T_5	55.36 c	3.83 bcd	6.93 bc
T_6	55.29 c	4.15 bc	7.48 bc
T_7	61.31 a	1.82e	2.96 e
T_8	58.99 b	1.85 e	3.14 e
T_9	50.34 d	6.76 a	13.42 a
LSD value	2.056	.677	1.164
CV (%)	2.10	11.06	10.53

[In a column, numeric data represents the mean values of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick (STPBS); T_2 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval + STPBS; T_3 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_6 : Spraying of Sweet apple leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + STPBS; T_8 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval + STPBS; T_9 : Untreated control without any support of the tomato plants.]

From these results it is revealed that the trend of the number of fruits per five plants at late fruiting stage was observed due to application of the different management practices against tomato fruit borer as $T_7 > T_8 > T_3 > T_2 > T_1 > T_4 > T_5 > T_6 > T_9$.

The highest number of infested fruits per five plants (6.76) was recorded in T_9 treatment which was statistically different from all other treatments and was followed by T_4 (4.38), T_6 (4.15) and T_5 (3.83). On the other hand, the lowest number of infested fruits per five plants (1.82) was recorded in T_7 treatment which was statistically similar with T_8 (1.85) and T_3 (2.19) treatments (Table 7). In this case, more or less similar but inverse trend of the results found in number of infested fruits per five plants at late fruiting stage was observed and the trend is $T_9 > T_4 > T_6 > T_5 > T_1 > T_2 > T_3 > T_8 > T_7$.

The highest percent fruit infestation in number (13.42) was recorded in T_9 treatment which was statistically different from all other treatments and was followed by T_4 (7.89), T_6 (7.48) and T_5 (6.93). On the other hand, the lowest percent fruit infestation in number (2.96) was recorded in T_7 treatment followed by T_8 (3.14) and T_3 (3.72) treatments (Table 7). In this case, more or less similar trend of the results in percent fruit infestation in number at late harvesting stage was observed and the trend is $T_9 > T_4 > T_6 > T_5 > T_1 > T_2 > T_3 > T_8 > T_7$.

4.3.3.2 Weight of tomato fruit

Statistically significant variation was recorded in weight of fruits per five plants, weight of infested fruits per five plants and percent fruit infestation in weight at late fruiting stage in controlling tomato fruit borer for different control measures (Table 8). The highest total weight of fruit per five plant (4.78 kg) was recorded in T_7 treatment followed by T_8 (4.60 kg), T_3 (4.59 kg), T_2 (4.48 kg) and T_1 (4.45 kg) treatments. On the other hand, the lowest weight of total fruit per five plants (3.93 kg) was recorded in T_9 treatment followed by treatment T_6 (4.31 kg), T_5 (3.32 kg) and T_4 (3.33 kg). From these results it is revealed that the trend of the weight of fruits per five plants at late fruiting stage was observed due to application of the different management practices against tomato fruit borer as $T_7 > T_8 > T_3 > T_2 > T_1 > T_6 > T_5 > T_4 > T_9$.

The highest weight of infested fruits per five plant (0.47 kg) was recorded in T_9 treatment which was statistically different from all other treatments and was followed by T_4 (0.31 kg), T_6 (0.29 kg), T_5 (0.27 kg) and T_1 (0.25 kg). On the other hand, the lowest weight of infested fruits per five plants (0.12 kg) was recorded in T_7 treatment which was statistically similar with T_8 (0.13 kg), T_3 (0.15 kg) treatments (Table 8). In this case, more or less similar but inverse trend of the results found in weight of infested fruits per five plants at late fruiting stage was observed and the trend is T_9 > T_4> T_6> T_5> T_1 > T_2>T_3> T_8 >T_7.

Table 8. Weight of fruit infested by tomato fruit borer due to application of treatments at late fruiting stage

Treatments	Weight of tomato fruits per 5 plants(kg)			
	Total fruits	Infested fruits	Infestation (%)	Reduction over untreated control (%)
T_1	4.45 bc	0.25 bc	5.73 cd	52.41
T_2	4.48 bc	0.22 c	4.97 d	58.72
T_3	4.59 b	0.15 d	3.34 e	72.26
T_4	4.33 c	0.31 b	7.09 b	41.11
T_5	4.32 c	0.27 bc	6.22 bc	48.34
T_6	4.31 c	0.29 b	6.72 bc	44.19
T_7	4.78 a	0.12 d	2.66 e	77.91
T_8	4.60 b	0.13 d	2.82 e	76.58
T_9	3.93 d	0.47 a	12.04 a	
LSD value (0.05)	0.16	0.06	1.04	
CV (%)	2.07	10.57	10.52	

[In a column, numeric data represents the mean values of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick (STPBS); T_2 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval + STPBS; T_3 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_6 : Spraying of Sweet apple leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + STPBS; T_8 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval + STPBS; T_9 : Untreated control without any support of the tomato plants.]

The highest percent fruit infestation in weight (12.04) was recorded in T_9 treatment followed by T_4 (7.09), T_6 (6.72) and T_5 (6.22). On the other hand, the lowest percent fruit infestation in weight (2.66) was recorded in T_7 treatment which was statistically similar with T_8 (2.82) and T_3 (3.34) treatments (Table 8). In this case, more or less similar trend of the results in percent fruit infestation in weight at late fruiting stage was observed and the trend is T_9 > T_4> T_6> T_5> T_1 > T_2> T_3>T_8 >T_7.

The highest (77.91) percentage of reduction over untreated control was recorded in T_7 treatment and the lowest percentage (41.11) reduction over untreated control was recorded in T_4 treatment (table 8).

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

4.4.1. Number of tomato fruit

Statistically significant variation was observed among different management practices in number of fruits per five plants during total cropping season (table 9). In case of T_7 (162.1), the highest number of fruit per five plants was recorded followed by T_8 (132.0). On the other hand, the lowest no of fruit per five plant was recorded in T_9 (132.0). In this case, more or less similar trend of the results found in number of infested fruits per plant during whole season was observed and the trend is $T_7 > T_8 > T_3 > T_2 > T_1 > T_6 > T_4 > T_5 > T_9$

The highest (19.27) number of infested fruits per five plant was recorded in T_9 treatment which was statistically different from all other treatments. On the other hand, the lowest (4.45) number of infested fruits per five plants was recorded in T_7 treatment which was statistically similar with T_8 (4.55) and T_3 (5.56) treatments (Table 9). In this case, more or less similar but inverse trend of the results found in number of infested fruits per plant during whole season was observed and the trend is $T_9 > T_4 > T_6 > T_5 > T_1 > T_2 > T_3 > T_8 > T_7$.

Table 9. Number of fruits infested by tomato fruit borer due to application of treatments during cropping season

Treatments	Number of tomato fruits per 5 plants		
	Total fruits	Infested fruits	Infestation (%)
T_1	151.8 cd	9.55 cd	6.28 cd
T_2	151.0 d	8.16 d	5.41 d
T_3	155.0 c	5.56 e	3.59 e
T_4	144.0 e	12.13 b	8.43 b
T_5	143.6 e	10.50 bc	7.31 bc
T_6	144.2 e	11.45 bc	7.92 b
T_7	162.1 a	4.45 e	2.74 e
T_8	158.7 b	4.55 e	2.87 e
T_9	132.0 f	19.27 a	14.61 a
LSD value	3.35	2.18	1.46
CV (%)	1.3	13.24	12.79

[In a column, numeric data represents the mean values of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick (STPBS); T_2 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval + STPBS; T_3 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_6 : Spraying of Sweet apple leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + STPBS; T_8 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval + STPBS; T_9 : Untreated control without any support of the tomato plants.]

