MANAGEMENT OF *TOMATO YELLOW LEAF CURL VIRUS* THROUGH INSECTICIDES, BOTANICALS AND LIGHT REFLECTING SILVER COLORED MULCH

BY

SOMIYA AKTER

DEPARTMENT OF PLANT PATHOLOGY

SHER-E-BANGLA AGRICULTURAL UNIVERSITY

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Approved by:

Dr. Md. Belal Hossain

Associate Professor

Department of Plant Pathology

Sher-e-Bangla Agricultural University

Supervisor

Dr. Nazneen Sultana

Professor

Department of Plant Pathology

Sher-e-Bangla Agricultural University

Co-supervisor

Prof. Khadija Akhter

Chairman

Examination Committee

Department of Plant Pathology

Dr. Md. Belal Hossain
Associate Professor
Department of Plant Pathology
Sher-e Bangla Agricultural University
Dhaka-1207, Bangladesh
Cell Number: +88 01711988444
E-mail: mbhossainsau@yahoo.com

CERTIFICATE

*This is to certify that thesis entitled, "***MANAGEMENT OF *TOMATO YELLOW LEAF CURL VIRUS* THROUGH INSECTICIDES, BOTANICALS AND SILVER COLORED MULCH"***submitted to the Department of Plant Pathology, Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of MASTER OF SCIENCE IN PLANT PATHOLOGY, embodies the result of a piece of bona fide research work carried out by SOMIYA AKTER bearing Registration No. 11-04394 under my directsupervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any institute.*

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
Dr.Md.Belal Hossain
Dhaka, Bangladesh
Supervisor

Dedicated

To

My Beloved Parents

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The Author

MANAGEMENT OF *TOMATO YELLOW LEAF CURL VIRUS* THROUGH INSECTICIDES, BOTANICALS AND LIGHT REFLECTING SILVER COLORED MULCH

ABSTRACT

A field experiment was conducted at the Plant Pathology experimental field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during October 2016 to March 2017. The study was aimed to manage the *Tomato yellow leaf curl virus (TYLCV)* through insecticides, botanicals and physiological method using light reflecting silver colored mulch. In this study, in total 7 treatments including control were considered *viz*. T_1 =Imidacloprid, T_2 = ACmix, T_3 = Subicron, T_4 =Neemax, T_5 = Multineem, T_6 = light reflecting silver colored mulch and T_7 = Control. High yielding tomato variety BARI Tomato-14 that is susceptible to *TYLCV* was used. The field experiment was carried out in randomized complete block design with three replications. All the treatments showed significant influence on different assayed parameters in the test crop tomato. The lowest disease incidence (%), disease severity (%) and whitefly association was found in T_6 (light reflecting silver colored mulch) that was 13.33%, 1.96% and 2.0 respectively at 60 DAT. The highest disease incidence %, Disease severity % and whitefly association was found in $T_{7,}$ (control treatment) that was 46.67%, 46.22% and 18 respectively at 60 DAT. From the relationship study between disease incidence (%), and disease severity (%) with whitefly association, it was revealed that disease incidence and severity of *TYLCV* was increased with increasing of whitefly population and vise-versa. Among the treatments, growth parameters, yield and yield attributers were also found better in T_6 treatment (light reflecting silver colored mulch). From this study we can concluded that physical method is the best option instead of insecticides for controlling the insect vectors of *TYLCV*.

LIST OF CONTENTS

LIST OF CONTENTS (Cont'd)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

%	=	Percentage
AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSRI	=	Bangladesh Council of Scientific Research Institute
Ca	=	Calcium
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
e.g.	=	exempli gratia (L), for example
et al.,	=	And others
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
GM	=	Geometric mean
i.e.	=	id est (L), that is
K	=	Potassium
Kg	=	Kilogram (s)
L	=	Litre
LSD	=	Least Significant Difference
M.S.	=	Master of Science
m^2	=	Meter squares
mg	=	Miligram
ml	=	MiliLitre
NaOH	=	Sodium hydroxide
No.	=	Number
^oC	=	Degree Celceous
P	=	Phosphorus
SAU	=	Sher-e-Bangla Agricultural University
USA	=	United States of America
var.	=	Variety
WHO	=	World Health Organization
Mg	=	Microgram

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is belongs to the nightshade family Solanaceae. It is one of the most popular and nutritious vegetable all over the world including Bangladesh and second most growing vegetables next to potato. The world tomato productions scenarios are about 150 million tons of tomatoes were produced in the world in 2009. The largest producer China (41,864,750 tons), accounted for about one quarter of the global production followed by USA (12,902,000 tons) and India (11,979,700 tons) (FAO, 2013). At present, in Bangladesh 6.85% area in under tomato cultivation both in summer andwinter, the total production of tomato was about 2,32,000 tons from 24,700 hectares of land with an average yield of 9.39 tons per hectare (BBS, 2016). The yield of the tomato in Bangladesh is very low compare to those of some advanced tomato growing countries (Sharfuddin and Siddique, 1985).

Tomato is often described as "poor man orange" because it is a rich source of minerals, vitamins and organic acids. Nutritionally, it is a significant dietary source of vitamin A and C. Furthermore, recent studies have shown the importance of lycopene, a major component of red tomatoes, which has strong antioxidant properties that can act against human diseases such as cancer and heart disorders. It is also a good source of calcium, iron, minerals etc. (Matin *et al.,* 1996).

Tomato production in Bangladesh is affected by many factors, among them insect pest attack is the major one. Damage caused by the insect pest to commercial tomato may be directly through phloem feeding, or indirectly by the transmission of plant viruses such as *Tomato Yellow Leaf Curl Virus (TYLCV*) (Mehta *et al.,* 1994).*TYLCV*is one of the most important diseases of tomato causing heavy losses in yield and quality of fruits. It is one of the devastating diseases of the tomato crop and depending on the severity and stage of the infection causing heavy losses in yield (Kalloo, 1988). Yield loss exceeds 90 per cent, when infection occurred within four weeks after transplanting in the field (Saikia and Muniyappa, 1989).

The whitefly (*Bemisia tabaci*) is one of the most economically important pests of tomato in many tropical and sub-tropical regions (Block, 1982). It is polyphagous pests of great significance in agriculture worldwide (Kontsedalov *et al.,* 2012) and currently its host range has crossed 600 plant species (Oliveria *et al.,* 2001). It causes damage by sucking cell sap, secreting the honey dews and transmits a number of viral diseases (Khan and Ahmed, 2005).The insect whitefly breeds throughout the year and the female lays stalked yellow spindle shaped eggs singly on the lower surface of the leaf. Nymphs and adults suck the sap usually from the under surface of the leaves and excrete honeydew. Leaves appear sickly and get coated with sooty mold (Jayaraj et al. 1986). The whitefly serves as the potential vector for the spread of *Tomato Yellow Leaf Curl Virus* disease causing severe damage to tomato crop. The whitefly can acquire the virus after feeding on infected plants for 15 to 30 minutes, and can transmit the virus to tomato plants after about 24 hours of incubation within the insect. A period of at least 15 minutes feeding on the new tomato host is subsequently required for transmission of the virus. The whitefly retains the virus for up to 20 days and does not transmit it to its progeny. Symptoms develop on young plants after 10 to 14 days. Hot and dry conditions favor the whitefly, and therefore, help the spread of *TYLCV*. Whitefly populations decrease after heavy rain showers. Under normal conditions whiteflies are passively wind-driven over long distances. During the night they settle on the lower leaf surfaces. Disease incidence increases rapidly and can reach 100% infection at harvest. In the field, disease incidence varies with location rather than with season. Tobacco is a symptomless host and can therefore serve as a source for re-infection of tomato crops.

Hence, whitefly infestation can cause severe and also transmitted *Tomato Yellow Leaf Curl Virus* performed transmission by it, and crop damage can be reached up to 100%, so, it is urgently needed to control whitefly for successful tomato production in our country. Among the various control practices to suppress the prevalence of whitefly insecticides are the mostly used.Several crop protection chemicals belonging to organochlorine, organophosphate and carbamate group have been used to control insect pests. However, the application of these insecticides left a film of persistent poison over the foliage and fruits (Dikshit *et al.,* 2000) and insect developed resistance to these insecticides (Denholm *et al.*, 1996). Therefore, there is a need to replace these conventional insecticides with newer molecules with a lesser dose of a few grams per hectare. Profenophos (organophosphate group), imidacloprid (neo – nicotinyl group), cypermethrin (synthetic pyrethroid group), indoxacarb (oxadiazine group), profenophos + cypermethrin (mixture of organophosphate and synthetic pyrethroid) are new molecules and reported to be effective and economical in controlling insect- pests in many vegetable crops (Shah et al., 2012).The organochlorine and organophosphorus compounds have been reported to pose a potential threat to all types of ecosystem (Nayar et a., 1992). Different groups of insecticides have been recommended to control this white fly (Satpathy et al., 2004), and Suryawanshi et al., 2000).To consider the negative effects of insecticides used in controlling the whitefly population less toxic and environmentally friendly techniques are need to be introduced.

The purpose of this study was to find out the suitable chemical that would be less toxic, botanicals or other management practice like mulching through this way it may be possible to control the insect vector, whitefly. In some previous research has also evaluated less toxic and more environmentally safe phyto-chemicals to control whitefly. For example- Neemax (Neem leaf Extract) and Multineem (Neem Oil) and different types of mulching to regulate the population of whitefly.

