ECO-FRIENDLY MANAGEMENT OF WHITE FLY (*BEMISIA TABACI* (GENNADIUS)) IN TOMATO

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CERTIFICATE

This is to certify that the thesis entitled, "**ECO-FRIENDLY MANAGEMENT OF WHITE FLY (*BEMISIA TABACI* (GENNADIUS)) IN TOMATO**" submitted to the **Faculty of Agriculture**, Sher-e-Bangla Agricultural University (SAU), Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in **ENTOMOLOGY**, embodies the result of a piece of bona fide research work carried out by **Morzina Begum**, **Registration No. 11-04291** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2017

Place: Dhaka, Bangladesh

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ABSTRACT

A field experiment was conducted in the experimental field of Sher-e-Bangla Agricultural University to find out the effectiveness as well as hazards free management practice(s) of tomato, cultivated during Rabi season (October, 2016 to February, 2017). The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The experimental treatments were T_1 comprised of spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with 1 liter of water @ 7 days interval; T_2 comprised of spraying of neem seed kernel extract @ 5.0 ml/L of water at 7 days interval; T_3 comprised of spraying of garlic extract @ 5.0 ml/L of water at 7 days interval; T_4 comprised of spraying of soap water @ 3 gm/L of water at 7 days interval; T_5 comprised of spraying 3 ml neem oil and 10 ml trix mixed with 1 liter of water@ 7 days interval along with spraying of soap water @ 3 gm/L of water at 7 days interval; T_6 comprised of spraying 5.0 ml/L of water at 7 days interval along with spraying of soap water @ 3 gm/L of water at 7 days interval; T_7 comprised of spraying 5.0 ml/L of water at 7 days interval along with spraying of soap water @ 3 gm/L of water at 7 days interval; T_8 comprised of spraying Admire 200SL 0.20 ml/L of water at 7 days interval and T_9 comprised of spraying Sevin 85 WP 3.4 gm/L of water at 7 days interval and T_{10} comprised of untreated control. Among the treatments, T_5 contributed to reduce the highest number of white fly, Tomato Yellow Leaf Curl Virus (TYLCV) infected plant and infected branches were (9.11 white fly/ 5 tagged plant), (0.25 plant/plot) and (24.17 branches/plot) respectively. In the early flowering stage, T_5 also contribute to reduce the number of infected leaves (26.75 leaves/plant) and increase the number of healthy leaves (87.17 leaves/plant) and plant height (380.6 cm). In the mid flowering stage, T_5 also contribute to reduce the number of infected leaves (33.83 leaves/plant) and increase the number of healthy leaves (92.67 leaves/plant) and plant height (394.9 cm). In the late flowering stage, T_5 also contribute to reduce the number of infected leaves (33.50 leaves/plant) and increase the number of healthy leaves (96.83 leaves/plant) and plant height (399.3 cm). In case of total number of fruit (349.3 fruit/plot), weight of fruit (9.02 kg/ha) and yield (37.60 ton/ha) of tomato was recorded in T_5 comprising of spraying 3 ml neem oil and 10 ml trix mixed with 1 liter of water@ 7 days interval along with spraying of soap water @ 3 gm/L of water at 7 days interval.

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LIST OF ABBREVIATIONS AND ACRONYMS

Abbreviation	**Full meaning**
BADC	Bangladesh Agriculture Development Corporation
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
BCPC	British Crop Production Council
CV	Coefficient of variation
^{o}C	Degree Celsius
d.f.	Degrees of freedom
et al.	And others
EC	Emulsifiable Concentrate
FAO	Food and Agriculture Organization
g	Gram
Ha	Hectare
IPM	Integrated Pest Management
CRSP	Collaborative Research Support
J.	Journal
Kg	Kilogram
LSD	Least Significant Difference
Mg	Milli gram
Ml	Milli liter
MP	Muriate of Potash
%	Percent
RCBD	Randomized Complete Block Design
SAU	Sher-e-Bangla Agricultural University
TSP	Triple Super Phosphate
WP	Wettable Powder

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* Mill.) is one of the most popular and nutritious vegetable crops in Bangladesh. It belongs to the family Solanaceae. In Bangladesh, it ranks 2nd which is next to potato (BBS, 2012) and top the list of canned vegetables. Tomato is indigenous to the Peru and Equador region in South America and it probably evolved from *Lycopersicon esculentum* var. *cerasiforme*, the cherry form. However, it was domesticated and first cultivated in Central America by the early Indian civilizations of Mexico. The Spanish explorers introduced tomato into Spain and later it was taken to Morocco, Turkey and Italy (AIS, 2010). Its food value is very rich because of higher contents of vitamin A, B and C (Bose and Sam, 1990). It is used in salad, soups and processed into stable products like ketchup, sauce, pickles paste, chutney and juice. Bangladesh grew tomato in 58854 acres of land in the year 2010-2011 with a total production of 190213 M.T. and approximately showing an average yield of 2855kg/acre (BBS, 2012). The average yield of tomato in Bangladesh is very low as compared to world average or some other tomato growing countries. Average yield of tomato in the world is 27 ton/ha whereas in Bangladesh it is around 7 t/h (Anonymous, 2004). One of the major constraints for tomato production is the attack of insect pests. The attack of tomato fruit borer, *Helicoverpa armigera* (Hubner) and whitefly, *Bemisia tabaci* (Genn.) are considered most important. Tomato fruit borer is highly polyphagous insect pest and perhaps the most serious pest of tomato. This has been reported to cause damage to extent of about 50-60 percent fruits (Singh and Singh, 1977). Data revealed that damage by this pest might be up to 85-93 % (Tewari, 1985). Due to severe infestation, fruit as well as seed maturation hampered greatly and the viability of the seeds are reduced (Dhamo *et al*., 1984). A large number of tomato varieties are grown in Bangladesh; most of them lost their potentiality due to genetic deterioration, disease and insect infestation. In order to increase tomato production in Bangladesh, it is essential to identify cultivars capacity for year-round production with higher yield and resistance to pests (Hannan *et al.*, 2007). The whitefly adult and nymphs feed on the plant sap from the underside of the leaves. They secrete honeydew, which later helps the growth of sooty mould fungus thus reducing the photosynthetic area. The whitefly acts as a mechanical vector of tomato yellow leaf curl virus in (TYLCV) in tomato. Over 70 plant viruses are transmitted by whitefly. Among the identified viruses the TYLCV is the most damaging and widely distributed virus infecting tomato in Bangladesh. 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. 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 fresh 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 percent 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 pests of tomato by the application of chemical insecticides because the use of chemical insecticide has the quick knock down effect. 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 equipment (Husain, 1984). It gives importance on botanicals as it is regarded safe for environment. Botanical pesticide, especially neem oil is becoming popular day by day. Karim (1994) reported that weekly spray application of the extract of neem seed kernel is effective against *Helicoverpa armigera*. Other botanicals such as neem leaf extract, garlic extract etc. are used for controlling the insect pests of tomato. 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. The lure of Soap waters attracts and traps the male moth of tomato fruit borer. Thus the moth populations are disrupted due to lack of mating chance adult female moths with male moths. These are not hazardous for environment, human health & beneficial insects and also not costly. Therefore, the present study is proposed to undertake aiming to produce human health hazards free tomato production by the utilization of botanicals and Soap waters in comparison with traditionally used chemical insecticides against major insect pests of tomato.

OBJECTIVES

1. To find out the abundance of white fly and virus infection on tomato plants treated with different management practices.
2. To compare the effectiveness and impact of botanicals, soap water and chemical insecticides on white fly and virus infection.

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 buildup 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 BW_1 and BW_2 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 4.0 ha 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 5 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-T_1 (Manik), BARI-T_2 (Ratan), BARI-T_4, BARI-T_5, BARI-T_6 (Apurba), BARI-T_7 (Chaity), BARI-T_1 and BARI-T_2 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 & 6 R_2 = 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 aganist 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 cultiver and resistance against 7 the TYLCV were observed for total soluble solids,pH, ascorbec 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 (5d) 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 Soap waters @ 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 [*R0*] 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 [rm] 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.