The highest (14.61) percent fruit infestation in number was recorded in T_9 treatment which was statistically different from all other treatments and was followed by T_4 (8.43), T_6 (7.92) and T_5 (7.31). On the other hand, the lowest percent fruit infestation in number (2.74) was recorded in T_7 treatment which was statistically similar with T_8 (2.87) and T_3 (3.59) treatments (Table 9). In this case, more or less similar trend of the results in percent fruit infestation in number during whole season was observed and the trend is $T_9 > T_4 > T_6 > T_5 > T_1 > T_2 > T_3 > T_8 > T_7$

4.4.2. Weight of tomato fruit

Statistically significant variation was recorded in weight of fruits per five plants, weight of infested fruits per five plants and percent fruit infestation during total cropping season in controlling tomato fruit borer for different control measures (table 10). The highest total weight of fruits per five plants (12.65 kg) was recorded in T_7 treatment followed by T_8 (12.37 kg), T_3 (12.09 kg), T_1 (11.84 kg) and T_2 (11.78 kg) treatments. On the other hand, the lowest weight of fruit per five plant (10.29 kg) was recorded in T_9 treatment. From these results it is revealed that the trend of the weight of fruits per five plant during total cropping season was observed due to application of the different management practices against tomato fruit borer as $T_7 > T_8 > T_3 > T_1 > T_2 > T_6 > T_4 > T_5 > T_9$.

The highest (1.33 kg) weight of infested fruits per five plant was recorded in T_9 treatment which was statistically different from all other treatments. On the other hand, the lowest weight of infested fruit per five plant (0.31 kg) was recorded in T_7 treatment which was statistically similar with T_8 (0.31 kg) and T_3 (0.39 kg) treatments (Table 10). In this case, more or less similar but inverse trend of the results found in weight of infested fruit per five plants during total cropping season was observed and the trend is $T_9 > T_4 > T_6 > T_5 > T_1 > T_2 > T_3 > T_8 > T_7$.

Table 10. Weight of fruit infested by tomato fruit borer due to application of treatments during cropping season

Treatments	Weight of tomato fruits per 5 plants in weight (kg)			
	Total fruits	Infested fruits	Infestation (%)	Reduction over untreated control (%)
T_1	11.84 cd	0.66 cd	5.57 cd	56.95
T_2	11.78 d	0.56 d	4.79 d	62.93
T_3	12.09 c	0.39 e	3.18 e	75.38
T_4	11.24 e	0.84 b	7.47 b	42.25
T_5	11.20 e	0.72 bcd	6.48 bc	49.88
T_6	11.25 e	0.79 bc	7.02 b	45.73
T_7	12.65 a	0.31 e	2.44 e	81.15
T_8	12.37 b	0.31 e	2.54 e	80.33
T_9	10.29 f	1.33 a	12.93 a	-
LSD value (0.05)	0.26	0.15	1.29	-
CV (%)	1.29	13.29	12.76	-

[In a column, numeric data represents the mean values of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick (STPBS); T_2 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval + STPBS; T_3 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_6 : Spraying of Sweet apple leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + STPBS; T_8 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval + STPBS; T_9 : Untreated control without any support of the tomato plants.]

The highest percent fruit infestation in weight (12.93) was recorded in T_9 treatment which was statistically different from all other treatments. On the other hand, the lowest percent fruit infestation in weight (2.44) was recorded in T_7 treatment which was statistically similar with T_8 (2.54) and T_3 (3.18) treatments (Table 10). In this case, more or less similar trend of the results in percent fruit infestation in weight during whole season was observed and the trend is $T_9 > T_4 > T_6 > T_5 > T_1 > T_2 > T_3 > T_8 > T_7$.

The highest (81.15) percentage of reduction over untreated control was recorded in T_7 treatment and the lowest (42.25) percentage reduction over untreated control was recorded in T_4 treatment (table 10).

4.5. Effect of management practices on yield and yield contributing characters of BARI Tomato-2 (Ratan) variety applied against tomato fruit borer

Maximum (82.65 cm) plant height was found in T_7 which followed by T_3 (81.07 cm). This was followed by T_8 (80.30 cm) and T_1 (79.88 cm). On the other hand, minimum (69.99 cm) plant height was found in T_9 followed by T_6 (74.05 cm), T_4 (74.95 cm) and T_5 (75.75 cm) (table 11). The trend was $T_7 > T_3 > T_8 > T_1 > T_2 > T_5 > T_4 > T_6 > T_9$.

The highest number of leaf per plant (79.67) was found in T_8 which was statistically similar with T_7 (79.33). On the other hand, the lowest (66.00) number of leaf per plant was found in T_9 (table 11). The trend was $T_8 > T_7 > T_3 > T_1 > T_2 > T_6 > T_5 > T_4 > T_9$.

Table 11. Effect of control measures on yield and yield contributing characters as controlling tomato fruit borer on BARI tomato-2 (Ratan) variety

Treatments	Plant height (cm)	Number of leaf /plant	Number of bunch of fruit /plant	Single fruit weight (gm)	Yield (ton/ha)
T_1	79.88 bc	72.00 bc	8.85 cd	0.08 ab	51.01 cd
T_2	78.30 c	71.67 bc	8.81 d	0.08 ab	50.75 d
T_3	81.07 ab	75.67 ab	9.04 c	0.08 a	52.08 c
T_4	74.95 d	69.33 cd	8.40 e	0.08 ab	48.40 e
T_5	75.75 d	69.67 cd	8.37 e	0.08 ab	48.24 e
T_6	74.05 d	70.33 c	8.41 e	0.08 ab	48.45 e
T_7	82.65 a	79.33 a	9.46 a	0.08 a	54.48 a
T_8	80.30 bc	79.67 a	9.25 b	0.08 ab	53.31 b
T_9	69.99 e	66.00 d	7.70 f	0.07 b	44.35 f
LSD value	1.948	3.847	.1974	.005	1.126
CV (%)	2.81	3.06	1.29	1.59	1.3

[In a column, numeric data represents the mean values of 3 replications; each replication is derived from 5 plants per treatment; in a column means having similar letter(s) are statistically identical and those having dissimilar letter(s) differ significantly as per 0.05 level of probability.

T_1 : Spraying of Neem leaf extract @ 3.0 ml/L of water at 7 days interval + supporting the tomato plants with bamboo stick (STPBS); T_2 : Spraying of Neem oil @ 3.0 ml/L of water at 7 days interval + STPBS; T_3 : Spraying of Neem seed kernel extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_4 : Spraying of Garlic extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_5 : Spraying of Thuza leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_6 : Spraying of Sweet apple leaf extract @ 3.0 ml/L of water at 7 days interval + STPBS; T_7 : Spraying of Admire 200 SL @ 1.0 ml/L of water at 7 days interval + STPBS; T_8 : Spraying of Sevin 85WP @ 2.00gm/L of water at 7 days interval + STPBS; T_9 : Untreated control without any support of the tomato plants.]

The highest number of cluster of fruit per plant (9.46) was found in T_7. This was followed by T_8 (9.25). On the other hand, the lowest number of bunch of fruit per plant (7.70) was found in T_9 followed by T_6 (8.41), T_4 (8.40) and T_5 (8.37) (table 11). The trend was $T_7 > T_8 > T_3 > T_1 > T_2 > T_6 > T_4 > T_5 > T_9$.

The highest average single fruit weight (0.081 gm) was observed in both T_3 and T_7 which were statistically similar with all other treatments except T_9 (0.074 gm) (table 11). The trend was $T_7 = T_3 > T_8 > T_2 > T_1 > T_4 > T_5 = T_6 > T_9$.

Statistically significant variation was recorded in yield (ton/ha) of tomato for different control measures (table 11). The highest yield (54.48 ton/ha) was recorded in T_7 followed by T_8 (53.31 ton/ha). On the other hand, the lowest yield (44.35 ton/ha) was recorded in T_9 followed by T_5 (48.24 ton/ha), T_4 (48.40 ton/ha) and T_6 (48.45 ton/ha). From these results it is revealed that the trend of the yield of tomato was observed due to application of the different management practices against tomato fruit borer as $T_7 > T_8 > T_3 > T_1 > T_2 > T_6 > T_4 > T_5 > T_9$.