OBJECTIVES

This study was carried out to achieve the following specific objectives-

1. To evaluate the disease incidence and severity of *Tomato yellow leaf curl virus (TYLCV).*
2. To control the insect vector, whitefly (*Bemisia tabaci*) by using selected insecticides, botanicals and Silver colored mulch for management of *TYLCV*.
3. To increase the ultimate yield of tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato (*Solanum lycopersicum* L.) is one of the most popular and widely grown vegetables in the world ranking second in importance to potato in many countries. Pest and diseases are the major limiting factors in tomato cultivation. Tomato leaf curl virus disease has recently emerged as a major threat to the cultivation and production of tomato in Bangladesh.

2.1 Historical Perspective

The first incidence of Tomato yellow leaf curl virus (*TYLCV*) in Israel drew attention of the scientists due to its high prevalence in the field and severe damage to the crops (Cohen and Nitzany, 1966). In the early 1960s *TYLCV* was reported as one of the most economically important viruses among the Gemini viruses infecting tomato in different tomato growing areas of the world (Polston and Anderson, 1997). Worldwide distribution of *TYLCV* as a severe virus of tomato was recognized by Goodman in a review paper published in (1981). Semi-persistent transmission of the virus by whitefly*(Bemisia tabaci*) and non-availability of tomato cultivars makes the situation more vulnerable in respect to the management of *TYLCV* (Polston and Anderson, 1997). In the paper published by Polston and Anderson (1997), Al-Musa (1982), Tomlinson (1987) suggested the management of *TYLCV* by growing tomato seedlings in insect proof protective conditions, manipulation of the sowing time, planting of trap crops in the tomato field, as well as judicial use of insecticide as integrated pest management components.

Tomato yellow leaf curl virus (*TYLCV*) mainly affects tomatoes but other crops paprika (*Capsicum annuum*), bean (*Phaseolus vulgaris*), tobacco, lisianthus (*Eustoma grandiflorum*), Zinnia, etc. were also sensitive. Some weeds, with or without symptoms that were widely distributed in France can serve as reservoirs

(*Solarium nigrum*, *Datura stramonium*, and *Malva sp*.) reported by Dalmon and Marchoux (2000).

In spain two viral species of tomato yellow leaf curl virus were present, *TYLCV*-Sar and *TYLCV*-Is. *TYLCV*-Sar (43.4%) and *TYIXV*-Is(56.6%) coexisted in tomato crops and displacement of *TYLCV*-Sar for *TYLCV*-Is was observed. A search for alternative hosts that may serve as disease reservoirs wasconducted by testing 210 samples of 95 weed species. The following species were found to beinfected: *Conyza sumatrensis, Chenopodium murale*, *Datura stramonium, Dittrichia viscosa*, *Malva parviflora*, *Solarium nigrum*, *Convolvulus* sp., and *Cuscuta* sp. This was the first reference of *Conyza sumatrensis*, *Chenopodium murale*, *Convolvulus* sp. and *Cuscuta* sp. as natural hosts of *TYLCV* reported by Jorda *et al*. (2001).

Tomato is affected by two types of leaf curl virus *viz*. *Tomato yellow leaf curl virus (TYLCV*) and *Tomato leaf curl virus (ToLCV*). *Tomato yellow leaf curl virus* was first reported from Israel by Avidov in 1940. Martinez *et al*. (2003) reported the infection of this disease around 7 million ha of crop plants in 40 countries and so far it is not reported from Indian subcontinent (Rishi, 2004; Glick *et al*., 2009).

2.2 Disease symptoms

In the world,*Tomato yellow leaf curl virus (TYLCV*) was first studied by Cohen and Harpez (1964) in Israel. They studied the symptoms, damaging nature and involvement of whitefly with a new disease of tomato plant in Israel. The disease was studied extensively by Cohen and Nitzany (1966) in respect to transmission and host range and named the causal virus as Tomato yellow leaf curl virus (*TYLCV*).

Singh and Sastry (1979) reported that *TYLCV* was characterized by severe stunting of plants with downward rolling and crinkling of leaves. The newly formed leaves also exhibited cholorosis symptoms. Older leaves became leathery and brittle. The nodes and internodes were much reduced in size. The infected plant looked pale and produced more lateral branches resulting in bushy growth.

Dhanju and Verma (1987) mentioned that *TYLCV* was a complex disease with symptoms of crinkling, yellowing and premature withering of leaves together with stunting and profuse branching of plant. They observed that the disease occurred due to combined infection more than one virus.

Pilowsky and Cohen (1990) demonstrated that in Israel *TYLCV* caused severe damage of tomatoes. The affected plants were markedly stunted and their branches and petioles tend to assume erect positions. Leaflets were rolled upward and inward showing interveinal chlorosis. Infected plants were smaller than healthy plants. Fruits sets were greatly reduced and infected young plants produced almost no marketable yield.

Abdel Salam (1991) stated that tomato leaf curl virus, causing various symptoms of leaf curl interveined yellowing and stunting. Both *Phaseolus vulgaris* cv. *Bouniful* and *Xanthium* developed lesion on the primary leaves folded by systemic infection and developed lesion on the primary leaves followed by systemic infection.

Moriones *et al.* (1993) observed symptoms of *TYLCV* as typical yellowing and curling of leaf margin and general stunting of tomato plants in eastern Spain in autumn 1992. This was the first report of *TYLCV* in Spain.

Bosco (1993) reported the epidemiology of *TYLCV* and distribution of *B. tabaci* in Sardinia and some others parts of Italy. The vector was found on nine wild and six cultivated plant species besides tomato. None of the wild plant species was naturally infected by *TYLCV*, but *Solarium* could be infected experimentally and showed clear typical symptoms of *TYLCV*.

As reported by McGlashan *et al.* (1994) from Jamaica tomato fields during the spring 1993 and 1994, which displayed symptoms, consisted of upward curling of the leaves, severely reduced leaf size, yellowing of the leaf margin and veins, flower abscission and severe plant stunting.

Kegler (1994) reviewed disease of tomato plants infected by *TYLCV* and noted that the infected plants were stunted, developed small chlorotic leaflets and curled lamina between the veins.

Polizzi *et al.* (1994) suggested that the type of symptoms varied depending on the temperature and the time of infection. However, stunting reduced leaf and mild chlorosis having reduced number of fruits and fruit size were observed.

2.3 Diagnosis and identification of virus

Czosnek *et al.* (1988) purified the *TYLCV* particles from infected tomato and datura plants and detected typical twined particles, characteristic of members of the geminivirus group. They confirmed that viruses containing fractions of purified preparations were infective in membrane transmission test with the white fly vector. They also characterised the genome of the virus particles as a circular single-strand DNA containing about 2800 nucleotides.

Navot *et al.* (1989) developed a method for rapid detection of *TYLCV* in squashes of infected plants and insects vector. They described that DNA sequence of *TYLCV* was detected specifically and sensitively by hybridization of infected plant tissues quashed onto a nylon membrane (Squash blot) with a specific DNA probe. No treatment of the sample was necessary before quashing and hybridization. The DNA of *TYLCV* could be detected in squash blots of tomato leaves, roots, flowers and fruits. Viral sequences were also detected in single whitefly that fed on infected plants. The authors also detected tobacco mosaic virus, Potato virus Y and two others RNA viruses in infected tobacco plants using the method. The squash blot method was applied for *TYLCV* infections in the field in Israel and for diagnosing *TYLCV* in Turkey.

Czosnek *et al.* (1990) surveyed for the first time on the TYLCV distribution in different countries of the world. *TYLCV* bigeminivirus was diagnosed in tomatoes collected fromMediterranean countries, America. Western Africa and Southeast-Asia by hybridizing tomato leaflets squash onto nylon membrane with a virus specific DNA probe. Samples positive for *TYLCV* were counted. The results revealed the worldwide distribution of *TYLCV*.

Abdel-Salam (1990) mechanically inoculated Egyptian isolates of *Beet curly top virus* (*BCTV)* and *TYLCV* to beet and tomato, respectively, and observed that both the geminiviruses were mechanically transmitted. When tested serological using agar gel double-diffusion test with an authentic American *BCTV* antiserum, both the Egyptian isolates and isolates of *TYLCV* from Jordan reacted positively showing their strong serological relationship. The facts were also confirmed by using immunosorbent electron microscopy test.

Acquisition of *TYLCV* by individual whitefly in relation to the length of the access period, the virus concentration and the developmental stage of plant tissues were studied by Zeidan and Czosnek (1991). The results revealed that the frequency of *TYLCV* detections increased with the length of access period. DNA was detected in 15% of whiteflies tested after a period of access to infected tissues for 30 minutes, regardless of whether it had high or low virus content. However, DNA was detected in all insects tested after an eight hours period of access to all the plant. The insects fed on youngest leaves of infected plants having high virus content, acquired detectable *TYLCV*-DNA within two hours. Viruliferous whiteflies retained *TYLCV* for at least 13 days when placed on uninfected tomato plants. In the experiments they used southern-blot analysis of nucleic acid extracted from a single whitefly to defect genomic DNA of *TYLCV*.

In Bangladesh Akanda (1991) collected 23 tomato samples on the basis of symptoms from different parts of Bangladesh and noted six different types of symptoms prevalent on tomato. The author specially identified yellow mosaic and purple vein as two different symptoms. Finally from those samples six different viruses like *Cucumber mosaic virus* (*CMV*), *Tobacco mosaic virus* (TMV), *Potato virus*(*PVY*), *Broad bean wilt virus* (*BBWV*), *Tomato rattle virus*(*ToRV*) and *Alfa alfa mosaic* (*AMV*) were identified on the basis of symptoms, electron microscopic study, inoculation test and serological test Akanda *et al.* (1991a and 1991b).

However, the authors commented that the two major symptoms (*Yellow mosaic and purple vein*) in respect to prevalence and crop damage could not be identified. The authors named the two viruses as *Tomato yellow leaf curl virus* (*TYLCV*) causing yellow mosaic symptom and *Tomato purple vein virus* (*TPVV*) causing purple vein symptom for the first time from Bangladesh.