CHAPTER III

MATERIALS AND METHODS

The present study was conducted to evaluate the eco-friendly management of whitefly of tomato at the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during October, 2016 to March, 2017. Required materials and methodology are described below under the following heading.

3.1. Location of the study

The experiments were conducted in the experimental field under the Department of Entomology, Sher-e-Bangla Agricultural University, Dhaka.

3.2. Characteristics of soil

The soil of the experimental area was silty loam belonging to the Non-Calcareous Dark grey Floodplain soils under the Agro Ecological Zone 12. The selected site was a well drained medium high land.

3.3. Season of the study

The study was conducted during Robi season (October 2016-March, 2017).

3.4. Materials used

The tomato variety BARI tomato 15 was cultivated in the field during Robi season for combating using different management practices.

3.5. Collection of seed and seedling raising

The seeds of selected tomato variety BARI-tomato 15 were collected from Horticulture Research Centre (HRC) of Bangladesh Agricultural Research Institute, Joydebpur, Gazipur. Before sowing seeds, the germination test was done and found 90% germination for all varieties. Seeds were then directly sown in the 30th October, 2016 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.

3.6. Design of experiment

The experiment was laid out in Randomized Completely Block Design (RCBD) with three replications. Total 30 plots were made for conducting the experiments. The whole experimental plot was 17.5 m long and 10.17 m broad, which was divided into 3 equal blocks. Each of the 3 equal blocks has 10 plots assigned for 10 treatments. The size of a unit plot was 2 m long and 1.2 m broad. Distance of 1 m between blocks and 0.5 m between the plots was kept to facilitate different intercultural operations.

3.7. Replication

Each treatment of the experiment was replicated with three times in the field of tomato.

3.8. Treatment

The white fly of tomato. will be controlled using following management practices:

Treatment	Iteam	Dose/Rate
T_1	Neem Oil	3 ml neem oil and 10 ml trix mixed with 1 liter of water @ 7 days interval
T_2	Neem Seed Kernel extract	5.0 ml/L of water at 7 days interval
T_3	Garlic extract	5.0 ml/L of water at 7 days interval
T_4	Soap water	3 gm/L of water at 7 days interval
T_5	Neem+ Soap water	3 ml neem oil and 10 ml trix mixed with 1 liter of water@ 7 days interval along with 3 gm/L of soap water at 7 days interval
T_6	Neem Seed Kernel extract + soap water	5.0 ml/L of water at 7 days interval along with 3 gm/L of soap water at 7 days interval
T_7	Garlic extract + Soap water	5.0 ml/L of water at 7 days interval along with 3 gm/L of soap water at 7 days interval
T_8	Admire 200 SL	0.20 ml/L of water at 7 days interval
T_9	Sevin 85 WP	3.4 gm/L of water at 7 days interval
T_{10}	Untreated control	No treatment will be applied

3.9. Land preparation

The land was ploughed with a power tiller and kept open to sunlight. The land was then cross-ploughed several times with a power tiller to obtain good tilth. All ploughing operations were followed by laddering for breaking up the clods and leveling the surface of soil. The weeds and stubbles were removed from the field during land preparation. The soil was well prepared and good tilth ensured for commercial crop production. The target land was divided into 30 equal plots (2m×1.2m) with plot to plot distance of 0.50 m and block to block distance was 1.0 m. The land of the experimental field was ploughed with a power tiller. Later on the land was ploughed three times followed by laddering to obtain desirable tilth. The corners of the land were spaded and larger clods were broken into smaller pieces. After ploughing and laddering, all the stubbles and uprooted weeds were removed and then the land was ready. The field layout and design of the experiment was followed immediately after land preparation.

3.10. 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.

3.11. Transplanting of seedling

The 30 days old healthy seedlings of tomato variety (BARI Tomato-15) was transplanted on November 28th, 2014 in the main field from the seed bed. Other intercultural operations were done as when necessary.

3.12. 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.

3.13. Treatment application

Various treatments as mentioned earlier were applied to the respective sub-plot of the tomato in the main field. The first application of the treatment was started just one week after the transplanting of the seedlings in the main field and continued up to one week before the harvest of the fruits.

3.13.1. Management with botanical insecticide spraying of neem oil

Neem oil (*Azadirachta indica*) was used as botanical insecticide in fruit fly management experiment. Neem oil was collected from the local market Siddique Bazar, Dhaka. The required spray volume was prepared by mixing 75 ml neem oil (3%), 1 ml Trix (liquid detergent as mixing agent) with 2.5 litres of water. The detergent was used to break the surface tension of water and to help the solubility of neem oil in water. This preparation might have repelling and antifeeding actions against fruit fly. The mixture was sprayed at each 7 days interval in the selected plots.

3.13.2. Management with soap water

Sex Soap water designed by BARI with cue-lure and soapy water, were used to conduct this experiment. The traps were hung up under bamboo scaffold, 60 cm above the ground. The soap water was replaced by new soap water at an interval of 4 days each. At each four days interval the number of insects trapped was recorded. In case of trapping, number of trapped fruit flies was counted. Total fruit and infested fruits were recorded and percentage of infested fruit was calculated.

3.13.3. Untreated control

The randomly selected 3 plots were kept untreated, where no treatment was applied.

3.14. Data collection: The collection of data was started at flower initiation of the tomato and collected from the fields at 7 days interval on following parameters:

3.14.1. Number of whitefly and number of TYLCV infected plant

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

3.14.2. Number of healthy and infected leaf

The number of healthy and infected leaf randomly selected 5tagged plants per plot at 7 days interval and counted separately for each treatment at each plot.

3.14.3. Number of inflorescence and fruit

The number of inflorescence and fruit randomly selected 5tagged plants per plot at 7 days interval and counted separately for each treatment at each plot.

3.14.4. Number of branch

The number of branch randomly selected 5tagged plants per plot at 7 days interval and counted separately for each treatment at each plot.

3.14.5. Total weight of fruits

For the estimation of total weight of fruits per plot, were randomly selected and weight was recorded, from each plot, at each time of data collection

3.14.6. Total number of fruits

For the estimation of total number of fruits per plot, fruits were randomly selected and counted from each plot, at each time of data collection

3.14.7. 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.

3.15. CALCULATION

3.15.1. 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:

$$\text{Percent of TYLCV infected plant} = \frac{\text{Number of TYLCV infected plant}}{\text{Total no. of plants per plot}} \times 100$$

3.15.2. Fruit infestation by number

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

$$\text{Percent of fruit infection by number} = \frac{\text{Number of infected fruit}}{\text{Total number of fruit}} \times 100$$

3.15.3. 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:

$$\text{Percent of fruit infection by weight} = \frac{\text{Weight of infected fruit}}{\text{Total fruit weight}} \times 100$$

3.15.4. 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:

$$\text{Percent infection reduction over control} = \frac{X1-X2}{X2} \times 100$$

Where, X1 = the mean value of the treated plot

X2 = the mean value of the untreated plot

3.15.5. 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:

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

3.16. 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 infestation.

3.17. SOME PLATES

	
Plate 1: Working in the field	Plate 2: Working in the field
	
Plate 3: Experimental field	Plate 4: Experimental field

CHAPTER IV

RESULT AND DISCUSSION

The results on the effect of eco-friendly management of white fly of tomato at the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during October, 2016 to March, 2017. The results of the present study have been discussed and possible interpretations are furnished and presented in this chapter under the following sub headings:

4.1. Effect of management practices on average number of white fly per 5 tagged plant per plot

The effect of management practices on white fly by number at early flowering stage has been shown in Table 1. Significant variations were observed among the treatments in terms of number of white fly per five tagged plant per plot of tomato. The highest number (16.67 white fly/ 5 tagged plant) of white fly of five tagged plant per plot was recorded in T_{10}, which was statistically different from other treatments and followed by T_9 (9.33 white fly/ 5 tagged plant), T_1 (7.67 white fly/ 5 tagged plant), T_2 (7.67 white fly/ 5 tagged plant), T_3 (7.33 white fly/ 5 tagged plant), T_4 (7.33 white fly/ 5 tagged plant) and T_8 (7.00 white fly/ 5 tagged plant). On the other hand, the lowest number (6.00 white fly/ 5 tagged plant) of white fly of five tagged plant per plot was recorded in T_5, which was statistically similar with T_7 (6.67 white fly/ 5 tagged plant) and T_6 (6.67 white fly/ 5 tagged plant).