Plate 1: Healthy plants

Plate 2: TYLCV infected plants

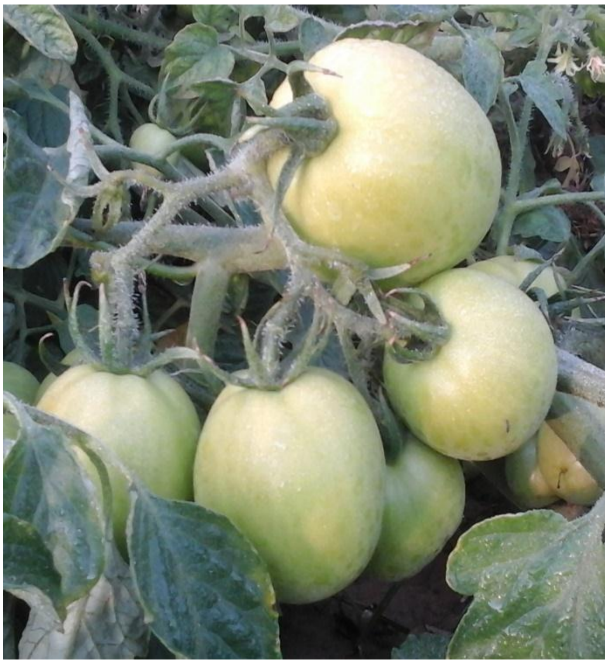

Plate 3: Healthy fruits

Plate 4: Borer infested fruits

4.6.1. Relationship between number of whitefly and TYLCV infected tomato plant

Significant relationship was found between number of whitefly per plant and percentage of TYLCV infected tomato plant when correlation was made between these two parameters. The highly significant ($p<0.01$), strong (R^2=0.9593) and positive (slope= 2.1896) correlation was found between number of whitefly per plant and percentage of TYLCV infected tomato plant (Fig. 1). Percentage of TYLCV infected tomato plant increases with the increase number of whitefly per plant.

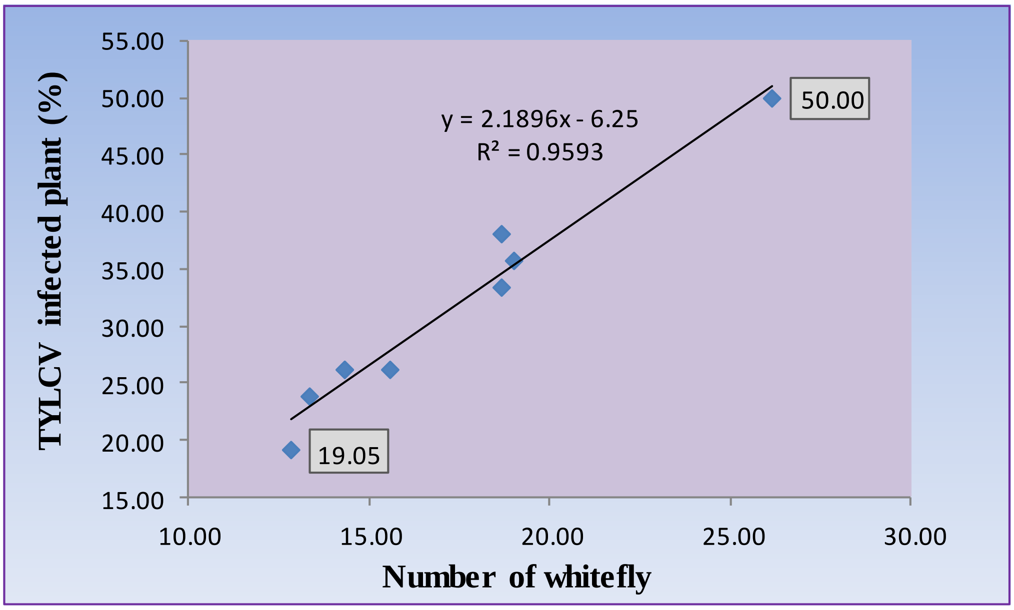

Figure 1: Relationship between number of whitefly and TYLCV infected plant

4.6.2. Relationship between TYLCV infected plants and yield (ton/ha) of tomato

Significant relationship was found between percentage of TYLCV infected plant and yield (ton/ha) of tomato when correlation was made between these two parameters. The highly significant ($p<0.01$), very strong (R^2=0.9442) and negative (slope = -0.3212) correlation was found between percentage of TYLCV infected plant and yield (ton/ha) of tomato (Fig. 2). Yield (ton/ha) of tomato decreased with the increasing percentage of TYLCV infected plant.

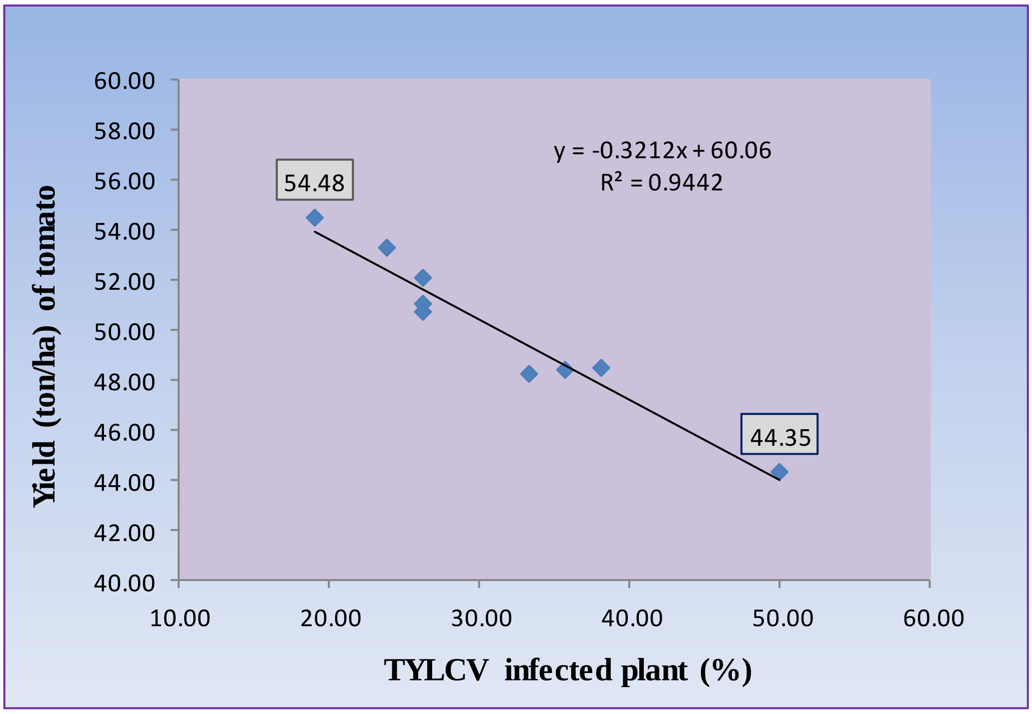

Figure 2: Relationship between TYLCV infected plant and yield of tomato

4.6.3. Relationship between fruit infestation and yield (ton/ha) of tomato

Significant relationship was found between percentage of fruit infestation and yield (ton/ha) of tomato when correlation was made between these two parameters.