Green (1998) published a manual on the rapid detection of plant viruses specially *TYLCV* in the name of "Making leaf tissue squashes on membranes for virus detection". The author described the method as an effective, sensitive and reliable method for virus diagnosis from the plant extract but simpler than the method suggested by Navot *et al.* (1989).

2.4 Vector and transmission of virus

Cohen and Harpaz (1964) studied the involvement of whitefly with a new disease of tomato plant in Israel, which was later identified as *TYLCV*.

Cohen and Nitzany (1966) reported that *TYLCV* was caused by a whitefly-borne virus, which could not be transmitted mechanically and named the causal virus as *TYLCV* for the first time. They noted that the minimum acquisition and inoculation period was 15-30 minutes, the latent period in the vector was at least 21 hours and the virus was persistent in the vector for a period up to 20 days. They found that it was semi-persistent in nature. They also noticed that the females of whitefly were more efficient than male vector of *TYLCV*.

Singh and Sastry (1979) stated that this disease was transmitted by an insect vector, the whitefly (*Bemisia tabaci* Gen.) in the field. Even a single viruliferous whitefly was able to transmit the virus. The virus was neither seed nor sap transmitted.

Makkoub (1978) found two different *TYLCV* isolates on the basis of symptoms produced on tomato and stated that both the isolates were transmitted by whitefly.Goodman (1981) mentioned that *TYLCV* was a whitefly transmitted geminivirus and it was highly prevalent in the Mediterranean region.

Thanapse *et al.* (1983) reported that the phloem of the tomato leaf curl infected plants contained virus particles of the geminivirus type, which could be transmitted by grafting. The host range of *TYLCV* included *Datura stramonium, Nicotiana glutinosa* and the tomato cvs. Sida and Marglobe.

Cherif and Russo (1983) examined, tissue samples of tomato plant from Tunisia naturally infected and graft inoculated with tomato yellow' leaf curl virus disease by electron microscopy. Their observation was that the tomato yellow leaf curl w'as a viral disease associated with a non-mechanically transmissible by virus.

Al-Hitty and Sharif (1987) reported that cucumber could be the best host of whitefly due to trapping of vector. *TYLCV* infection was reduced by 48% if planted as trap crop in tomato field. Such treatment also delayed the appearance of virus symptom by 17 days.

Verma *et al.* (1989) stated that the incidence of *TYLCV* on tomato was directly related to the population density of the vector developed during January when incidence of the disease also began to increase.

Brunt *et al.* (1990) noted *TYLCV* as a whitefly transmitted geminivirus having single stranded, circular DNA in the genome present in two parts (twinned particle). They recorded nine different plant species including tomato as its host.

The geminate particles size was 20 nm in diameter and 30 nm in length and these were phloem or phloem restricted in the host.Lukyanenko (1991) pointed out that *TYLCV* transmitted by whitefly was the most serious virus disease of tomato in tropical and sub-tropical Asian countries and part of Africa

Mansour and Al-Musa (1992) reported that the whitefly was an efficient vector. A single whitefly was able to transmit the virus. The minimum acquisition and the inoculation feeding period were 60 and 30 minutes, respectively and the latent period was 1 1 days.

Brown and Bird (1992) noted that plant viruses transmitted by whiteflies cause over 40 diseases of vegetable and fibre crops worldwide. Depending on the crops, season, whitefly prevalence and other factors, the yield losses ranged from 22-100%.

McGrath and Harrison (1995) compared the cultures of whitefly from Ivorycoast (IC), Pakistan (PK) and the USA (USA B-type) for the frequency with which they transmitted three tomato virus isolates namely Indian tomato leaf curl virus from Bangalore (*ITmLCV*) and tomato yellow leaf curl bigeminiviruses from Nigeria (*TYLCV*-Nig) and Senegal (*TYLCV*-Sen). The results demonstrated that the frequency of transmission from tomato to tomato depended both on the whitefly culture and the virus isolates.

Konate *et al.* (1995) surveyed the whitefly transmitted geminivirus disease of cassava, okra, tobacco and tomato in Burkina Faso. They used triple antibody sandwich ELISA with cross-reacting monoclonal antibodies for identification of the virus. They identified *African cassava mosaic virus* (*ACMV*) from cassava. *Okra leaf curl virus* (*OLCV)* from okra, *Tobacco leaf curl virus* (*TLCV*) from tobacco and *Tomato yellow leaf curl virus* (*TYLCV*) from tomato. *TYLCV* was noted as an economically serious disease reaching a high incidence in March following a peak population of the vector whitefly. They compared the epitope profile of the viruses and found that *TLCV* and *TYLCV* had the same epitope profile, which suggested that these two viruses were the same viruses.

Murad *et al.* (2001) reported that whiteflies were able to transmit *TYLCV* 8 h after they were caged with infected tomato plants. After increasing acquisition access periods (AAPs) on infected tomato plants, the stylets, the head, the midgut, a hemolymph sample, and the salivary glands dissected from individual insects were subjected to polymerase chain reaction (PCR) without any treatment; the presence of *TYLCV* was assessed with virus-specific primers. *TYLCV* DNA was first detected in the head of *B. tabaci* after a 10 min. AAP. The virus was present in the midgut after 40 min. and was first detected in the hemolymph after 90 min. *TYLCV* was found in the salivary glands 5.5 hr after it was first detected in the hemolymph.

Sohrab *et al*. (2013) also found that, tomato leaf curl virus (ToLCV) inciting yellow mosaic disease in Luffa was sap transmissible and opined that sap transmission for most of the Begomovirus is difficult, except a few. ToLCV is a bipartite virus and due to the presence of the DNA B genes (involved in virus movement), such viruses tend not to be phloem limited and thus likely to be mechanically transmissible. Graft transmission of ToLCV was reported by Vasudeva and Samraj in 1948 and many workers adopted it for screening (Divakaran, 2007 and Yadav, 2011).

ToLCV is transmitted in nature by whitefly, *Bemisia tabaci* (Naik *et al*., 2004; Rajasri *et al*., 2011). The greenhouse whitefly, Trialeurodes vaporariorum and aphid, Myzus persicae can acquire the virus non-specifically but are not able to transmit it (Antignus *et al*., 1994).

According to Naik *et al*. (2004) five adult whiteflies were required for cent per cent transmission of *ToLCV* from tomato to tomato, when acquisition and inoculation access periods were 24 h each. The minimum acquisition access and inoculation access periods were 10 and 20 min. respectively. A latent period of 6 h was necessary for *B. tabaci* to become viruliferous.

Rashid *et al*. (2008) noted that, when 3, 5 and 10 viruliferous whiteflies per plant were released, the disease transmission was 20, 30 and 70 per cent, respectively. Cent per cent transmission of TYLCV could be obtained with 15 whiteflies. Rajasri *et al*. (2011) reported 20 per cent transmission of *ToLCD* with a single adult whitefly and cent per cent was obtained with 15 adults /plant.

Prasannath *et al*. (2014) found that the incidence and types of insect-transmitted virus diseases of plants vary with the environmental factors, which have direct or indirect relationships on population dynamics of vectors. Alternative indirect strategies are essential to mitigate the environmental and health hazards of pesticide usage, which is the most predominant method of vector management used at present.

2.5 Yield loss

Sastry and Singh (1973) reported that timely use of correct insecticides not only reduce the white fly population but also checks the spread of the disease to a greater extent. They observed that foliar sprays with Dimethioate (0.05%) Methylparathion (0.02%) and oxydemetomethyl (0.02%) and phorate 10G (15 Kg/ha) at the time of planting not only reduced the population of white fly from 245 to 41 but also resulted in less spread of leaf curl virus. When the plants are infected within 20 days of planting the loss may be upto 92% while infections in 35 and 50 days old crop resulted 74% and 20%, yield loss, respectively.

Al-Musa (1982) worked on *TYLCV* in Jordan and found that in the Jordan valley the incidence of the virus at the end of the season ranged from 0-13.2% in the spring grown tomatoes and 93-100% in field grown tomatoes. He noted that 63% yield loss under greenhouse conditions when tomato plants were inoculated at 15 weeks after planting.

Tomlinson (1987) described the relative importance of 27 viruses in order of economic significance affecting 24 field and vegetable crops in 28 region of the world. He found that *TYLCV* was a leading virus in Thailand, Israel, Ivory Coast, Tunisia and some other countries. *TYLCV* was also considered as one of the economically important 18 viruses affecting six protected vegetable crops in Israel and some other countries.

Martelli and Quacquarelli (1982) listed 40 different virus infecting tomato in different countries of the world, which cause 70- 100%, yield loss of the crop. They also reported that tomato mosaic virus causing tomato mosaic disease, tomato leaf curl virus causing tomato yellow leaf curl disease, and tomato yellow leaf curl virus causing tomato leaf curl disease caused 80, 90, and 100% yield loss of tomato respectively, in most of the tomato growing countries during the survey.

Lukyanenko (1991) pointed out that *TYLCV* transmitted by whitefly was the most serious disease of tomato in tropical and subtropical Asian countries and parts of Africa where yield losses due to this disease were 100%.

MacIntosh *et al.* (1992) reported the severe occurrence of *TLCV*, *TYLCV* and *Abotilon mosaic virus* (AMV) three bigeminiviruses in different European countries causing severe yield loss of crops.

Whitefly transmitted geminiviruses cause over 40 diseases of vegetables and fibre crops worldwide were reviewed by Brown and Bird (1992). During the past decade both prevalence and distribution of whitefly transmitted plantviruses have increased and the impact have been devastating. Depending on the crop season, whitefly prevalence and other factors the yield losses ranged from 22-100%. They also remarked that *TYLCV* was one of the most damaging viruses of tomato prevalent worldwide.