In case of mid flowering stage, the highest number (45.00 white fly/ 5 tagged plant) of white fly of five tagged plant per plot was recorded in T_{10}, which was statistically different from other treatments and followed by T_9 (27.87 white fly/ 5 tagged plant), T_1 (27.67 white fly/ 5 tagged plant), T_2 (27.00 white fly/ 5 tagged plant), T_4 (26.33 white fly/ 5 tagged plant), T_3 (25.67 white fly/ 5 tagged plant) and T_8 (25.33 white fly/ 5 tagged plant). On the other hand, the lowest number (17.67 white fly/ 5 tagged plant) of white fly of five tagged plant per plot was recorded in T_5, which was statistically different from other treatments and followed by T_7 (22.00 white fly/ 5 tagged plant) and T_6 (22.00 white fly/ 5 tagged plant) (Table 1).

In case of late flowering stage, the highest number (13.33 white fly/ 5 tagged plant) of white fly of five tagged plant per plot was recorded in T_{10}, which was statistically different from other treatments and followed by T_9 (9.00 white fly/ 5 tagged plant), T_1 (8.33 white fly/ 5 tagged plant), T_2 (7.67 white fly/ 5 tagged plant), T_4 (6.67 white fly/ 5 tagged plant), T_3 (6.33 white fly/ 5 tagged plant) and T_8 (6.33 white fly/ 5 tagged plant). On the other hand, the lowest number (3.67 white fly/ 5 tagged plant) of white fly of five tagged plant per plot was recorded in T_5, which was statistically different from other treatments and followed by T_7 (4.00 white fly/ 5 tagged plant) and T_6 (4.33 white fly/ 5 tagged plant) (Table 1).

Considering the mean number of white fly of five tagged plant per plot, the highest number (25.00 white fly/ 5 tagged plant) of white fly of five tagged plant per plot was recorded in T_{10}, which was statistically different from other treatments and followed by T_9 (15.40 white fly/ 5 tagged plant), T_1 (14.56 white fly/ 5 tagged plant), T_2 (14.11 white fly/ 5 tagged plant), T_4 (13.44 white fly/ 5 tagged plant), T_3 (13.11 white fly/ 5 tagged plant) and T_8 (12.89 white fly/ 5 tagged plant). On the other hand, the lowest number

(9.11 white fly/ 5 tagged plant) of white fly of five tagged plant per plot was recorded in T_5, which was statistically different from other treatments and followed by T_7 (10.89 white fly/ 5 tagged plant) and T_6 (11.00 white fly/ 5 tagged plant) (Table 1).

Table 1. Effect of management practices on average number of white fly per five tagged plant per plot

Treatments	Average number of white fly of 5 tagged plant per plot				
	Early	Mid	Late	Mean	% reduction over control
T_1	7.67 c	27.67 b	8.33 b	14.56 b	41.77
T_2	7.67 c	27.00 b	7.67 cd	14.11 b	43.55
T_3	7.33 cd	25.67 bc	6.33 cd	13.11 bc	47.56
T_4	7.33 cd	26.33 bc	6.67 cd	13.44 bc	46.23
T_5	6.00 e	17.67 e	3.67 f	9.11 e	63.55
T_6	6.67 de	22.00 d	4.33 e	11.00 d	56.00
T_7	6.67 de	22.00 d	4.00 e	10.89 de	56.44
T_8	7.00 bcd	25.33 bc	6.33 cd	12.89 cd	48.45
T_9	9.33 b	27.87 b	9.00 b	15.40 b	38.40
T_{10}	16.67 a	45.00 a	13.33 a	25.00 a	0.00
LSD value	1.2682	1.9026	1.3294	1.5032	

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Spraying of garlic extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_4= Spraying of 3 gm /L Soap water at 7 days interval, T_5= T_1+T_4, T_5= T_2+T_4, T_6= T_3+T_4, T_8 = Spraying of Admire 200SL @ 0.2 ml mixed with per liter of water at 7 days interval, T_9= Spraying of Sevin 85 WP @ 3.4 gm mixed with per liter of water at 7 days interval, T_{10}=Untreated control]

From the above findings, the percent reduction of number of white fly, the highest reduction (63.55%) over control was observed in T_5, followed by T_7 (56.44%) and T_6 (56.00%). Whereas, the lowest reduction (38.40%) over control was observed in $T_{9.}$ In this case, more or less similar trend of average number of white fly of five tagged plant per plot was observed and the trend is T_{10}> T_9> T_1> T_2> T_4> T_3> T_8> T_6> T_7> T_5.

4.2. Effect of management practices on average number of TYLCV infected plant per plot

The effect of management practices on TYLCV infected plant by number at early flowering stage has been shown in Table 2. Significant variations were observed among the treatments in terms of TYLCV infection plants of tomato. The highest number (2.67 plant/plot) of infected plant per plot was recorded in T_{10}, which was statistically similar with T_9 (2.17 plant/plot), T_1 (1.83 plant/plot) and T_2 (1.67 plant/plot), followed by T_3 (1.33 plant/plot), T_8 (1.33 plant/plot) and T_4 (1.33 plant/plot). On the other hand, the lowest number (0.17 plant/plot) of infected plants per plot was recorded in T_5, which was statistically similar with T_7 (0.50 plant/plot) and T_6 (0.83 plant/plot).

In case of late flowering stage, the lowest number of infected plant (0.33 plant/plot) was recorded in T_5, which was statistically similar with T_7 (0.83 plant/plot) and T_6 (1.17 plant/plot). On the other hand, the highest number of infected plant (2.67 plant/plot) was recorded in T_{10} which was statistically similar with T_9 (2.33 plant/plot), T_1 (2.00 plant/plot), T_2 (2.00 plant/plot) and T_4 (2.00 plant/plot), followed by T_3 (1.50 plant/plot) and T_8 (1.50 plant/plot) (Table 2).

Considering the mean number of infected plant by TYLCV, the highest number of infected plant by TYLCV (2.67 plant/plot) was observed in T_{10} which was statistically similar with T_9 (2.33 plant/plot), T_1 (1.92 plant/plot) and T_2 (1.83 plant/plot), followed by T_4 (1.67 plant/plot), T_8 (1.46 plant/plot) and T_3 (1.41 plant/plot). On the other hand, lowest number of TYLCV infected plant (0.25 plant/plot) was observed in T_5 which was statistically different from other treatments and followed by T_7 (0.67 plant/plot) and T_6 (1.00 plant/plot) (Table 2).

Table 2. Effect of management practices on average number of Tomato Yellow Leaf Curl Virus (TYLCV) infected plant per plot

Treatments	Average number of TYLCV infested plant of 5 tagged plant per plot			
	Early	**Late**	**Mean**	**% reduction over control**
T_1	1.83 abc	2.00 abc	1.92 ab	28.14
T_2	1.67 abc	2.00 abc	1.83 ab	31.25
T_3	1.33 bcd	1.50 bcd	1.41 bc	46.89
T_4	1.33 bcd	2.00 abc	1.67 bc	37.51
T_5	0.17 e	0.33 e	0.25 e	90.63
T_6	0.83 cde	1.17 cde	1.00 c	62.50
T_7	0.50 de	0.83 de	0.67 d	75.00
T_8	1.33 bcd	1.50 bcd	1.46 bc	46.89
T_9	2.17 ab	2.33 ab	2.25 ab	15.64
T_{10}	2.67 a	2.67 a	2.67 a	0
LSD value	0.988	0.9690	0.9785	

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Spraying of garlic extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_4= Spraying of 3 gm /L Soap water at 7 days interval, T_5= T_1+T_4, T_5= T_2+T_4, T_6= T_3+T_4, T_8 = Spraying of Admire 200SL @ 0.2 ml mixed with per liter of water at 7 days interval, T_9= Spraying of Sevin 85 WP @ 3.4 gm mixed with per liter of water at 7 days interval, T_{10}=Untreated control]

From the above findings, the percent reduction of infected plant by number by TYLCV, the highest reduction (90.63%) over control was observed in T_5, followed by T_7 (75.00%)

and T_6 (62.50%). whereas, the lowest reduction (15.64%) over control was observed in T_9. In this case, more or less similar trend of average number of infected plant by TYLCV was observed and the trend is $T_{10} > T_9 > T_1 > T_2 > T_4 > T_3 > T_8 > T_6 > T_7 > T_5$.