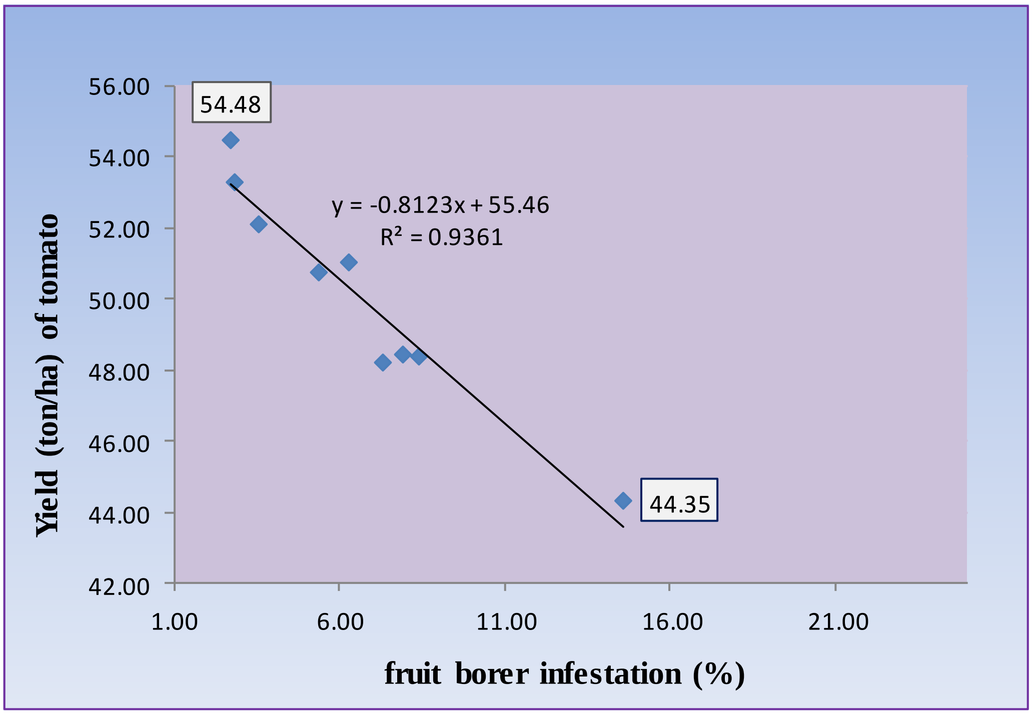

Figure 3: Relationship between fruit infestation and yield of fruits

The highly significant ($p<0.01$), very strong (R^2=0.9361) and negative (slope= -0.8123) correlation was found between percentage of fruit infestation and yield (ton/ha) of tomato (Fig. 3). Yield (ton/ha) of tomato decreases with the increase percentage of fruit infestation.

4.6.4. Relationship between fruit weight (gm) and yield (ton/ha) of fruits

Significant relationship was found between fruit weight (gm) and yield (ton/ha) of fruits. The highly significant ($p<0.01$), strong (R^2=0.8778) and positive (slope= 1095.5) correlation was found between fruit weight (gm) and yield (ton/ha) of fruits (Fig. 4). Yield of fruits increased with the increasing of fruit weight.

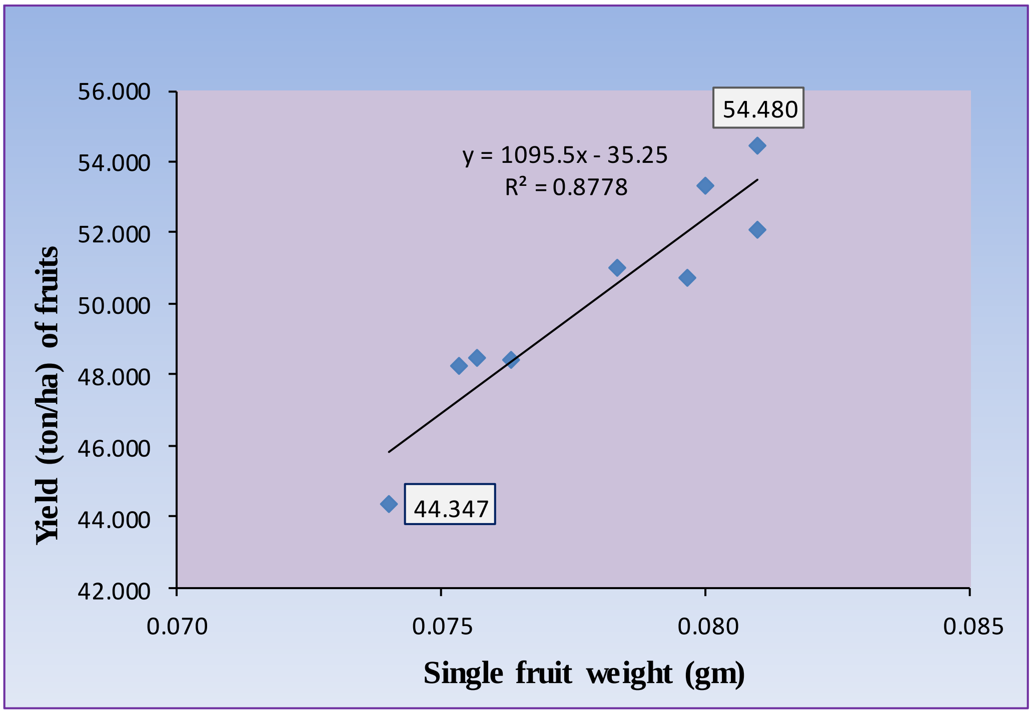

Figure 4: Relationship between single fruit weight and yield of tomato

CHAPTER V
SUMMARY AND CONCLUSION

The experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during the period from October, 2014 to March 2015 to evaluate some management practices applied against two major insect pests infesting winter tomato. The experiment consisted of control measures with chemical, botanical and physical methods.

Significant variation was found in number of whitefly at 15 days after transplanting (DAT) of tomato plant in different management practices. But at 30 DAT, the highest number of whitefly was found in T_9 (23.67). On the other hand, the lowest number of whitefly was found in T_7 (12.00) followed by T_8 (13.00), T_2 (13.33), T_3 (13.33). At 45 DAT, the highest number of whitefly (39.00) was found in T_9. On the other hand, the lowest number of whitefly was found in T_7 (20.33). At 60 DAT, the highest number of whitefly (34.00) was found in T_9. On the other hand, the lowest number of whitefly was found in T_7 (11.33) followed by T_8 (12.33), T_2 (13.67), T_3 (14.33).

During flowering stage the highest percentage of TYLCV infected tomato plant (33.33) was recorded in T_9. On the other hand, the lowest percentage of TYLCV infected plant (14.29) was recorded in T_7. During flowering stage, the highest percentage of TYLCV infected tomato plant (50.00) was found in T_9. But the lowest percentage of TYLCV infected plant (19.05) was found in T_7 followed by T_8 (23.81), T_1 (26.19), T_2 (26.19) and T_3 (26.19).

During early fruiting stage the highest percent fruit infestation (16.74) was recorded in T_9 treatment. On the other hand, the lowest percent fruit infestation in number (2.27) was recorded in T_7 treatment which was statistically similar with T_8 (2.34) and T_3 (3.19).

During early fruiting stage the highest weight of fruit (3.50) was recorded in T_7 treatment. On the other hand, the lowest weight of total fruit per five plants (2.77) was recorded in T_9 treatment. The highest percent fruit infestation in weight (14.59) was recorded in T_9 treatment. On the other hand, the lowest percent fruit infestation in weight (1.97) was recorded in T_7 treatment which was statistically similar with T_8 (2.04) and T_3 (2.78).

During mid fruiting stage highest percent fruit infestation in number (14.28) was recorded in T_9 treatment. On the other hand, the lowest (2.89) percent fruit infestation in number was recorded in T_7 treatment which was statistically similar with T_8 (3.01) and T_3 (3.78) treatments.

During mid fruiting stage the highest weight of fruits per five plants (4.36 kg) was recorded in T_7 treatment which was statistically similar with T_8 treatment (4.28 kg) and T_3 (4.13 kg). On the other hand, the lowest weight of fruit per five plants (3.60 kg) was recorded in T_9 treatment. The highest percent fruit infestation in weight (12.63) was recorded in T_9 treatment. On the other hand, the lowest percent fruit infestation in weight (2.56) was recorded in T_7 treatment.

At late fruiting stage the highest number of fruits per five plants (61.31) was recorded in T_7 treatment followed by T_8 (58.99), T_3 (58.81). On the other hand, the lowest number (50.34) of fruits per five plants was recorded in T_9 treatment. The highest number of infested fruits per five plants (6.76) was recorded in T_9 treatment. On the other hand, the lowest number of infested fruits per five plants (1.82) was recorded in T_7 treatment. The highest percent fruit infestation in number (13.42) was recorded in T_9 treatment. On the other hand, the lowest percent fruit infestation in number (2.96) was recorded in T_7 treatment.