Pilowsky *et al.* (1993) conducted an experiment using *TYLCV* tolerant tomato cultivars TY-20 and TY-10 and susceptible cultivars Naama and Ravit and tolerant cultivars showed only mild symptoms, whereas the susceptible cultivars became markedly stunted with much reduced fruit set and yield and upward rolled leaflets. Infected TY-20 and TY-10 plants were smaller than healthy plants. Yield reduction 50% and 54% in infected TY-20 and TY-10 plants, respectively. Infected Naama and Ravit plants were studded and produced severe disease symptoms resulting 99% yield reduction.

Polston *et al.* (1994) reported that a new virus disease of tomato was observed in Dominican Republic in 1989 and the causal agent was identified as *TYLCV*, which caused 90% yield loss of tomato.

According to Green and Kalloo (1994) *TYLCV* was distributed all over the world, especially it was a threat of tomato production in the Mediterranean Basin, West and East Africa. *TYLCV* caused 50- 70% yield reduction usually, which may be as high as 100%. They also reported that *TYLCV* resistant and tolerant tomato cultivars were available in Israel, Egypt and France, which transferred from wild *Solarium* species like *Lycopersiconpimpinellifolium*, *L.peruvianum*. *L. hirsuhum* and *L.cheesmanii*, however, they concluded that the level of resistant or tolerant and its stability need to have further investigation.

Considering the prevalence and severity of *TYLCV*, Alam *et al.* (1994) studied on its effects on cellular components of infectedleaves and revealed that the virus infection caused 44% and 50% of chlorophyll and B-carotene, respectively compared to healthy plant. They also observed 25% reduction of phosphorus in infected leaves whilenitrogen, protein and carbon content in infected leaves were increased. Organic acids like oxalic acid, citric acid and melanic acid were found to be drastically reduced in infected leaves of tomato.

Ali *et al.* (2005) reported that in Bangladesh and north east India tomato is cultivated at a commercial scale but one of the limiting factors affecting the successful cultivation of this crop is the existence of whiteflies. Damage caused by this insect pest to commercial tomato may be directly through phloem feeding, or indirectly by the transmission of plant viruses such as Tomato Yellow Leaf Curl Virus (*TYLCV*). In spite of a variety of control measures applied against pests, crop losses have consistently shown an increasing trend. High infestation levels were found from mid-February to mid-March observed the insect vectors Whitefly (*Bemisia tabaci* Genn.) attack tomato plants during April-November (Maximum damage during Aug-Oct) causing heavy losses.

Pun *et a*l. (2005) also reported that the incidence of white fly population had a significant and positive correlation with temperature and sunshine hours while a negative correlation with relative humidity and total rainfall. The disease incidence had a significant and positive correlation with white fly population.

2.6 Management of *TYLCV*

Efforts to manage tomato leaf curl disease have been made since the early phase of plant protection as this disease causes severe damage to tomato crop. Effects of cultural practices, plant protection chemicals, botanicals and bioagents in the management of disease have practical importance and scientific interest. Many workers have conducted extensive studies on these aspects.

Incidence of *TYLCV* is generally characterized by great regional and seasonal variations, which are usually attributed to respective fluctuations in the population density of the whitefly vector Nitzany (1975).

TYLCV resistance from *Lycopcrsicon pimpinellifolium* is monogenic with incomplete dominance inheritance Pilowsky and Cohen (1975). Al Musa (1982) studied the effect of some intercrops on *TYLCV* of tomato. In the field trial cucumber, eggplant and crop were planted in alternate rows of tomato 30 days before the tomato seedlings were transplanted. *TYLCV* was effectively delayed in cucumber interplant plots whereas; corn or eggplant was not found suitable.

Vani *et al.* (1989) evaluated yellow, transparent polyethylene and straw mulch for the management of mosaic disease in muskmelon. All type of mulches reduced the incidence of mosaic disease caused by*Cucumber green mottle mosaic virus*(*CGMMV*) and *Watermelon mosaic virus*-1 (*WMV-1*). The reduction was greater in yellow color mulch. Mulching also increased plant growth and yield.

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

Ahmed *et al.* (1996) reported that intercropping tomato with coriander (*Coriandrum saliva),*as whitefly repellent can be an effective disease control strategy against *TYLCV*.

The effect of mulching with polyethylene sheets of deferent colours (black, transparent, white, and aluminum) on*Bemisia tabaci*and spread of TYLCV. Polyethylene mulching reduced whitefly and *TYLCV* infection. But mulching with aluminum colour was found to be most effective in reducing number of whiteflies and delay the infection of TYLCV (Davino*et al.*, 1996).

Azam *et al.* (1997) investigated that insecticides (carbofuran, endosulfan, Dimethoate, buprofezin and triazophos) and cultural methods (covering the plants with polyester for 30, 45 or 60 days) are most effective for the control of whitefly and TYLCV in tomatoes. Plants covered in polyester had the lowest populations of whitefly the lowest incidences of *TYLCV* and the highest yields. Of the insecticides, endosulfan had the most affect.

Cohen *et al.* (1998) reported that UV-blocking nets greatly reduced the population of key insect pests in greenhouses and correspondingly reduced the incidence of virus disease carried by various insects. The use of such films can lead to a major breakthrough in reducing the use of chemical insecticides in conventional agriculture.

Effect of netting in the seedbed was assessed to control *TYLCV* in tomato. Disease incidence and yield did not vary significantly in treated and control plots. Low density of vector during seedling stage might be the reason for such results Kung (1999).

Wongklom (1999) evaluated effectiveness of nylon net (40 mesh) as a physical harrier to control white fly and *TYLCV*. Results indicated that nylon net barrier is effective in controlling whitefly and *TYLCV* incidence.

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

Pilowsky and Cohen (2000) reported that 25 wild *Lycopcrsicon* accessions were screened in the greenhouse for resistance to the whitefly-borne TYLCV. High levels of resistance were detected in 7 of 9 accessions of L. *peruvianum* and in all 5 accessions of *L.chilense* tested. In contrast, plants of 7 accessions of *L. hirsutum*and 3 of 4 accessions of *L.pimpinellifolium* were highly susceptible. Plants of accession CIAS 27 (L. *pimpinellifolium*) showed moderate resistance to TYLCV.

Simone and Momol (2001) reported that to identify early symptoms of *TYLCV* and rogue infected and infectcd-looking plants from field and place in plastic bags immediately at the beginning of the season, especially during first 3-4 weeks.

Spread of any whiteflics to healthy plants should be prevented.

Ahmed *et al.* (2001) used imidacloprid insecticide, in two applications at four rates (47.6, 71.4, 95.2, and 119g) for indirectly controlling TYLCV through control of its vector whitefly in conjunction with integrated pest management (IPM) practices, in the field crops of tomato cv. Peto 86 California. T his spray regimen was compared with standard applications of cypermethrins at 10 to 15 days intervals (with or without IPM) throughout the growing season. In three field trails in Sudan (in the winter season of 1997 and in the summer and winter seasons of 1998), a combination of IPM practices and two applications ofConfidor at the two highest rates immediately after sowing and 6 weeks later protected tomato plantsagainst the disease until 12 weeks after sowing. All rates of Confidor reduced disease incidence compared with standard chemical control applied in an integrated strategy and quantitative efficacy increased with increase of insecticide rate.

Kalb (2004) suggested growing seedlings in an insect proof net house (50 mesh or fine), spraying infected plants with imidacloprid before rouging, interplanting tomato with bait plants like cucumber, application of systemic insecticides as soil drenches during seedling stage. Rotation of insecticides is necessary otherwise resistance may develop in the vector. Chemical control is infective when disease incidence is high.

Tahir *et al.* (2004) used five different planting dates (May to July) at 15 days interval to manage cotton leaf curl virus *(CLCuV*) in the field. Maximum *CLCuV* incidence was recorded in June 1 planting. Results suggested that plantings should be done before June 1 to minimize the disease loss. .

Momol and Perneny (2006) used imidacloprid (Admire®) in the transplant water. Rates recommended are Admire®, 16 oz/A. Do not use Pravado® if plants were treated with imidacloprid or similar insecticide at transplanting. Insect growth regulator insecticides can be applied when scouts find nymphal densities to exceed 5 to 10 per leaflet by standard sampling procedures. Repellants (e.g. crop oil, UV-reflective mulch) can be used to interfere with secondary virus spread.

Bajpai (2005) obtained better management of chilli leaf curl virus with combined application of commercial botanical viricides, Pre-vental B.V/ Action 100 (0.2 per cent) with imidacloprid (1ml/3ltr) by reducing the incidence to 6 and 5 per cent respectively against 89 per cent in control. Reddy (2006) observed suppression of tomato leaf curl disease with Clerodendron inermis and Gliricidia leaf extract at the early stage of the crop (45 DAT) with 13.37 and 14.50 per cent incidence as compared to 48.33 per cent in control.

Arunakumara *et al*. (2010) observed reduction in tomato early blight disease with 0.1 and 0.2 percent perfect. Meena (2012) reported the efficacy of perfect in preventing the growth and sporulation of Alternaria pori, causing purple blotch of onion under in vitro conditions and also noticed reduction in disease incidence of 28.29 per cent against 72.09 per cent in control.

Karthikeyan *et al*. (2009) obtained 90 per cent reduction of leaf crinkle disease in black gram with the leaf extracts of Mirabilis jalapa and Bougainvillea spectabilis. Extracts of Thuja orientalis, Tamarix brachystachy, and Lawsonia inermis had exhibited inhibitory effects on *TYLCV* multiplication in tomato treated plants with protection periods of 10 to 12 days (Al-ani *et al*., 2011).