4.3. Effect of management practices on number of infected branches of tomato plant

The effect of management practices on infected branches by number at early flowering stage has been shown in Table 3. Significant variations were observed among the treatments in terms of TYLCV infected branches of 5 tagged plants per plot of tomato. The highest number (77.33 branches/plot) of infected branches of 5 tagged plants per plot was recorded in T_{10}, which was statistically different from other treatments, followed by T_9 (60.17 branches/plot), T_1 (56.00 branches/plot) and T_2 (47.50 branches/plot). On the other hand, the lowest number (24.33 branches/plot) of infected branches of 5 tagged plants per plot was recorded in T_5, which was statistically different from other treatments and followed by T_7 (32.83 branches/plot), T_6 (42.00 branches/plot), T_8 (43.33 branches/plot), T_3 (43.67 branches/plot) and T_4 (46.17 branches/ plot).

In case of mid flowering stage, the lowest number (23.50 branches/plot) of infected branches of 5 tagged plants per plot was recorded in T_5, which was statistically similar with T_7 (31.00 branches/plot) and followed by T_8 (36.50 branches/plot), T_3 (37.33 branches/plot), T_6 (38.33 branches/plot) and T_4 (41.83 branches/ plot). On the other hand, the highest number (74.50 branches/plot) of infected branches of 5 tagged plants per plot was recorded in T_{10}, which was statistically similar with T_9 (65.50 branches/plot) and followed by T_1 (62.17 branches/plot) and T_2 (46.33 branches/plot) (Table 3).

In case of late flowering stage, the lowest number (24.67 branches/plot) of infected branches of 5 tagged plants per plot was recorded in T_5, which was statistically similar with T_7 (31.50 branches/plot) and followed by T_8 (33.83 branches/plot), T_6 (37.00 branches/plot) and T_3 (38.17 branches/plot). On the other hand, the highest number (73.83 branches/plot) of infected branches of 5 tagged plants per plot was recorded in T_{10}, which was statistically different from other treatments and followed by T_9 (63.00 branches/plot), T_1 (61.50 branches/plot), T_4 (47.50 branches/plot) and T_2 (47.33 branches/plot) (Table 3).

Considering the mean number of infected branches of 5 tagged plants per plot by TYLCV, the highest number of infected branches of 5 tagged plants by TYLCV (75.22 branches/plot) was observed in T_{10} which was statistically similar with T_9 (62.89 branches/plot) and followed by T_1 (59.89 branches/plot) and T_2 (47.05 branches/plot). On the other hand, the lowest number of TYLCV infected branches of 5 tagged plants (24.17 branches/plot) was observed in T_5 which was statistically similar with T_7 (31.78 branches/plot) and followed by T_8 (37.89 branches/plot), T_6 (39.11 branches/plot), T_3 (39.72 branches/plot) and T_4 (45.17 branches/plot) (Table 3).

Table 3. Effect of management practices on number of virus infected branches of tomato plant

Treatments	Average number of branches of 5 tagged plant per plot				
	Early	Mid	Late	Mean	% reduction over control
T_1	56.00 bc	62.17 b	61.50 b	59.89 b	20.38
T_2	47.50 bc	46.33 c	47.33 c	47.05 c	37.45
T_3	43.67 cd	37.33 cd	38.17 d	39.72 cd	47.20
T_4	46.17 cd	41.83 cd	47.50 c	45.17 cd	39.95
T_5	24.33 e	23.50 e	24.67 e	24.17 e	67.87
T_6	42.00 cd	38.33 cd	37.00 d	39.11 cd	48.01
T_7	32.83 de	31.00 de	31.50 de	31.78 de	57.75
T_8	43.33 cd	36.50 cd	33.83 d	37.89 cd	49.63
T_9	60.17 b	65.50 ab	63.00 b	62.89 ab	16.39
T_{10}	77.33 a	74.50 a	73.83 a	75.22 a	0
LSD value	12.92	10.64	8.123	10.56	

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Spraying of garlic extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_4= Spraying of 3 gm /L Soap water at 7 days interval, T_5= T_1+T_4, T_5= T_2+T_4, T_6= T_3+T_4, T_8 = Spraying of Admire 200SL @ 0.2 ml mixed with per liter of water at 7 days interval, T_9= Spraying of Sevin 85 WP @ 3.4 gm mixed with per liter of water at 7 days interval, T_{10}=Untreated control]

From the above findings, the percent reduction of infected branches of 5 tagged plants by number by TYLCV, the highest reduction (67.87%) over control was observed in T_5, followed by T_7 (57.75%), T_8 (49.63%), T_6 (48.01%) and T_3 (47.20%). Whereas, the lowest reduction (16.39%) over control was observed in T_9. In this case, more or less similar trend of average number of infected plant by TYLCV was observed and the trend is T_{10}> T_9> T_1> T_2> T_4> T_3> T_6> T_8> T_7> T_5. As plant is fixed, but infestation level is decreased because of maturity of plant and reduce the succulence of leaves of tomato plant.

4.4. Effect of management practices on fruit bearing status of tomato plant

4.4.1. Early flowering stage

Maximum (380.6 cm) plant height was found in T_5 which was statistically similar with T_6 (355.9 cm) and followed by T_7 (350.8 cm), T_8 (330.7 cm), T_3 (326.6 cm) and T_2 (300.1 cm). On the other hand, minimum (242.1 cm) plant height was found in T_{10} which was statistically similar with T_4 (248.4 cm) followed by T_9 (271.2 cm) and T_1 (281.3 cm) (Table 4). The trend was T_{10}> T_4> T_9> T_1> T_2> T_3> T_8> T_7> T_6> T_5.

The highest number of healthy leaves per plant (87.17 leaves/plant) was found in T_5 which was statistically similar with T_8 (71.83 leaves/plant) and T_7 (71.17 leaves/plant) and followed by T_6 (69.50 leaves/plant), T_3 (62.83 leaves/plant), T_2 (56.50 leaves/plant) and T_1 (54.17 leaves/plant). On the other hand, the lowest (36.33 leaves/plant) number of healthy leaves per plant was found in T_{10} which was followed by T_9 (47.33 leaves/plant) and T_4 (53.50 leaves/plant) (Table 4). The trend was T_{10}> T_9> T_4> T_1> T_2> T_3> T_6> T_7> T_8> T_5.

The highest number of infected leaves per plant (88.50 leaves/plant) was found in T_{10} which was statistically similar with T_4 (74.83 leaves/plant) and followed by T_9 (68.83 leaves/plant), T_1 (61.83 leaves/plant), T_2 (56.00 leaves/plant) and T_8 (55.00 leaves/plant). On the other hand, the lowest (31.83 leaves/plant) number of infected leaves per plant was found in T_5 which was statistically similar with T_6 (38.33 leaves/plant), T_7 (39.17

leaves/plant) and T_3 (43.50 leaves/plant) (Table 4). The trend was T_{10}> T_4> T_9> T_1> T_2> T_8> T_3> T_7> T_6> T_5.