During late fruiting stage, the highest weight of fruit per five plant (4.78 kg) was recorded in T_7 treatment followed by T_8 (4.60 kg), T_3 (4.59 kg). On the other hand, the lowest weight of fruit per five plants (3.93 kg) was recorded in T_9 treatment. The highest weight of infested fruits per five plant (0.47 kg) was recorded in T_9 treatment. But the lowest weight of infested fruits per five plants (0.12 kg) was recorded in T_7 treatment. The highest percent fruit infestation in weight (12.04) was recorded in T_9 treatment. On the other hand, the lowest percent fruit infestation in weight (2.66) was recorded in T_7 treatment which was statistically similar with T_8 (2.82) and T_3 (3.34) treatments.

During total cropping season the highest number of fruit per five plants was recorded in T_7 (162.1). On the other hand, lowest number of fruit per five plant was recorded in T_9 (132.0). The highest number of infested fruits per five plant (19.27) was recorded in T_9 treatment. While the lowest number of infested fruits per five plants (4.45) was recorded in T_7 treatment. The highest percent fruit infestation in number (14.61) was recorded in T_9 treatment. On the other hand, the lowest percent fruit infestation in number (2.74) was recorded in T_7 treatment which was statistically similar with T_8 (2.87) and T_3 (3.59) treatments

During total cropping season the highest weight of fruits per five plants (12.65 kg) was recorded in T_7 treatment followed by T_8 (12.37 kg), T_3 (12.09 kg). On the other hand, the lowest weight of fruit per five plant (10.29 kg) was recorded in T_9 treatment. The highest weight of infested fruits per five plant (1.33 kg) was recorded in T_9 treatment. On the other hand, the lowest weight of infested fruit per five plant (0.31 kg) was recorded in T_7. The highest percent fruit infestation in weight (12.93) was recorded in T_9 treatment. On the other hand, the lowest percent fruit infestation in weight (2.44) was recorded in T_7 treatment which was statistically similar with T_8 (2.54) and T_3 (3.18) treatments.

Maximum plant height (82.65 cm) was found in T_7 which was statistically similar with T_3 (81.07 cm). On the other hand, minimum plant height (69.99 cm) was found in T_9. The highest single fruit weight (0.081 gm) was found in both T_3 and T_7 which were statistically similar with all other treatments except T_9 (0.074). The highest yield (54.48 ton/ha) was recorded in T_7 followed by T_8 (53.31 ton/ha) and T_3 (52.08 ton/ha). On the other hand, lowest yield (44.35 ton/ha) was recorded in T_9 treatment.

Findings of the experiment reveal that insecticide treatment produced maximum yield among the treatment but considering the environment point of view and less health hazards botanicals may be recommended as treatment against *Bemisia tabaci* and *Helicoverpa armigera* hubner of tomato by sacrificing yield.

REFERENCES

Abd-Rabou, S. and Simmons, A.M. (2012). Some cultural strategies to help manage, *Bemisia tabaci* (Hemiptera: Aleyrodidae) and whitefly-transmitted viruses in vegetable crops. *African Entomol*. **20**(2): 371-379.

Abou-Fakhr Hammad, E.M., Nemer, N.M., Hawi, Z.K. and Hanna, L.T. (2000). Responses of the sweet potato whitefly, *Bemisia tabaci* to the chinaberry tree (*Melia azedarach* L.) and its extracts. *Annals of Applied Biol*. **137**(2): 79-88.

Abou-Fakhr Hammad, E.M., Zournajian, H. and Talhouk, S. (2001). Efficacy of extracts of *Melia azedarach* L. callus, leaves and fruits against adults of the sweet potato whitefly *Bemisia tabaci* (Homopmtera: Aleyrodidae). *J. Appl. Entmol.* **125**: 483-488.

Ahmed, K.U. (1976). Phul Phal O Shak Shabji (in Bangla). 2nd Edition, p.470.

Ahmed, M.Z., Shatters, R.G., Ren, S.X., Jin, G.H., Mandour, N.S. and Qiu, B.L. (2009). Genetic distinctions among the Mediterranean and Chinese populations of *Bemisia tabaci* Q biotype and their Wolbachia infection. *J. Appl. Entomol.* **133**: 733-741.

Alam, S.N., Rahman, A.K.M.Z. and Dutta, N.K. (2007). Annual report 2006-2007. Division of Entomology, BARI, Gazipur- 1701. p. 163.

Alam, S.N., Sarkar, D. and Rashid, M.H. (2011). Integrated management of borer complex in late winter tomato at north-western region of Bangladesh. Annual Report 2010–2011. Division of Entomology, BARI, Joydebpur, Gazipur. p. 190.

Ali, S., Kumar, R. and Kumar, S. (2011). Efficacy of bio-pesticides against *Helicoverpa armigera*, Hubner in Tomato. *Annals Plant Protection Sci.* **19**(1): 29-32.

Al-mazra'awi, M.S. and Ateyyat, M. (2009). Insecticidal and repellent activities of medicinal plant extracts against the sweet potato whitefly, *Bemisia tabaci* (Homoptera: Aleyrodidae) and its parasitoid *Eretmocerus mundus* (Hymenoptera: Aphelinidae). *J. Pest Sci.* **82**(2): 149-154.

Alomar, O., Riudavets, J. and Castane, C. (2006). Macrolophus caliginosus in the biological control of *Bemisia tabaci* on greenhouse melons. *Biol. Control*. **36**(2): 154-162.

Anonymous, (1988). FAO Production Year Book. Food and Agricultural Organization, United Nation, Rome, Italy, 43: 190-193.

Arno, J., Gabarra, R., Liu, T.X., Simmons, A.M. and Gerling, D. (2010). Natural enemies of *Bemisia tabaci*: predators and parasitoids, **In**: Stansly, P.A., Naranjo, S.E. (Eds.), Bemisia: Bionomics and Management of a Global Pest. New York, Springer, London. pp. 385-422.

Ashfaq, M., Sajjad, M., Ane, M.N. and Rana, N. (2012). Morphological and chemical characteristics of tomato foliage as mechanisms of resistance to *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) larvae. *African J. Biotech*. **11**(30): 7744.

Barati, R., Golmohammadi, G., Ghajarie, H., Zarabi, M. and Mansouri, R. (2013). The effects of some botanical insecticides and pymetrozine on life table parameters of silver leaf whitefly, *Bemisia tabaci* Gennadius (Hemiptera: Aleyrodidae). *Pesticidi i Fitomedicina*. **28**(1): 47-55.

Barman, S.C. (2007). Real adoption impact measure of tomato technologies on production at farmers' level in Bangladesh. *Bangladesh J. Sci. Ind. Res.* **42**(1): 15-28.

BBS (2006). Bangladesh Bureau of Statistics, Statistical Pocket Book. Statistics Division, Ministry of Planning, Government of the People’s Republic of Bangladesh, Dhaka.

BBS (2011). Bangladesh Bureau of Statistics, Statistical Pocket Book of Bangladesh. Statistics Division, Ministry of Planning, Govt. of the People’s Republic of Bangladesh, Dhaka. p.215.

Boykin, L.M., Shatters, R.G., Rosell, R.C., McKenzie, C.L., Bagnall, R., De Barro, P. and Frohlich, D.R. (2007). Global relationships of *Bemisia tabaci* (Hemiptera: Aleyrodidae) revealed using Bayesian analysis of mitochondrial COI DNA sequences. *Mol. Phylogenet. Evol.* **44**: 1306-1319.

Brar, K.S., Singh, J., Shenhmar, M., Kaur, S., Sanehdeep, K., Joshi, N., Singh, I., Kaur, S., Tandon, P.L. (ed.) Ballal, C.R. (ed.) Jalali, S. K. (ed.) and Rabindra, R.J. (2003). Integrated management of *Helicoverpa armigera* (Hubner) on tomato. Biological control of Lepidopteran pests. Proceedings of the Symposium of Biological Control of Lepidopteran Pests, July- 17-18,-2002, Bangalore, India. p. 271-274.