The application of 3.5 % neemazol, 2% neem oil and 5% NSKE were found superior in reducing the whitefly population in okra by Naik *et al*. (2012).

Samiyappan (2003) reported the efficacy of Pseudomonas fluorescens in suppressing the viral infection and inducing systemic resistance in tomato plants against whiteflies and thrips.

Mishra *et al*. (2012) screened fifty rhizobacterial isolates against tomato leaf curl virus (ToLCV) disease under glasshouse condition and found that application of rhizobacteria based bioformulations to seed, soil and foliage significantly reduced the disease severity from 85.72 to 28.58 per cent with two isolates of Pseudomonas sp. Mishra *et al*. (2014) reported that, application of chitin based Pseudomonas reduced the disease severity of 90.33 to 80.33 per cent and also observed that, addition of chitosan has enhanced the bioefficacy of Pseudomonas against *ToLCV*.

Treatment of tobacco mosaic virus (*TMV*) contaminated tools with 20 per cent solution of nonfat dry milk (*NFDM*) and 0.1per cent Tween-20 completely eliminated TMV transmission in Petunia (Lewandowski, *et al*., 2010).

Abdelbacki *et al*. (2010) observed suppression of Tomato yellow leaf curl virus infection with the application of native or modified whey proteins fractions at 15 days of treatment.

The chemicals like chlorinated hydrocarbons, organophosphates, neonicotinoids, pyridine-azomethines, and pyrethroids were reported to be effective against whitefly. But, whiteflies have developed resistance to many of these chemicals and efficacies had decreased over time (Ahmed *et al*., 2001).

In addition to these insecticides, oils, insecticidal soaps, and insect growth regulators have also been used for controlling whiteflies. The most effective and widely used class of insecticides to reduce whitefly populations is the neonicotinoids of which thiomethoxam, imidacloprid, and dinotefuran have been widely used to reduce incidence of tomato leaf curl virus in many tropical countries (Polston and Lapidot, 2007).

Iersel *et al*. (2000) reported that, the application of imidacloprid to Poinsettia by subirrigation as a practical and effcient method to control silverleaf whiteflies. Zacharia (2006) observed reduction in the bittergourd distortion mosaic disease with imidacloprid 0.025 per cent. The application of imidacloprid 0.05 per cent at 15 days interval was found effective for the control of whitefly population to reduce the incidence of ToLCD (Reddy, 2006).

Ramu *et al*. (2011) carried out an experiment to manage B. tabaci, the vector of yellow vein mosaic of mesta and found that, acetamiprid (@ 0.2g/l) and thiamethoxam (@ 0.2g/l) were found most effective which recorded lowest whitefly population, disease incidence (3.15%) and highest fibre yield(18.00q/ha) and followed by imidacloprid (@ 0.2ml/l) and triazophos@ 2ml/l.

Chandrashekharaiah *et al*. (2013) found that, imidacloprid applied green gram plots recorded less whitefly population, yellow vein mosaic incidence and highest yield.

Patel *et al*. (2013) carried out a field experiment to know the effect of different insecticides, biopesticides and its combination on incidence of tomato yellow leaf curl virus (TYLCV) disease and population of whitefly on tomato cv. Pusa Ruby. The disease incidence of *TYLCV* was recorded periodically from 15 to 90 days after transplanting (DAT) with an interval of 15 days by visual observation. Among the all treatments; thiacloprid treated plots showed lowest average whitefly population and proved to be effective treatment with lowest mean disease incidence 30.24 per cent and highest marketable fruit yield 18.38 q/ha^{-1} while the more average whitefly population was observed in Cowdung + cow urine @ 20ml/l treated plots and control plots showed highest disease incidence and more number of whiteflies per plant.

Prasannath *et al*. (2014) conducted a study to determine the variation of virus disease incidence and the population of insect vectors in field grown tomato (*Solanum lycopersicum* L.) cv. Thilina in different environmental conditions using two crop management systems namely, existing management system with pesticide applications and an integrated management package (IMP) with less reliance on pesticides. Results revealed that there was no significant ($p=0.05$) difference between the two types of management systems in terms of virus disease incidence indicating the equal efficiency of the tested IMP treatment and existing pest control method on virus disease management. Abundance of insect vectors and beneficial insect populations were significantly ($p<0.05$) influenced by the interaction effect of the management system and location.

Subba *et al*. (2017) conducted a research to study the population dynamics of whitefly (*Bemisia tabaci* Genn.) infesting tomato (*Lycopersicon esculentus* L.) and their sustainable management using biopesticides. The insecticide acetamiprid was found most lethal against whitefly providing 76.59% suppression, closely followed by extracts of neem + Spilanthes providing 62.39% suppression. Neem and Spilanthes individually did not produce good results but when used as a mixture they recorded better results. Highest yield (30.15 t/ha) were recorded from acetamiprid treated plots followed by neem + Spilanthes (27.55 t/ha). Azadirachtin and Plant extracts are biopesticides having less or no hazardous effects on human health and environment. Thus they can be incorporated in IPM programmes and organic farming in vegetable cultivation.

Jha and Kumar (2017) conducted a field trial on a tomato crop variety Avinash 2 to evaluate the efficacy of different insecticidal treatments against whitefly, *Bemisia tabaci*. Three sprays at ten days interval of ten treatments with three replications were applied in the field. The treatment were profenophos @ 500 g a.i. ha-1, imidacloprid @ 20 g a.i. ha^{-1}, cypermethrin @ 25 g a.i. ha^{-1}, indoxacarb @ 50 g a.i. ha^{-1}, profenophos 40% + cypermethrin 4% @ 440 g a.i. ha^{-1}, neem seed kernel extract 5%, neem oil 2%, tobacco decoction 5%, yam bean seed extract 5% and control (water spray). The data (population of whitefly) were recorded one day before first spraying and first, fifth and seventh day of each spray. The data revealed that after each spray all the insecticidal treatments were significantly superior over control in reducing whitefly population and efficacy was maximum in imidacloprid followed by profenophos 40% + cypermethrin 4% and it was minimum in tobacco decoction while efficacy of other insecticides were in between these insecticides.

CHAPTER III
MATERIALS AND METHODS

The present study regarding management of *Tomato yellow leaf curl virus* (*TYLCV*) through insecticides, botanicals and Silver colored mulch has been conducted during October 2016 to March 2017 at the experimental fields of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. Required materials and methodology are described below under the following headings and subheadings.

3.1 Location of the experimental field

The experiment was conducted at the central farm of Sher-e-Bangla Agricultural University, Dhaka. The site is 22°46′N and 90°22′ E Latitude and at Altitude of 9 m from the sea level. The location of the experiment field have been in Appendix I.

3.2 Characteristics of soil

The soil of the experimental site is a medium high land belonging to the Modhupur Tract under the Agro Ecological Zone (AEZ) 28. The soil texture was silty loam with a pH 6.7. Soil samples of the experimental plot was collected from a depth of 0 to 30 cm before conducting the experiment and analyzed in the Soil Resources Development Institute (SRDI), Farmgate, Dhaka. Details of the mechanical analysis of soil sample have been in Appendix II.

3.3 Weather conditions during the experiment

The weather condition of the experimental site was under the sub-tropical monsoon climate, which is characterized by heavy rainfall during Kharif season (April to September) and in the Rabi season (October to March)low rainfall associated with moderately low temperature, low humidity and short day. There was no rain fall during the month of December, January and February, little rain in

March. Rabi is the more favorable for vegetable production. Details of the meteorological data in respect of temperature, rainfall and relative humidity during the study period were collected from Bangladesh Meteorological Department, Agargoan, Dhaka- 1207, Dhaka and have been presented in Appendix III.

3.4 Plant material

The tomato variety “BARI Tomato-14” was used in this study.It was an open pollinated high yield indeterminate type variety developed by the Vegetable Division of Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI), Gazipur.

3.5 Collection of insecticides and Multineem (Neem oil)

Three insecticidenamely Imidacloprid, ACmix and Subicron and Multineem (neem oil) were collected from local market.

3.6 Preparation of Silver colored mulch and Neemax

For preparation of Silver colored mulch, at first we have collected clear polythene paper and aluminum foil paper for the local market and then aluminum foil was pasted on polythene paper to prepare the silver metallic mulch. Neem leaves were collected from Sher-e-Bangla Agricultural University campus for preparation of Neemax (Neem leaves extract).For preparation of neem leeves extracts, collected leaves were weighted in an electric balance and then washed in the water. After washing the big leaves were cut into small pieces. For getting extract, weighted plant parts were blended in a mortar & pastel and then distilled water was added into the mortar. The pulverized mass was squeezed through 3 folds of fine cotton cloth. For getting 1:2 (w/v) ratio 200 ml of distilled water was added with 100 g plant parts.

Figure 1. Aluminum foil on selected plot (T_6).

Figure 2. Neemax (Neem leaf extract).

3.7 Raising of seedlings

Tomato seedlings were raised in seedbeds situated on a relatively high. The size of each seed bed was 3 m × l m. The area was well prepared with spade and made into loose, friable and dried mass to obtain fine tilth. All weeds and stubbles were removed and the soil was mixed with well decomposed cow dung. Sevin 85 SP was applied around each seedbed as precautionary measure against ants and cutworms. Ten grams of seeds were sown in each seedbed. After sowing, the seeds were covered with light soil to a depth of about 0.6 cm. Complete germination of the seeds took place within 4-6 days of' sowing. Necessary shading by bamboo mat was provided over the seedbed to protect the young seedlings from the scorching sunshine or heavy rain. Dithane M-45 was sprayed on the seedbeds at the rate of 2g/l to protect the seedlings from damping-off and other diseases. Weeding, mulching, and irrigation were done from time to time as and when needed. No chemical fertilizer was used in the seedbed.