Table 4. Effect of management practices on fruit bearing status (plant height and leaf infection by white fly) of tomato plant at early stage

Treatment	Plant height (cm)	Number of healthy leaves	Number of infected leaves	% of leaf infection
T_1	281.3 ef	54.17 cde	61.83 bc	53.30 bc
T_2	300.1 de	56.50 bcde	56.00 cd	49.78 cd
T_3	326.6 cd	62.83 bcde	43.50 de	40.91 cd
T_4	248.4 gh	53.50 de	74.83 ab	58.31 b
T_5	380.6 a	87.17 a	31.83 e	26.75 f
T_6	355.9 ab	69.50 bcd	38.33 e	35.55 ef
T_7	350.8 bc	71.17 abc	39.17 e	35.50 ef
T_8	330.7 bc	71.83 ab	55.00 cd	43.37 cd
T_9	271.2 fg	47.33 ef	68.83 bc	59.25 b
T_{10}	242.1 h	36.33 f	88.50 a	70.90 a
LSD value	27.13	15.84	14.44	

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Spraying of garlic extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_4= Spraying of 3 gm /L Soap water at 7 days interval, T_5= T_1+T_4, T_5= T_2+T_4, T_6= T_3+T_4, T_8 = Spraying of Admire 200SL @ 0.2 ml mixed with per liter of water at 7 days interval, T_9= Spraying of Sevin 85 WP @ 3.4 gm mixed with per liter of water at 7 days interval, T_{10}=Untreated control]

From the above findings, the level of infection, the lowest percent (26.75%) of leaves infected by number was recorded in T_5, which was statistically similar with T_7 (35.50%)

and T_6 (35.55%) and followed by T_3 (40.91%), T_8 (43.37%) and T_2 (49.78%). On the other hand, the highest percent (70.90%) of inflorescence infestation by number was recorded in T_{10} which was statistically different from other treatment and followed by T_9 (59.25%), T_4 (58.31%) and T_1 (53.30%). The trend was T_{10}> T_9> T_4> T_1> T_2> T_8> T_3> T_6> T_7> T_5.

4.4.2. Mid flowering stage

Maximum (394.9 cm) plant height was found in T_5 which was statistically similar with T_6 (379.6 cm), T_7 (378.4 cm), T_3 (369.5 cm) and T_8 (365.6 cm) and followed by T_2 (346.5 cm) and T_1 (323.7 cm). On the other hand, minimum (287.9 cm) plant height was found in T_{10} which was statistically similar with T_9 (304.5 cm) and followed by T_4 (317.7 cm) (Table 5). The trend was T_{10}> T_9> T_4> T_1> T_2> T_8> T_3> T_7> T_6> T_5.

The highest number of healthy leaves per plant (92.67 leaves/plant) was found in T_5 which was statistically similar with T_7 (88.00 leaves/plant) and T_6 (85.17 leaves/plant) and followed by T_8 (74.17 leaves/plant), T_3 (73.17 leaves/plant) and T_2 (61.83 leaves/plant). On the other hand, the lowest (38.67 leaves/plant) number of healthy leaves per plant was found in T_{10} which was followed by T_9 (55.50 leaves/plant), T_1 (55.50 leaves/plant) and T_4 (58.17 leaves/plant) (Table 5). The trend was T_{10}> T_9> T_1> T_4> T_2> T_3> T_8> T_6> T_7> T_5.

The highest number of infected leaves per plant (92.33 leaves/plant) was found in T_{10} which was statistically similar with T_1 (81.17 leaves/plant) and T_4 (80.67 leaves/plant) and followed by T_8 (74.33 leaves/plant), T_2 (72.67 leaves/plant) and T_9 (65.33 leaves/plant). On the other hand, the lowest (33.83 leaves/plant) number of infected leaves per plant was found in T_5 which was statistically similar with T_7 (39.17 leaves/plant) and T_6 (41.17 leaves/plant) and followed by T_3 (56.67 leaves/plant) (Table 5). The trend was $T_{10}> T_1> T_4> T_8> T_2> T_9> T_3> T_6> T_7> T_5$.

Table 5. Effect of management practices on fruit bearing status (plant height and leaf infection by white fly) of tomato plant at mid stage

Treatment	Plant height (cm)	Number of healthy leaves	Number of infected leaves	% of leaf infection
T_1	323.7 cd	55.50 bc	81.17 ab	59.39 bc
T_2	346.5 bc	61.83 b	72.67 bc	54.03 bc
T_3	369.5 ab	73.17 ab	56.67 d	43.65 cd
T_4	317.7 cde	58.17 bc	80.67 ab	58.10 bc
T_5	394.9 a	92.67 a	33.83 e	26.74 e
T_6	379.6 a	85.17 a	41.17 e	32.59 e
T_7	378.4 a	88.00 a	39.17 e	30.80 e
T_8	365.6 ab	74.17 ab	74.33 bc	50.05 bcd
T_9	304.5 de	55.50 bc	65.33 cd	54.07 bc
T_{10}	287.9 e	38.67 c	92.33 a	70.48 a
LSD value	29.56	20.28	12.95	

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Spraying of garlic extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_4= Spraying of 3 gm /L Soap water at 7 days interval, T_5= T_1+T_4, T_5= T_2+T_4, T_6= T_3+T_4, T_8 = Spraying of

Admire 200SL @ 0.2 ml mixed with per liter of water at 7 days interval, T_9= Spraying of Sevin 85 WP @ 3.4 gm mixed with per liter of water at 7 days interval, T_{10}=Untreated control]

From the above findings, the level of infection, the lowest percent (26.74%) of leaves infected by number was recorded in T_5, which was statistically similar with T_7 (30.80%) and T_6 (32.59%) and followed by T_3 (43.65%) and T_8 (50.05%). On the other hand, the highest percent (70.48%) of inflorescence infestation by number was recorded in T_{10} which was statistically different from other treatment and followed by T_1 (59.39%), T_4 (58.10%), T_9 (54.07%) and T_2 (54.03%). The trend was T_{10}> T_1> T_4> T_9> T_2> T_8> T_3> T_6> T_7> T_5.

4.4.3. Late flowering stage

Maximum (399.3 cm) plant height was found in T_5 which was statistically similar with T_7 (386.0 cm), T_6 (374.3 cm) and T_3 (362.6 cm) and followed by T_8 (351.4 cm) and T_2 (339.3 cm). On the other hand, minimum (293.2 cm) plant height was found in T_{10} which was statistically similar with T_9 (302.0 cm) and followed by T_4 (327.2 cm) and T_1 (332.1 cm) (Table 6). The trend was T_{10}> T_9> T_4> T_1> T_2> T_8> T_3> T_6> T_7> T_5.

The highest number of healthy leaves per plant (96.83 leaves/plant) was found in T_5 which was statistically similar with T_7 (87.67 leaves/plant), T_6 (83.oo leaves/plant) and T_3 (82.33 leaves/plant) and followed by T_8 (70.67 leaves/plant), T_1 (65.67 leaves/plant) and T_2 (64.17 leaves/plant) and T_4 (63.00 leaves/plant). On the other hand, the lowest

(38.67 leaves/plant) number of healthy leaves per plant was found in T_{10} which was statistically similar with T_9 (50.17 branches/plant) (Table 6). The trend was T_{10}> T_9> T_4> T_2> T_1> T_8> T_3> T_6> T_7> T_5.

The highest number of infected leaves per plant (100.5 leaves/plant) was found in T_{10} which was statistically different from other treatments and followed by T_1 (83.33 leaves/plant), T_4 (81.00 leaves/plant), T_9 (73.17 leaves/plant), T_2 (63.17 leaves/plant) and T_8 (60.00 leaves/plant). On the other hand, the lowest (33.50 leaves/plant) number of infected leaves per plant was found in T_5 which was statistically similar with T_7 (41.83 leaves/plant) and T_6 (45.33 leaves/plant) and followed by T_3 (51.17 leaves/plant) (Table 6). The trend was T_{10}> T_1> T_4> T_9> T_2> T_8> T_3> T_6> T_7> T_5.