Byrne, D.N., Bellows, T.S. and Parella, M.P. (1990). Whiteflies in agricultural systems. In D. Gerling (ed.), whiteflies, their bionomics, pest status and management. Intercept. Andover, UK. p. 201-204

Chaudhary, C.S., Gauns, K.H., Gaikwad, S.M., Gade, R.S. and Bhingare, C.R. (2014). Evaluation of green muscardine fungi *Metarhizium anisopliae* on tomato fruit borer *Helicoverpa armigera* under field condition. *Trends in Biosci.* **7**(11): 1062-1065.

Chavan, R.D., Yeotikar, S.G., Gaikwad, B.B. and Dongarjal, R.P. (2015). Management of major pests of tomato with biopesticides. *J. Entomol. Res.* **39**(3): 213-217.

Chavan, S.M., Sushil, K. and Arve, S.S. (2012). Efficacy and economics of various pest management modules against tomato fruit borer, *Helicoverpa armigera* (Hubner). *Agri. Sci. Digest – Res. J.* **32**(4): 296-300.

Cuthbertson, A.G.S., Mathers, J.J., Northing, P., Prickett, A.J. and Walters, K.F.A. (2008). The integrated use of chemical insecticides and the entomopathogenic nematode, *Steinernema carpocapsae* (Nematoda: Steinernematidae), for the control of sweetpotato whitefly, *Bemisia tabaci* (Hemiptera: Aleyrodidae). *Insect Sci*. **15**(5): 447-453.

Dhaka, S.S., Singh, G., Ali, N., Yadav, A. and Yadav, A. (2010). Field evaluation of insecticides and bio-pesticides against *Helicoverpa armigera* on tomato. *Annals Plant Protec. Sci*. **18**(1): 13-16.

Duraimurug, P. and Regupathy, A. (2005). Synthetic pyrethroid resistance in field strains of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) in Tamil Nadu, South India. *American J. Appl. Sci*. **2**(7): 1146-1149.

Frohlich, D.R., Torres-Jerez, I., Bedford, I.D., Markham, P.G. and Brown, J.K. (1999). A phylogeographical analysis of the *Bemisia tabaci* species complex based on mitochondrial DNA markers. *Mol. Ecol.* **8**: 1683-1691.

Gajendra, C., Chandrakar, G., Ganguli, R.N., Kaushik, U.K. Dubey, V.K. and Chandrakar, G. (1999). Management of tomato fruit borer, *Heliothis armigera* Hubn. using biopesticides. *J. Appl. Zool. Res.* **10**(2): 105-107.

Gajendra, C., Ganguli, R.N., Kaushik, U.K., Dubey, V.K., Chandrakar, G., Reddy, P.P. (ed.) Kumar, N.K.K. (ed.) and Verghese, A. (1998). Resistance to the fruit borer, *Helicoverpa armigera* in tomato. Advances in IPM for horticultural crops. Proceedings of the First National Symposium on Pest

Management in Horticultural Crops: environmental implications and thrusts, Bangalore, India. p. 73-74.

Gelman, D.B., Gerling, D., Blackburn, M.B. and Hu, J.S. (2005). Host-parasite interactions between whiteflies and their parasitoids. *Arch. Insect Bioch. Physiol.* **60**: 209-222.

Gopalakrishnan, S. (2011). Efficacy of botanical extracts and entomopathogens on control of *Helicoverpa armigera* and *Spodoptera litura*. *African J. Biotechnol*. **10**(73): 16667.

Gorri, J.E.R., Pereira, R.C., Alves, F.M., Fernandes, F.L., Silva, I.W. and Fernandes, M.E.S. (2015). Toxicity effect of three insecticides on important pests and predators in tomato plants. *Agri. Sci.* **3**(1): 01-12.

Gosalwad, S.S., Toprope, V.N. and Tikotkar, A.B. (2015). Efficacy of insecticides against whitefly and leaf minar in tomato (*Lycopersicon esculentum* Mill). *Bioinfolet - Quarterly J. Life Sci*. **12**(3): 631-634.

Greenberg, S.M., Jones, W.A. and Liu, T.X. (2008). *Bemisia tabaci* (Homoptera: Aleyrodidae) instar effects on rate of parasitism by *Eretmocerus mundus* and *Encarsia pergandiella* (Hymenoptera: Aphelinidae). *Entomol. Sci.* **11**: 97-103.

Gupta, N.D. (2000). Occurrence of Tomato yellow leaf curl virus (TYLCV) and Tomato purple vein virus (TPVV) and their effect on growth and yield of tomato. An MS thesis submitted to the Department of Plant Pathology, BSMRAU, Salna, Gazipur, Bangladesh. p. 77.

Gupta, S., Gajbhiye, V.T., Sharma, R.K. and Gupta, R.K. (2011). Dissipation of cypermethrin, chlorpyriphos and profenofos in tomato fruits and soil following application of pre-mix formulations. *Environmental Monitoring and Assessment*. **174**(1): 337-345.

Haider, J., Marutomo and Azad, A. K. 1991. Estimation of microbial biomass carbon and nitrogen in Bangladesh. *Soil Sci. Plant Nutr.* **37**(4): 591-599.

Hossain, M.E., Alam, M.J., Hakim, M.A., Amanullah, A.S.M. and Ahsanullah, A.S.M. (2010). An assessment of physicochemical properties of some tomato genotypes and varieties grown at Rangpur. *Bangladesh Res. Pub. J.* **4**(3): 135-243.

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

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

Jahan, S.M.H. (2012). Occurrence of two genotypic clusters of *Bemisia tabaci* (Gennadius) (Hemiptera: Aleyrodidae) in Bangladesh. *Eco-friendly Agril. J.* **5**(8): 114-122.

Jeyarani, S., Karuppuchamy, P. and Sathiah, N. (2011). Influence of *Pseudomonas fluorescens*-Induced plant defenses on efficacy of Nucleo polyhedro virus of *Helicoverpa armigera* in Okra and Tomato. *Int. J. Vegetable Sci.* **17**(3): 283.

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

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

Kabir, M.H. and Rainis, R. (2015). Adoption and intensity of integrated pest management (IPM) vegetable farming in Bangladesh: an approach to sustainable agricultural development. *Environment, Development and Sustainability*. **17**(6): 1413-1429.

Kakar, K.L., Sharma, J.P. and Dogra, G.S. (1990). Feasibility of using *Trichogramma* spp. against *Heliothis armigera* Hubner on tomato. *Indian J. Plant Protection*. **18**(2): 237-239.

Karabhantanal, S.S. and Awaknavar, J.S. (2012). Bio intensive approach for the management of tomato fruit borer, *Helicoverpa armigera* (Hubner). *Pest Management in Horticultural Ecosystems*. **18**(2): 135-138.

Karim, M.A. (1994). Insect pest management of vegetable crops. Proceeding of a symposium on recent advances in vegetable development of Bangladesh, 24-25 April, 1994, pp. 198-199.

Katroju, R.K., Cherukuri, S.R., Vemuri, S.B. and Narasimha, R.K. (2014). Bio-efficacy of insecticides against fruit borer (*Helicoverpa armigera*) in tomato (*Lycopersicon esculentum). Int. J. Appl. Biol. Pharmaceutical Technol*. **5**(1): 239-243.

Khanam, U.K.S. (2000). Varietal resistance in tomato to tomato fruit borer, *Heliothis armigera* (Hub.) and tomato aphid, *Aphis craccivora* (Koch.) and its relation to plant characters. MS thesis. Department of Entomology, Bangladesh Agricultural University, Mymensingh, Bangladesh. p. 96.

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

Krishnamoorthy, A. and Mani, M. (1996). Biosuppression of *Helicoverpa armigera* (Hubn.) on tomato using two egg parasitoids, *Trichogramma brasiliensis* (Ashm.) and *T. pretiosum* (Riley). *J. Entomol. Res.* **20**(1): 37-41.