3.8 Layout and design

The experiment comprised 7 treatments of single factor and laid out in Randomized Complete Block Design (RCBD) with three replications. The whole field was divided into three blocks and each block consisted of 7 plots. Altogether there were 21 unit plots. Each plot was 6 m^2 (3 m × 2 m) in size.The distance between plot to plotwas 1.0 m and distance between plant to plant was 60 cm and row to row row was 40 cm (Appendix IV).

3.9 Fertilizer and manure application

The following doses of manure and fertilizers were used.

Manure/fertilizer	Dose/ha
Cow-dung	10 ton
Urea	400 kg
TSP	250 kg
MP	200 kg

3.10 Treatments of the Experiment

In total seven (7) treatments were considered in this experiment. These were as follows:

T_1 =Imidacloprid

T_2 = ACmix

T_3 = Subicron

T_4 = Neemax (Neem leaf Extract)

T_5 = Multineem (Neem Oil)

T_6 = Light reflecting silver colored mulch

T_7 = Control

3.11 Cultivation of tomato

The seedlings were always kept under close observation. Necessary intercultural operations were done throughout the cropping season to obtain proper growth and development of the tomato plants.

3.11.1 Land preparation

The selected land for the experiment was first opened in October, 2016 by power tiller and expose to the sun for a week. After one week the land was ploughed and cross-ploughed several times with a power tiller and laddering was done to obtain good tilth. Weeds and stubble's were removed and the large clods were broken into smaller pieces to obtain a desirable tilth of soil for sowing of seeds. After removal of the weeds, stubbles and dead roots, the land was leveled and the experimental plot was separated in to the unit plots and were prepared as 10 cm raised beds.

3.11.2 Transplanting of seedlings

Healthy and uniform sized 30 days old seedlings were uprooted separately from the seedbeds. The seedbeds were watered before uprooting the seedlings so as to minimize the root injury. The seedlings were transplanted in the pits of the experimental plots in the afternoon on10 November, 2016 maintaining a spacing of 40 cm and 60 cm between the rows and plants, respectively. Light irrigation was given immediately after transplanting by using a watering cane. In order to gap filling and to check the border effect, some extra seedlings were also transplanted around the border area of the experimental field.

3.11.3. Intercultural operations

The following intercultural operations were done for better growth and development of the plants during the period of the experiment.

3.11.3.1 Gap filling

Gap filling was done in place of dead or wilted seedlings in the field using healthy seedlings of the same stock previously planted in the border area.

3.11.3.2 Weeding and mulching

Weeding and mulching were accomplished as and whenever necessary to keep the crop free from weeds, for better soil aeration and to break the soil crust. It also helps in conservation of soil moisture. Four subsequence weeding were done manually at 15, 30, 45 and 55 DAS to keep the plots free from weeds. The selected plots under the treatment ofT6 were Silver colored mulch.

3.11.3.3 Staking

When the plants were well established, staking was given to each plant by Dhaincha (*Sesbania* sp.) and Bamboo sticks to keep them erect.

3.11.3.4 Drainage

Stagnant water effectively drained out at the time of heavy rains.

3.1.3.5 Irrigation

Irrigations were given throughout the growing season as and when necessary.

3.11.3.6 Spraying Spraying Insecticide, Botanicals for 3 times at 25, 40 and 55 DAT in the plot

3.12 Identification and estimation of disease incidence (%) and disease severity (%)

Identification of the virus disease was done mainly through visual observation of typical symptoms of *TYLCV* infection like upward curling, cupping, with or without marginal chlorosis, smaller leaflets and stunting of the plant (Green and Kalloo1994 and Sinistera *et al*., 2000).The incidence of *TYLCV* was calculated by counting the infected plants 30, 45 and 60 DAT on the basis of the appearance of symptoms.. The plants were inspected every day morning to note the appearance of the symptoms starting from the following day of transplantation.

The following formulas were used tocalculate the percentage of disease incidence and severity

$$\text{Disease incidence (\%)} = \frac{Xi}{X} \times 100$$

X= Total number of plants in a unit

X_1 = Number of infected plants in a unit plot

$$\text{Disease severity} = \frac{Ai}{A} \times 100$$

A_i =Number of infected leaves

A= Total number of leaves in selected infected plant

3.12.Evaluation the efficacy of treatments in whitefly association

The sampling on the incidence of whitefly association and the occurrence of *TYLCV* diseases by direct visual method (Hirano *et al*., 1993). The sampling of the study for whitefly association was taken at vegetative, early flowering and early fruiting at 15 days interval. The plants were carefully checked visually for the presence of whitefly. Sometimes plants were shaken gently to observe their presence and count their number accurately. While the population of whitefly was very low the number was recorded per 5 plants. Sampling on whitefly incidence was taken at both pre and post application of treatments. Two post treatment counts were taken at each vegetative, early flowering and early fruiting stages.

3.13 Evaluation the efficacy of treatments in whitefly association:

The following parameters were assayed:

1. Number of infected plants/plot
2. Number of healthy leaves/plant
3. Number of infected leaves/plant
4. Whitefly association
5. Number of branches/plant
6. Plant height (cm)
7. Number of flowers/plant
8. Number of fruits/plant
9. Single fruit weight (g)
10. Weight of fruits/plant (kg)
11. Average fruit diameter (cm)
12. Fruit yield (t/ha)

3.14 Statistical analysis

Data were analyzed by using computer based software MSTAT-C. The means of growth and yield data were compared by DMRT Bar diagram and graphs were also used to interpret the data as and when necessary.

CHAPTER IV

RESULTS AND DISCUSSIN

The present experiment was conducted to study the management of *Tomato Yellow Leaf Curl Virus* (*TYLCV*) through insecticides, botanicals and Silver colored mulch. The data on disease incidence (%), Disease severity (%), whitefly association and yield & yield attributing characters are studied. The results have been presented and discussed under the following headings and subheadings.

4.1 The Morphological Features which are identical,in relation to disease incidence(%) and disease severity (%) of *Tomato yellow leaf curl virus (TYLCV)* in tomato

The typical symptoms produced by *TYLCV* in tomato in the experiment field which was used for identification of the virus are shown in figure 3. On the basis of symptomology appear in tested plants, it was observed that the disease incidence (%) and disease severity (%) of *TYLCV* under different treatments was varied significantly.

Figure 3.Typical symptoms of *TYLCV*showed in tomato in the experiment field.

4.1.1 Effect of different treatments on disease incidence (%) at 30, 45 and 60DAT

The disease incidence (%) of *TYLCV* under different treatments was varied significantly. It was found that the disease incidence (%) of *TYLCV* was ranged 11.11 to 33.33%, 13.33 to 40.00 (%) and 13.33 46.67 (%) at 30, 45 and 60 DAT respectively.

At 30 DAT, the lowest disease incidence (11.11%) was found in T_6 (Silver colored mulch) and the highest disease incidence (33.33%) was recorded in T_7 (control treatment). Among the chemical treatments, the lowest disease incidence (15.56%) was found in T_1 (Imidacloprid) followed by T_2 (ACmix) and T_3 (Subicron) and there disease incidence was 17.78% and 17.78% respectively. In case of botanical treatments Multineem, T_5 (Neem oil) showed moderate disease incidence (22.22%) at 30 DAT which was nearest with other botanical treatment, Neemax, T_4 (24.44%).

At 45 DAT, the lowest disease incidence (13.33%) was also found in T_6 (Silver colored mulch) and the highest disease incidence (40.00%) was recorded in T_7 (control treatment). Among the chemicals treatments, the lowest disease incidence (22.22%) was found in T_1 (Imidacloprid) and T_2 (ACmix) treatments which is statistically same with each other followed by T_3 (Subicron) and it's disease incidence was 24.44%. In case of botanical treatments, Multineem, T_5 (Neem oil) showed moderate disease incidence (26.67%) which is statistically different with Neemax, T4 (31.11%).

At 60 DAT, the lowest disease incidence (13.33%) was again found in T_6 (Silver colored mulch) and the highest disease incidence (46.67%) was found in T_7 (control treatment). Among the chemical treatments, the lowest disease incidence (24.44%) was found in T_1 (Imidacloprid) which is statistically different with T_2 (ACmix) and T_3 (Subicron) and there disease incidence was 26.67% and 28.89% respectively. In case of botanical treatments, Multineem, T_5 (Neem oil) showed moderate disease incidence (28.89%) which is statistically different with Neemax, T_4 (33.33%). These results are presented in Table 1. From the all investigation, it was noticed that the disease incidence (%) was very low in Silver colored mulching plots as clearly shown in Figure 3.

Table 1. Disease incidence (%) of *TYLCV* under different treatments at 30, 45 and 60 DAT

Treatments	Disease incidence (%) of *TYLCV*		
	30 DAT	45 DAT	60 DAT
T_1	15.56 e	22.22 e	24.44 e
T_2	17.78 d	22.22 e	26.67 d
T_3	17.78 d	24.44 d	28.89 c
T_4	24.44 b	31.11 b	33.33 b
T_5	22.22 c	26.67 c	28.89 c
T_6	11.11 f	13.33 f	13.33 f
T_7	33.33 a	40.00 a	46.67 a
$LSD_{0.05}$	1.014	1.109	1.127
CV (%)	5.855	7.367	8.214

T_1 =Imidacloprid, T_2 = ACmix, T_3 = Subicron, T_4 =Neemax (Neem leaf extract)
T_5 = Multineem (Neem oil) T_6 = Silver colored mulch, T_7 = Control

Figure 4. Tomato plants in Silver colored mulch plot.