Table 6. Effect of management practices on fruit bearing status (plant height and leaf infection by white fly) of tomato plant at late stage

Treatment	Plant height (cm)	Number of healthy leaves	Number of infected leaves	% of leaf infection
T_1	332.1 def	65.67 cd	83.33 b	55.93 b
T_2	339.3 cde	64.17 cd	63.17 cd	49.61 bc
T_3	362.6 abcd	82.33 ab	51.17 def	38.33 de
T_4	327.2 def	63.00 cd	81.00 b	56.25 b
T_5	399.3 a	96.83 a	33.50 g	25.70 e
T_6	374.3 abc	83.00 ab	45.33 efg	35.32 de
T_7	386.0 ab	87.67 a	41.83 fg	32.30 de
T_8	351.4 bcd	70.67 bc	60.00 cde	45.92 cd
T_9	302.0 ef	50.17 de	73.17 bc	59.32 b
T_{10}	293.2 f	38.67 e	100.5 a	72.21 a
LSD value	36.71	15.25	15.72	

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Spraying of garlic extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_4= Spraying of 3 gm /L Soap water at 7 days interval, T_5= T_1+T_4, T_5= T_2+T_4, T_6= T_3+T_4, T_8 = Spraying of Admire 200SL @ 0.2 ml mixed with per liter of water at 7 days interval, T_9= Spraying of Sevin 85 WP @ 3.4 gm mixed with per liter of water at 7 days interval, T_{10}=Untreated control]

From the above findings, the level of infection, the lowest percent (25.70%) of leaves infected by number was recorded in T_5, which was statistically similar with T_7 (32.30%), T_6 (35.32%) and T_3 (38.33%) and followed by T_8 (45.92%). On the other hand, the highest percent (72.21%) of leaves infected by number was recorded in T_{10} which was statistically different from other treatment and followed by T_9 (59.32%), T_4 (56.25%), T_1 (55.93%) and T_2 (49.61%). The trend was T_{10}> T_9> T_4> T_1> T_2> T_8> T_3> T_6> T_7> T_5.

4.5. Effect of management practices on yield contributing characters

The highest number of total fruit per plot (349.3 fruits/plot) was found in T_5. This was followed by T_7 (289.0 fruits/plot), T_6 (284.3 fruit/plot), T_3 (279.7 fruits/plot) and T_8 (229.7 fruits/plot). On the other hand, the lowest number of total fruit per plot (116.0 fruits/plot) was found in T_{10} which was statistically similar with T_9 (143.0 fruits/plot), T_4

(147.7 fruits/plot) and T_1 (172.3 fruits/plot) and followed by T_2 (184.3 fruits/plot) (Table 7). The trend was $T_5 > T_7 > T_6 > T_3 > T_2 > T_1 > T_4 > T_9 > T_{10}$.

The highest fruit weight per plot (9.02 kg/plot) was observed in T_5 which was statistically similar with T_7 (8.23 kg/plot), T_6 (8.18 kg/plot) and T_8 (7.38 kg/plot) and followed by T_3 (7.17 kg/plot), T_2 (6.59 kg/plot) and T_1 (6.44 kg/plot). On the other hand, the lowest fruit weight per plot (5.69 kg/plot) was observed in T_{10} which was followed by T_9 (5.99 kg/plot) and T_4 (6.27 kg/plot) (Table 7). The trend was $T_5 > T_7 > T_6 > T_8 > T_3 > T_2 > T_1 > T_4 > T_9 > T_{10}$.

Table 7. Effect of management practices on number of fruit, weight of fruit and yield of tomato

Treatments	Number of total fruit /plant / plot	Weight of fruit per plot (kg/plot)	Total yield (ton/ha)
T_1	172.3 ef	6.44 bc	26.83 bc
T_2	184.3 de	6.59 bc	27.44 bc
T_3	279.7 bc	7.17 bc	29.86 ab
T_4	147.7 ef	6.27 cd	26.11 c
T_5	349.3 a	9.02 a	37.60 a
T_6	284.3 bc	8.18 ab	34.10 a
T_7	289.0 b	8.23 ab	34.30 a
T_8	229.7 cd	7.38 ab	30.73 ab
T_9	143.0 ef	5.99 cd	24.95 d
T_{10}	116.0 f	5.69 d	23.70 e
LSD vale	53.93	1.31	1.89

[In a column, means followed by the same letter(s) are not significantly different at 1% level of probability by Duncan's Multiple Range Test (DMRT). Here,T_1= Spraying of neem oil @ 3 ml neem oil and 10 ml trix mixed with per liter of water at 7 days interval, $T_{2=}$ Spraying of neem seed kernel extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_3= Spraying of garlic extract @ 0.5 ml neem seed kernel extract mixed with per liter of water at 7 days interval, T_4= Spraying of 3 gm /L Soap water at 7 days interval, T_5= T_1+T_4, T_5= T_2+T_4, T_6= T_3+T_4, T_8 = Spraying of Admire 200SL @ 0.2 ml mixed with per liter of water at 7 days interval, T_9= Spraying of Sevin 85 WP @ 3.4 gm mixed with per liter of water at 7 days interval, T_{10}=Untreated control]

Statistically significant variation was recorded in yield (ton/ha) of tomato for different control measures (Table 7). The highest yield (37.60 ton/ha) was recorded in T_5 which was statistically similar with T_7 (34.30 ton/ha) and T_6 (34.10 ton/ha) and followed by T8 (30.73 ton/ha), T_3 (29.86 ton/ha), T_2 (27.44 ton/ha) and T_1 (26.83 ton/ha). On the other hand, the lowest yield (23.70 ton/ha) was recorded in T_{10} followed by T_9 (24.95 ton/ha) and T_4 (26.11 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 white fly and TYLCV virus as $T_5 > T_7 > T_6 > T_8 > T_3 > T_2 > T_1 > T_4 > T_9 > T_{10}$.

4.6. Relationship between number of white fly and yield of tomato

Significant relationship was found between number of white fly and yield of tomato plant when correlation was made between these two parameters. The highly significant ($p<0.01$), strong ($R^2=0.6177$) and negative (slope=0.8324) correlation was found between number of white fly and yield of plant (Fig. 1). Yield of tomato increases with the decreases of number of white fly tomato plant.

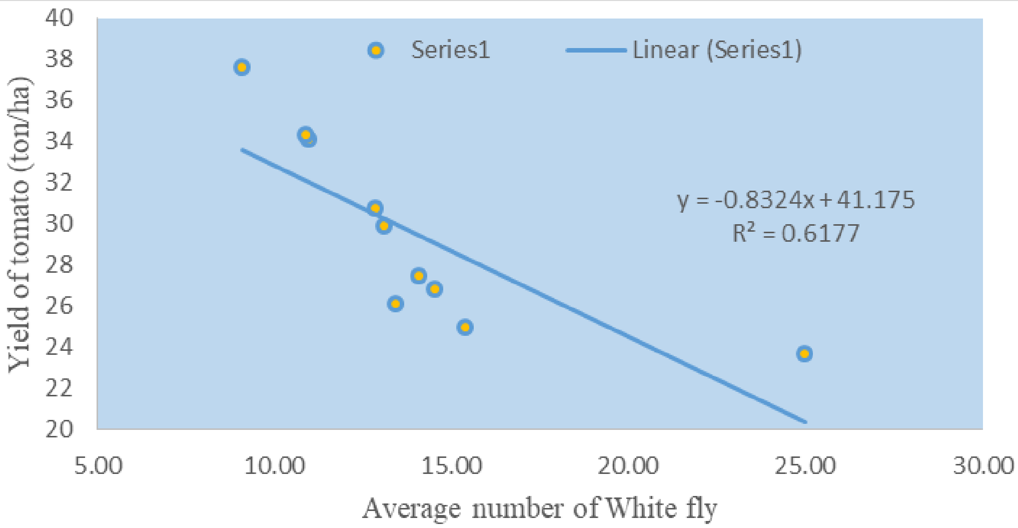

Figure 1: Relation between number of white fly and yield of tomato

4.7. Relationship between number of TYLCV infected plant and yield of tomato

Significant relationship was found between number of TYLCV infected plant and yield of tomato plant when correlation was made between these two parameters. The highly significant ($p<0.01$), strong ($R^2=0.9425$) and negative (slope= 6.1145) correlation was found between number of TYLCV infected plant and yield of plant (Fig. 2). Yield of tomato increases with the decreases of number of TYLCV infected tomato plant.