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

Kuldeep, S. (2013). Seasonal abundance of fruit borer, *Helicoverpa armigera* (Hubner) and its impact on marketable fruit production in tomato, *Lycopersicon esculentum* (Mill.). *Agri. Sci. Digest - Res. J.* **33**(4): 247-252.

Kuldeep, S., Singh, D.K. and Raju, S.V.S. (2009). Bioefficacy of certain neem based formulations against whitefly, *Bemisia tabaci* Gennadius causing leaf curl disease in tomato. *Indian J. Entomol.* **71**(2): 165-167.

Kumar, H. and Kumar, V. (2004). Tomato expressing Cry 1A (b) insecticidal protein from *Bacillus thuringiensis* protected against tomato fruit borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) damage in the laboratory, greenhouse and field. *Crop Protection*. **23**(2): 135–139.

Kumar, K. and Indira, D.M. (2014). Field efficacy, net profit and cost benefit ratio of certain insecticides against fruit borer, *Helicoverpa armigera* (Hubner) in tomato. *Int. J. Agri., Environ. Biotech.* **7**(2): 343-346.

Kumar, K.I. (2014). Population dynamics of *Helicoverpa armigera* Hubner (Noctuidae: Lepidoptera) in tomato. *Trends in Biosci*. **7**(2): 112-114.

Kumar, P. and Poehling, H.M. (2007). Effects of Azadirachtin, Abamectin, and Spinosad on sweetpotato whitefly (Homoptera: Aleyrodidae) on tomato plants under laboratory and greenhouse conditions in the humid tropics. *J. Econ. Entomol*. **100**(2): 411-420.

Lapidot, M. and Friedmann, M. (2002). Breeding for resistance to whitefly-transmitted geminiviruses. *Ann. Appl. Biol.* **140**: 109–127.

Leite, G.L.D., Fialho, A., Zanuncio, J.C., Junior, R.R. and Da Costa, C.A. (2014). Bagging tomato fruits: a viable and economical method of preventing diseases and insect damage in organic production. *Florida Entomol. Society*. **97**(1): 50-60.

Mandal, S.K. (2015). Adoption of IPM technology in Tomato at Village level. *Annals of Plant Protection Sciences*. **23**(1): 30-33.

Mandloi, R., Rajesh, P., Sunil, P. and Satyendra, P. (2015). Seasonal incidence of insect complex on tomato (*Solanum lycopersicon* L.). *J. Entomol. Res.* **39**(4): 347-352.

Mansaray, A. and Sundufu, A.J. (2010). Effect of three bean species on the development and reproduction of a population of the parasitoid, *Encarsia bimaculata*, on the whitefly, *Bemisia tabaci*. *J. Insect Sci.* **10**: 28.

Marcic, D., Prijovic, M., Drobnjakovic, T., Peric, P., Sevic, M. and Stamenkovic, S. (2011). Effects of bioinsecticides in control of greenhouse whitefly (*Trialeurodes vaporariorum* Westwood) on tomato. *Pesticidi i Fitomedicina*. **26**(4): 363-369.

Martinez-Carrillo, J.L. and Brown, J.K. (2007). First report of the Q biotype of *Bemisia tabaci* in southern Sonora, Mexico. *Phytoparasitica.* **35**: 282-284.

Maruthi, M.N., Alam, S.N., Kader, K.A., Rekha, A.R., Cork, A. and Colvin, J. (2009). Nucleotide sequencing, whitefly transmission, and screening tomato for resistance against two newly described begomoviruses in Bangladesh. *Phytopathol*. **95**(12): 1472-1481.

Mason, G., Rancati, M. and Bosco, D. (2000). The effect of thiamethoxam, a second generation neonicotinoid insecticide, in preventing transmission of tomato yellow leaf curl geminivirus (TYLCV) by the whitefly *Bemisia tabaci* (Gennadius). *Crop Protection*. **19**(7): 473-479.

Meena, L.K. and Raju, S.V.S. (2014). Bio-efficacy of insecticides against whitefly and leafhopper of tomato under field conditions. *Ann. Pl. Prot. Sci*. **22**(1): 14-17.

Mehta, P.K., Vaidya, D.N. and Kashyap, N.P. (2000). Management of tomato fruit borer, *Helicoverpa armigera* (Hubner) using pesticides and biopesticides. *Himachal J. Agri. Res.* **26**(1 and 2): 50-53.

Milind, P., Nitin, B. and Seema, B. (2011). Is Life-Span Under Our Control?? *Int. Res. J. Pharmacy.* **37**(1): 40-48.

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

Moreno-Ripoll, R., Gabarra, R., Symondson, W.O.C., King, R.A. and Agusti, N. (2014). Do the interactions among natural enemies compromise the biological control of the whitefly *Bemisia tabaci*? *J. Pest Sci.* **87**(1): 133-141.

Mughra, R.B., Liu, S.S. and Zhou, X. (2008). Tomato yellow leaf curl virus and tomato leaf curl Taiwan virus invade south-east coast of China. *J. Phytopathol.* **156**: 217–221.

Mukhtar, S., Hashim, A. and Peterschmitt, M. (2013). Using of neem (*Azadirachta indica*) in management of whitefly (*Bemisia tabaci* genn) in Sudan. International Conference on Oceanography & Natural Disasters. *J. Marine Sci. Res. Dev.* **3**: 3.

Muqit, A. and Akanda, A.M. (2007). Management of tomato yellow leaf curl virus through netting. *The Agriculturists*. **5**(1 and 2): 1-5.

Muqit, A., Akanda, A.M. and Bari, M.A. (2006). Effect of insecticides and vegetable oil on tomato yellow leaf curl virus (TYLCV). *Int. J. Sust. Cr. pdn.* **1**(1): 22-25.

Nasreen, A. and Ghulam, M. (2000). Biology of *Helicoverpa armigera* (Hubner) reared in laboratory on natural diet. *Pakistan J. of Bio. Sci.* p. 1668:1669

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

Oji, F.L. (2003). Integrated management of whitefly and sunscald on tomato. *African Crop Science Conference Proceedings.* **6**: 264-266.

Oliveira, M.R.V., Henneberry, T.J. and Anderson, P. (2001). History, current status, and collaborative research projects for *Bemisia tabaci*. Publications from USDA-ARS / UNL Faculty. p. 352.

Padmanaban, N., Ramesh, A. and Arora. R. (2002). Field evaluation of native nucleo polyhedron virus for the management of tomato fruit borer, *Helicoverpa armigera* (Hubner). *Pesticide Res. J.* **14**(1): 113-119.

Patange, N.R. and Dange, M.T. (2016). Evaluation of different IPM components against *Helicoverpa armigera* (Hubner). *Ann. Pl. Protec. Sci.* **24**(1): 23-26.

Pathania, S.S., Verma, A.K. and Gupta, P.R. (2009). Economics of IPM modules against *Helicoverpa armigera* (Hubner) on tomato. *Indian J. Entomol.* **71**(4): 302-306.

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

Qayyuma, M.A., Wakila, W., Arifa, M.J., Sahib, S.T. and Dunlapc, C.A. (2015). Infection of *Helicoverpa armigera* by endophytic *Beauveria bassiana* colonizing tomato plants. *Biological Control*. **90**: 200–207.

Rahman, A.H.M.A., Akanda, A.M. and Ashraful Alam, A.K.M. (2006). Relationship of whitefly population build up with the spread of TYLCV on eight tomato varieties. *J. Agri. Rural Develop.* **4**(1): (67-74).

Rahman, A.K.M.Z., Haque, M.H., Alam, S.N. and Dutta, N.K. (2014). Efficacy of microbials as insecticides for the management of tomato (*Lycopersicon esculentum*) Fruitworm, *Helicoverpa armigera* (Hubner). *The Agriculturists*. **12**(1): 68-74.