Figure 5: Tomato plants in control plot

4.1.2 Number of healthy leaves/plant

Number of healthy leaves/plant affected by *TYLCV* differed significantly under different treatments. Results revealed that the treatment T_6 (Silver colored mulch) produced the highest number of healthy leaves/plant (34.07, 98.31 and 95.50 at 30, 45 and 60 DAT respectively) followed by T_1 (Imidacloprid) and T_2 (ACmix) at 45 and 60 DAT where the lowest number of healthy leaves/plant (27.20, 51.75 and 45.15 at 30, 45 and 60 DAT respectively) was achieved from Control treatment (T_7). Among the treated plants, the lowest number of healthy leaves/plant was achieved from T_5 (Multineem) followed by T_4 (Neemax).

Table 2. Number of healthy leaves/plant in different treatments at 30, 45 and 60 DAT

Treatments	Number of healthy leaves/plant		
	30 DAT	45 DAT	60 DAT
T_1	31.33 c	90.85 b	87.45 b
T_2	32.27 b	77.66 c	73.85 c
T_3	30.93 c	71.63 d	67.03 d
T_4	30.20 d	62.30 f	57.51 f
T_5	30.73 c	68.87 e	64.67 e
T_6	34.07 a	98.31 a	95.50 a
T_7	27.20 e	51.75 g	45.15 g
$LSD_{0.05}$	0.607	1.142	2.014
CV (%)	6.348	10.556	9.417

T_1 =Imidacloprid, T_2 = ACmix, T_3 = Subicron, T_4 = Neemax(Neem Seed Kernel Extract extract)T_5 =Multineem(Neem oil)T_6 = Silver colored mulch, T_7 = Control

4.1.3 Number of infected leaves/plant

Number of infected leaves/plant affected by *TYLCV* differed significantly under different treatments. Results revealed that the treatment T_6 (Silver metallic plastic mulch) showed the lowest number of infected leaves/plant (0.67, 2.07 and 1.65 at 30, 45 and 60 DAT respectively) followed by T_1 (Imidacloprid) and T_2 (ACmix) where the highest number of infected leaves/plant (7.02, 14.20 and 20.87 at 30, 45 and 60 DAT respectively) was achieved from Control treatment (T_7). Among the treated plants, the highest number of infected leaves/plant was achieved from T_4 (Neemax) followed T_5 (Multineem).

Table 3. Number of infected leaves/plant in different treatments at 30, 45 and 60 DAT

Treatments	Number of infected leaves/plant		
	30 DAT	45 DAT	60 DAT
T_1	1.47 d	6.47 e	13.19 d
T_2	2.43 bc	8.57 cd	15.24 c
T_3	2.07 d	9.07 c	15.76 c
T_4	3.17 b	10.40 b	17.33 b
T_5	2.83 b	9.13 c	15.83 c
T_6	0.67 e	2.07 f	1.65 e
T_7	7.02 a	14.20 a	20.87 a
$LSD_{0.05}$	0.401	0.514	1.046
CV (%)	5.246	7.374	8.221

T_1 =Imidacloprid, T_2 = ACmix, T_3 = Subicron, T_4 = Neemax, T_5 = Multineem, T_6 = Silver colored mulch, T_7 = Control

4.1.4 Effect of different treatments on disease severity (%) at 30, 45 and 60 DAT

It was found that the disease severity (%) of *TYLCV* was ranged 1.96 to 25.80%, 2.10 to 27.43(%) and 1.72 to 46.22(%) at 30, 45 and 60 DAT respectively. At 30 DAT the lowest disease incidence was found (1.96%) in T6 (Silver colored mulch) and the highest disease severity was (25.80%) was recorded in T7 (Control treatment). Among the chemical treatments the lowest disease severity (4.69%) was found in T_1 (Imidacloprid) which is statistically similar with T_2 (ACmix) and T_3 (Subicron) and disease severity was 7.53% and 6.69% respectively. In case of botanical treatments Multineem, T_5 (Multineem) showed moderate disease incidence (9.20%) which is statistically similar with other botanical treatment, Neemax, T_4 (10.49%).

At 45 DAT the lowest disease Severity (2.10%) was found in T_6 (Silver colored mulch) and the highest disease severity (27.43%) was recorded in T_7 (Control treatment). Among the chemicals treatments the lowest disease severity (7.12%) was found in T_1 (Imidacloprid) which is statistically similar with T_2(ACmix) and T_3 (Subicron) and disease incidence was 11.26% and 12.66% respectively. In case of botanical treatment Multineem,T_5 (Neem oil) showed moderate disease severity (13.25%) which is statistically similar with Neemax,T_4 (16.69%).

At 60 DAT the lowest disease severity (1.72%) was found in T_6 (Silver colored mulch) and the highest disease severity (46.22%) was found in T_7 (Control treatment). Among the chemical treatments the lowest disease severity (15.08%) was found in T_1 (Imidacloprid) which is statistically similar with T_2 (ACmix) and T_3 (Subicron) and disease incidence was 20.63% and 23.51% respectively. In case of botanical treatment Multineem,T_5 (Neem oil) showed moderate disease incidence (24.47%) which is statistically similar with Neemax,T_4 (30.13%).

Table 4. Effect of different treatments on disease severity (%) of *TYLCV* in tomato at 30,45 and 60 DAT

Treatments	Disease Severity (%)		
	30 DAT	45 DAT	60 DAT
T_1	4.69 e	7.12 e	15.08 e
T_2	7.53 d	11.26 cd	20.63 d
T_3	6.69 d	12.66 c	23.51 c
T_4	10.49 b	16.69 b	30.13 b
T_5	9.20 bc	13.25 c	24.47 c
T_6	1.96 f	2.10 f	1.72 f
T_7	25.80 a	27.43 a	46.22 a
$LSD_{0.05}$	1.076	1.213	2.057
CV (%)	6.274	8.152	8.875

T_1 =Imidacloprid, T_2 = Acme, T_3 = Subicron, T_4 = Neemax, T_5 = Multineem, T_6 = Silver colored mulch, T_7 = Control

4.2 Effect of different treatments on whitefly association at 30, 45 and 60 DAT in pre and post treatment

In terms of whitefly association, significant variation was observed among the performance of treatments against whitefly (Figure 6). It was observed that the lowest whitefly association (2.0, 4.0 and 2.0 at 30, 45 and 60 DAT respectively) was found in T_6 (Silver colored mulch) followed by T_1 (Imidacloprid), T_2 (ACmix) and T_3 (Subicron) treatments.The highest whitefly association (19, 23 and 18 at 30, 45 and 60 DAT respectively) was recorded in Control treatment (T_7) during crop duration. Among the treated plants the moderate whitefly association (14, 14 and 12 at 30, 45 and 60 DAT respectively) was observed in T_4 (Neemax) which was statistically identical with T_5 (Multineem) at different observation. The results of the present study demonstrated that T_6 (Silver colored mulch), T_1 (Imidacloprid) and T_2 (ACmix) treatment were as the best to control whitefly association.

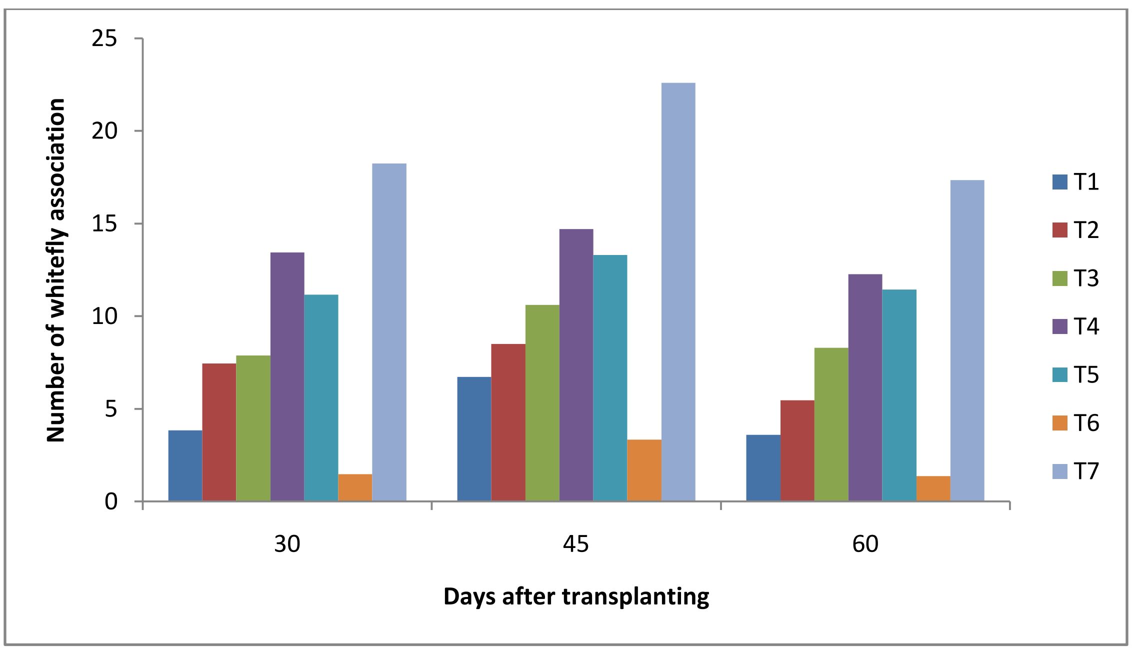

Figure 6. Whitefly association at 30, 45 and 60 DAT under different treatment

T_1 =Imidacloprid, T_2 = ACmix, T_3 = Subicron, T_4 = Neemax, T_5 = Multineem, T_6 = Silver colored mulch, T_7 = Control

4.3. Relationship between disease incidence (%) and whitefly association

From the figure 7, it is revealed that % disease incidence was increased with the increased of whitefly association. The highest disease incidence (46.67 %) was recorded in T_7 (control) and whitefly association (18) were recorded in T_7. The lowest number of whitefly (2.0) were recorded in the T_6 (mulch treatment) and disease incidence was 13.33%.