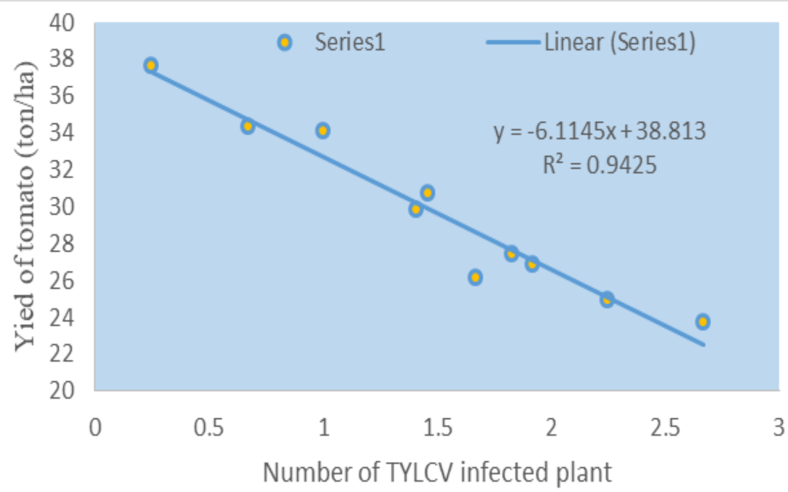

Figure 2: Relation between number of TYLCV infected plants and yield of tomato

4.8. Relationship between number of infected branches and yield of tomato

Significant relationship was found between number of TYLCV infected branches and yield of tomato plant when correlation was made between these two parameters. The highly significant ($p<0.01$), strong ($R^2= 0.8013$) and negative (slope= 0.2643) correlation was found between number of TYLCV infected branches and yield of tomato plant (Fig.

3). Yield of tomato decreases with the increasing of number of TYLCV infected branches.

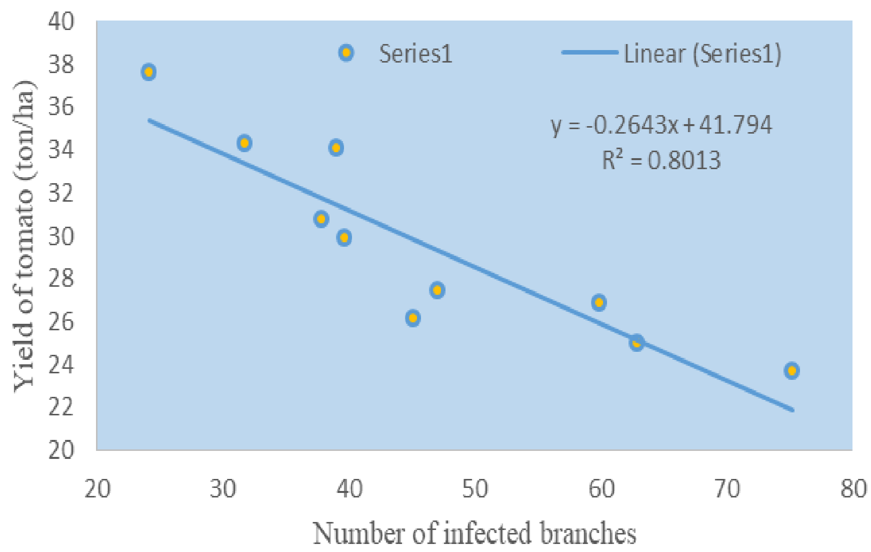

Figure 3: Relation between number of infected branches and yield of tomato

4.9. Relationship between number of fruit and yield of tomato

Significant relationship was found between number of total fruit of tomato and yield of tomato plant when correlation was made between these two parameters. The highly significant ($p<0.01$), strong (R^2=0.9344) and positive (slope= 0.0567) correlation was found between number of total fruit of tomato and yield of tomato plant (Fig. 4). Yield of tomato increases with the increases of number of total fruit of tomato.

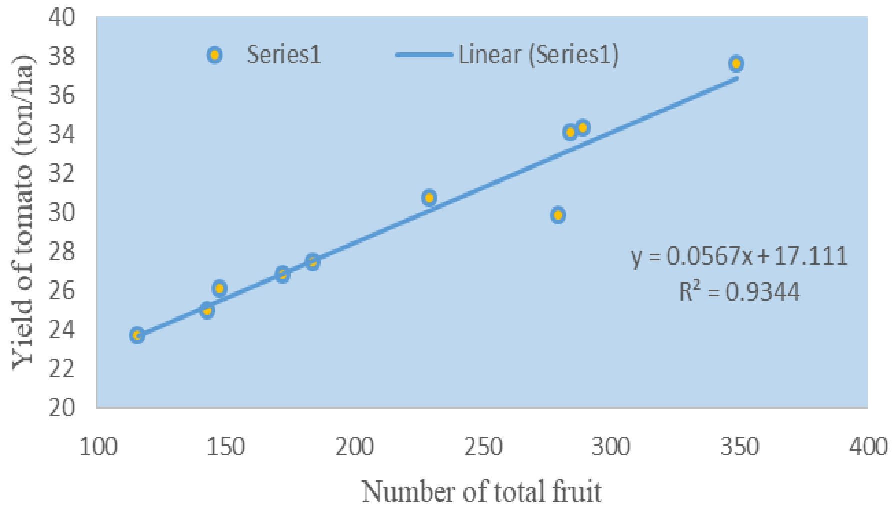

Figure 4: Relation between number of total fruit and yield of tomato

4.10. Relationship between fruit weight and yield of tomato

Significant relationship was found between weight of total fruit of tomato and yield of tomato plant when correlation was made between these two parameters. The highly significant ($p<0.01$), strong ($R2= 1$) and positive (slope= 4.1757) correlation was found between weight of total fruit of tomato and yield of tomato plant (Fig. 5). Yield of tomato increases with the increases of weight of total fruit of tomato.

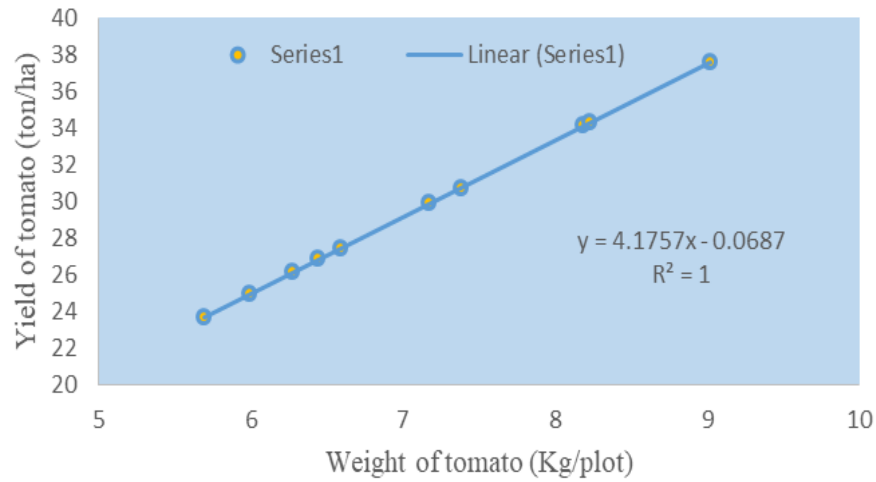

Figure 5: Relation between weight of fruit and yield of tomato

CHAPTER V

SUMMARY AND CONCLUSION

The present study was conducted to evaluate the eco-friendly management of major insect pests of tomato at the experimental field of Sher-e-Bangla Agricultural University (SAU), Dhaka, Bangladesh during October, 2016 to March, 2017. The experiment consisted of control measures with chemical, botanical and physical methods.