Rahman, A.K.M.Z., Haque, M.H., Alam, S.N., Mahmudunnabi, M. and Dutta, N.K. (2014). Efficacy of Botanicals against *Helicoverpa armigera* (Hubner) in Tomato. *The Agriculturists*. **12**(1): 131-139.

Rajasri, M., Lakshmi, K.V., Prasada Rao, R.D.V.J. and Reddy, K.L. (2009). Management of *Bemisia tabaci* and consequent spread of tomato leaf curl virus with certain insecticides in tomato. *Indian J. Plant Protection.* **37**(1 and 2): 123-126.

Rasdi, M., Salmah, C.M.R., Hassan, A., Hamady, D., Hamaseh, A. and Ismail, F. (2012). Field evaluation of some insecticides on whitefly (*Trialeurodes vaporariorum*) and predator (*Macrolophus caliginosus*) on brinjal and tomato plants. *Asian J. Agri. Rural Develop*. **2**(3): 302-311.

Reddy, G.R.S., Divakar, B.J., Reddy, S.M. (ed.), Srivastava, H.P. (ed.), Purohit, D.K. (ed.) and Ram, R.S. (1997). Effect of two microbial bioagents on the tomato borer, *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae). *Microbial Biotechnol*. p. 140-142.

Rehman, H., Nadeem, M., Ayyaz, M. and Begum, H. (2015). Comparative efficacy of neem oil and lambdacyhalothrin against whitefly (*Bemisia tabaci*) and jassid (*Amrasca Devastans* Dist.) in okra field. *Plant Protection.* **41**(2): 138-145.

Rishikesh, M., Rajesh, P., Sunil, P. and Satyendra, P. (2015). Seasonal incidence of insect complex on tomato (Solanum lycopersicon L.). *J. Entomol. Res.* **39**(4): 347-352.

Roermund, H.J.W., Lenteren, J.C. and Rabbinge, R. (1997). Biological control of greenhouse whitefly with the parasitoid, *Encarsia Formosa* on tomato: an individual-based simulation approach. *Biol. Control.* **9**(1): 25-47.

Saini, S. and Raj, D. (2008). Efficacy of insecticides against *Helicoverpa armigera* (Hubner) on tomato in mid hill zone of Himachal Pradesh (India). *J. Entomol. Res.* **32**(2): 143-145.

Sandeep, K. and Subash, S. (2014). Field efficacy of systemic insecticides and microbial pesticides against aphid and fruit borer on tomato in Punjab. *Vegetable Sci.* **41**(2): 171-176.

Sandip, P., Das, B.C., Dhote, V.W. and Samanta, A. (2015). Efficacies and economics of some novel insecticides for management of major lepidopteran pests of tomato. *Res. Crops*. **16**(3): 579-589.

Sardana, H.R., Vikas, K., Bhat, M.N. and Singh, R.V. (2013). Farmers' driven approach for field validation and economic analysis of adaptable IPM technology in tomato. *Indian J. Entomol.* **75**(3): 185-188.

Sedaratian, A., Fathipour, Y. and Talaei-Hassanloui, R. (2014). Deleterious effects of *Bacillus thuringiensis* on biological parameters of *Habrobracon hebetor* parasitizing *Helicoverpa armigera*. *Biocontrol*. **59**(1): 89- 98.

Selvanarayanan, V. and Narayanasamy, P. (2004). Antixenosis resistance in tomato to the fruit borer, *Helicoverpa armigera* (Hubner). *Int. J. Tropical Insect Sci*. **24**(3): 201-206.

Selvanarayanan, V. and Narayanasamy, P. (2006). Factors of resistance in tomato accessions against the fruit worm, *Helicoverpa armigera* (Hubner). *Crop Protection*. **25**(10): 1075-1079.

Sharfudin, A.F.M. and Siddique, M.A. (1985). Sabji Bigyan. 1st Edition, Bangladesh Agricultural University, Mymensingh. p. 4.

Shefali, M., Jagadeesh, K.S., Krishnaraj, P.U., Byadagi, A.S. and Vastrad, A.S. (2012). Biological management of tomato leaf curl virus (ToLCV) by inducing systemic resistance through rhizobacterial strains. *Bioinfolet - Quarterly J. Life Sci.* **9**(3): 417-427.

Shefali, M., Jagadeesh, K.S., Krishnaraj, P.U., Byadagi, A.S. and Vastrad, A.S. (2014). Synergistic effect of chitosan and *Pseudomonas* sp on the biological control of tomato leaf curl virus in tomato. *Indian J. Plant Protection*. **42**(4): 437-447.

Singh, K. (2012). Bio-Efficacy of BT based microbial formulations against fruit borer, *Helicoverpa armigera* (Hubner) of tomato, *Solanum Lycopersicon* (Mill.). *Bioinfolet - Quarterly J. Jife Sci*. **9**(2): 214-216.

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

Srinivasan, R. (Ed.). (2010). Safe tomato production methods: A field guide for soil fertility and pest management. AVRDC-The world vegetable center, Shanhua, Taiwan. AVRDC Publication Number 10-740. p. 97.

Suarez, M.H., Pallares, J.R., Mesa, D.R., Rodriguez, E.R. and Romero, C.D. (2008). Variation of the chemical composition of tomato cultivars (*Lycopersicon esculentum* Mill.) according to resistance against the tomato yellow leaf curl virus (TYLCV). *J. Sci. Food Agri.* **88**(11): 882-1891.

Sundarajan, G. (2002). Control of caterpillar, *Helicoverpa armigera* using botanicals. *J. Ecotoxicol. Environ. Monitoring*. **12**(4): 305-308.

Suradkar, A. and Ukey, S.P. (2015). Management of tomato fruit borer, *Helicoverpa armigera* hubner. *Bioinfolet - Quarterly J. Life Sci.* **12**(1B): 224-226.

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

Tyagi, A., Gaurav, S.S., Prasad, C.S. and Ud din, M.M. (2010). Efficacy and economics of biopesticides combinations and insecticide against tomato fruit borer. *Annals Plant Protection Sci.* **18**(1): 148-152.

Ud Din, M.M., Gaurav, S.S., Prasad, C.S. and Tyagi, A. (2010). Field efficacy of HaNPV against *Helicoverpa armigera* on tomato. *Annals Plant Protection Sci.* **18**(2): 301-303.

Wakil, W., Ghazanfar, M.U., Nasir, F., Qayyum, M.A. and Tahir, M. (2012). Insecticidal efficacy of *Azadirachta indica*, Nucleo Polyhedro Virus and chlorantraniliprole singly or combined against field populations of *Helicoverpa armigera* Hubner (Lepidoptera: Noctuidae). *Chilean J. Agri. Res.* **72**(1): 53.

Walker, G.P., Herman, T.J.B., Kale, A.J. and Wallace, A.R. (2010). An adjustable action threshold using larval parasitism of *Helicoverpa armigera* (Lepidoptera: Noctuidae) in IPM for processing tomatoes. *Biol. Control*. **52**(1): 30-36.

Xiao, Y.F., Chen, J.J., Cantliffe, D., Mckenzie, C., Houben, K. and Osborne, L.S. (2011). Establishment of papaya banker plant system for parasitoid, *Encarsia sophia* (Hymenoptera: Aphelinidae) against *Bemisia tabaci* (Hemiptera: Aleyrodidae) in greenhouse tomato production. *Biol. Control*. **58**: 239-247.

Yang, Y., Sherwood, T.A., Patte, C.P., Hiebert, E. and Polston, J.E. (2004). Use of tomato yellow leaf curl virus (TYLCV) Rep gene sequences to engineer TYLCV resistance in tomato. *Phytopathol*. **94**(5): 490.

Yaobin, L., Yawei, B. and Jinming, Z. (2012). Are yellow sticky traps an effective method for control of sweetpotato whitefly, *Bemisia tabaci*, in the greenhouse or field? *J. Insect Sci.* **12**(113): 1-12.

Zang, L.S. and Liu, T.X. (2009). Food-deprived host-feeding parasitoids kill more pest insects. *Biocontrol Sci. Tech.* **19**: 573-583.