Considering the mean number of white fly of five tagged plant per plot, the highest number (25.00 white fly/ 5 tagged plant) of white fly of five tagged plant per plot was recorded in T_{10} but on the other hand, the lowest number (9.11 white fly/ 5 tagged plant) of white fly of five tagged plant per plot was recorded in T_5.

Considering the mean number of infected plant by TYLCV, the highest number of infected plant by TYLCV (2.67 plant/plot) was observed in T_{10} which was statistically similar with T_9 (2.33 plant/plot), T_1 (1.92 plant/plot) and T_2 (1.83 plant/plot) but on the other hand, lowest number of TYLCV infected plant (0.25 plant/plot) was observed in $T_{5.}$

Considering the mean number of infected branches of 5 tagged plants per plot by TYLCV, the highest number of infected branches of 5 tagged plants by TYLCV (75.22 branches/plot) was observed in T_{10} which was statistically similar with T_9 (62.89 branches/plot) but on the other hand, the lowest number of TYLCV infected branches of 5 tagged plants (24.17 branches/plot) was observed in T_5 which was statistically similar with T_7 (31.78 branches/plot).

In early flowering stage, maximum (380.6 cm) plant height was found in T_5 and minimum (242.1 cm) plant height was found in T_{10}.

Considering the level of infection, the lowest percent (26.75%) of leaves infected by number was recorded in T_5 and highest percent (70.90%) of inflorescence infestation by number was recorded in $T_{10.}$

In case of mid flowering stage, maximum (394.9 cm) plant height was found in T_5 and minimum (287.9 cm) plant height was found in T_{10}.

Considering the level of infection, the lowest percent (26.74%) of leaves infected by number was recorded in T_5 and the highest percent (70.48%) of inflorescence infestation by number was recorded in T_{10}.

In case of late flowering stage, maximum (399.3 cm) plant height was found in T_5 and minimum (293.2 cm) plant height was found in T_{10}.

Considering the level of infection, the lowest percent (25.70%) of leaves infected by number was recorded in T_5 and the highest percent (72.21%) of leaves infected by number was recorded in T_{10}.

Statistically significant variation was recorded in yield (ton/ha) of tomato for different control measures. The highest yield (37.60 ton/ha) was recorded in T_5 which was statistically similar with T_7 (34.30 ton/ha) and T_6 (34.10 ton/ha). On the other hand, the lowest yield (23.70 ton/ha) was recorded in T_{10} followed by T_9 (24.95 ton/ha) and T_4 (26.11 ton/ha).

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

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

1. Further study may be needed for ensuring the efficiency of botanical pesticides in relation to growth and yield performance in different agro-ecological zones (AEZ) of Bangladesh for regional adaptability.

2. More mechanical and botanical treatments against white fly may be needed to include for future study as sole or different combination to avoid total rely on insecticides.

CHAPTER VI

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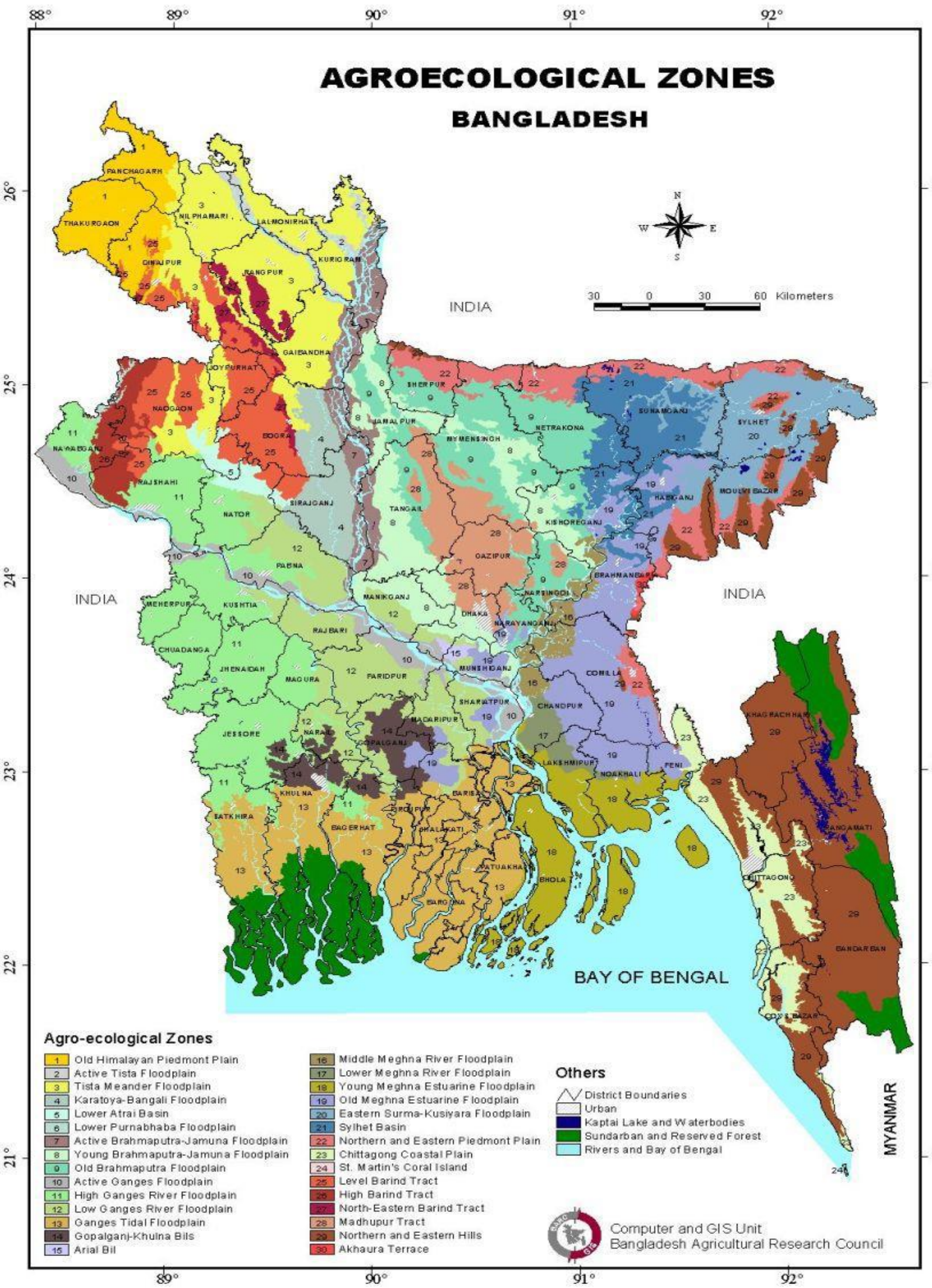
CHAPTER VII

APPENDICES

Appendix I. Agro-Ecological Zones of Bangladesh



Appendix II. Monthly record of air temperature, rainfall and relative humidity of the experimental site during the period from November 2016 to February 2017

Date/Week	Air temperature (^{0}C)		R. H. (%)	Rainfall (mm) (Total)
	Maximum	Minimum		
November, 2016	25.8	16.0	78	0
December, 2016	22.4	13.5	74	0
January, 2017	24.5	12.4	68	0
February, 2017	27.1	16.7	67	30

Source: Bangladesh Meteorological Department (Climate and Weather Division), Agargoan, Dhaka-1207.

Appendix III: Morphological characteristics of the experimental field

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

Source: SRDI, 2013

Appendix IV. The physical and chemical characteristics of soil of the experimental site as observed prior to experimentation (0-15 cm depth)

CONSTITUENTS	PERCENT
Sand	26
Silt	45
Clay	29
Textural class	Silty clay

Chemical composition:

Soil characters	Value
Organic carbon (%)	0.54
Organic matter %	0.45
Total nitrogen (%)	0.027
Phosphorus	6.3 µg/g soil
Sulphur	8.42 µg/g soil
Magnesium	1.17 meq/100 g soil
Boron	0.88 µg/g soil
Copper	1.64 µg/g soil
Zinc	1.54 µg/g soil
Potassium	0.10 meq/100g soil

Source: Soil Resources Development Institute (SRDI), Khamarbari, Dhaka