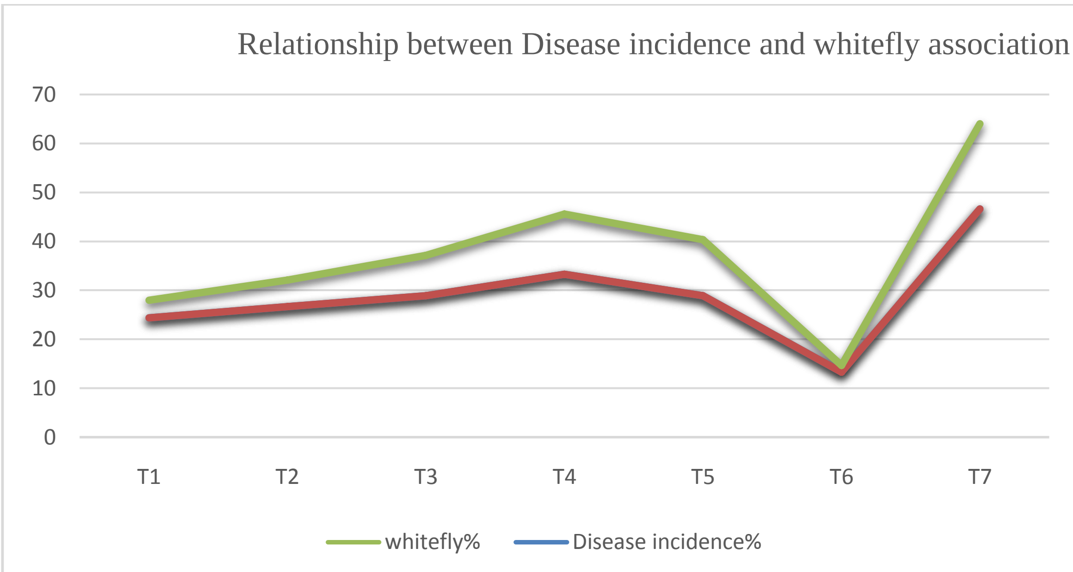

Figure 7: Relationship between disease incidence and whitefly association

T_1 = Imidacloprid, T_2 = ACmix, T_3 = Subicron, T_4 = Neemax, T_5 = Multineem, T_6 = Silver colored mulch, T_7 = Control

4.4. Relationship between disease severity and whitefly association:

The highest disease severity and whitefly association were recorded in T_7

From the figure 8, it is revealed that % disease severity was increased with the increased of whitefly association. The highest disease severity (46.22 %) was recorded in T_7 (control) and whitefly association (18) were recorded in T_7. The lowest number of whitefly (2.0) were recorded in the T_6 (mulch treatment) and disease severity was 2.87%.

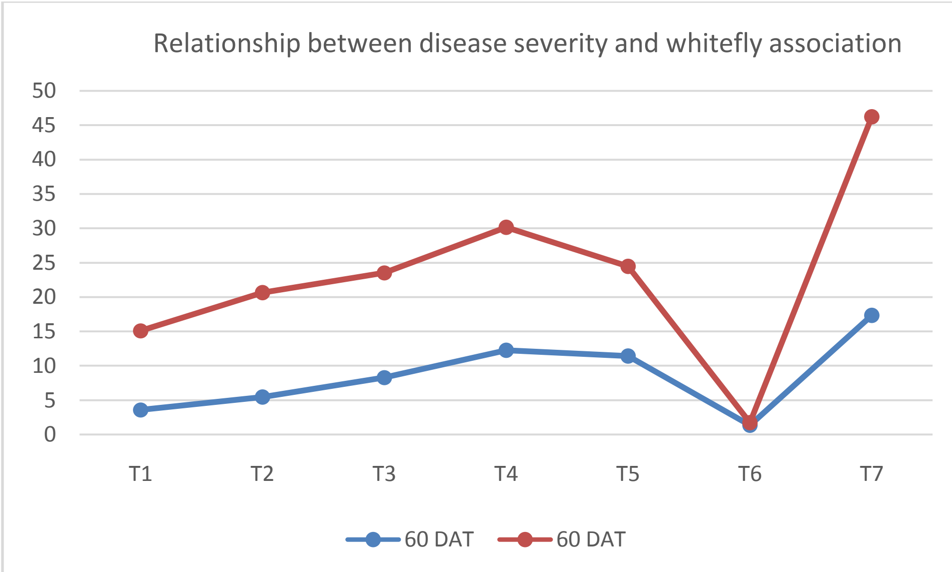

Figure 8: Relationship between disease incidence and whitefly association

T_1 = Imidacloprid, T_2 = ACmix, T_3 = Subicron, T_4 = Neemax, T_5 = Multineem, T_6 = Silver colored mulch, T_7 = Control

4.5 The Morphological Features which are identical, in relation to growth promoting characters in tomato against *Tomato Yellow Leaf Curl Virus*

4.5.1 Number of branches/plant

Significant variation was found for number of branches/plant at different days after transplanting affected by *TYLCV* considering the performance of different treatments applied to the test crop (Table 5). It was found that the treatment T_6 (Silver mulch) showed the highest number of branches/plant (6.20, 7.21 and 8.07 at 30, 45 and 60 DAT respectively) followed by T_1 (Imidacloprid) and T_2 (ACmix) where the lowest number of branches/plant (7.00, 7.33 and 5.22 at 30, 45 and 60 DAT respectively) was achieved from Control treatment (T_7). Among the treated plants, the lowest number of branches/plant was achieved from T_4 (Neemax) followed T_5 (Multineem).

Table 5. Number of branches/plant at 30, 45 and 60 DAT under different treatments

Treatments	Number of branches/plant		
	30 DAT	45 DAT	60 DAT
T_1	5.60 b	6.08 b	6.91 b
T_2	5.47 b	5.93 b	6.73 b
T_3	5.27 c	5.38 d	6.19 d
T_4	4.13 d	5.28 d	6.14 d
T_5	5.20 c	5.67 c	6.50 bc
T_6	6.20 a	7.21 a	8.07 a
T_7	4.00 d	4.33 e	5.22 e
$LSD_{0.05}$	0.152	0.216	0.264
CV (%)	4.934	6.115	6.539

T_1 =Imidacloprid, T_2 = ACmix, T_3 = Subicron, T_4 = Neemax, T_5 = Multineem, T_6 = Silver colored mulch, T_7 = Control

4.5.2 Plant height (cm)

The results on the effect of *TYLCV* infection on plant height of tomato under different treatments are summarized in (Table 6). Significant variation was found on plant height among the treatments. Irrespective of treatments healthy plants produced higher plant height in comparison to *TYLCV* infected plants. The T_6 (Silver colored mulch) treatment produced the highest plant height 99.21 cm at followed by T_1 (Imidacloprid) ,94.25 cm and T_2 (ACmix), 91.39 cm The lowest plant height 79.99 cm was achieved from Control treatment (T_7). Among the treated plants, the lowest plant height was achieved from T_5 (Multineem), 85.75 cm followed by T_4 (Neemax), 83.83 cm.

Table 6. Effect on plant height of *Tomato Yellow Leaf Curl Virus* under different treatments

Treatments	Plant height (cm)
T_1	94.25 b
T_2	91.39 c
T_3	87.37 d
T_4	83.83 e
T_5	85.75 f
T_6	99.21 a
T_7	79.99 g
$LSD_{0.05}$	1.361
CV (%)	10.642

T_1 =Imidacloprid, T_2 = ACmix, T_3 = Subicron, T_4 =Neemax, T_5 = Neem oil,T_6 = Silver mulch, T_7 = Control

4.6 The Morphological Features which are identical, in relation to yield contributing parameters in tomato against *Tomato Yellow Leaf Curl Virus*

4.6.1 Number of flowers/plant

Number of flowers/plant was significantly affected by *TYLCV* under different treatments (Table 7). Among the different treatments, T_6 (Silver mulch) performed best for number of flowers/plant 34.60 which was significantly different from all other treatments. It was also found that the treatment Control treatment (T_7) showed lowest number of flowers/plant 21.36 Among the treated plants, the lowest number of flowers/plant was achieved from T_4 (Neemax) ,23.22 which was statistically identical with T_5 (Multineem), 24.73.

4.6.2 Number of fruits/plant

Number of fruits/plant was significantly influenced by *TYLCV* performed against different treatments applied to the crop to control whitefly (Table 7). Results indicated that the treatment, T_6 (Silver colored mulch) produced highest number of fruits/plant (31.84) which was significantly different from all other treatments. The Control treatment (T_7) showed lowest number of fruits/plant (16.08) which was also significantly different from all other treatments. Among the treated plants, the lowest number of fruits/plant was found from T_4 (Neemax), 20.93.

4.6.3 Weight of fruits/plant

Weight of fruits/plant affected by *TYLCV* was significantly against different treatments applied to the crop (Table 7). Results revealed that the treatment, the highest weight of fruits/plant (3.08 kg) was found from the treatment, T_6 (Silver mulch) which was significantly different from all other treatments. The lowest weight of fruits/plant (1.24 kg) was produced from the Control treatment (T_7) which was also significantly different from all other treatments. Among the treated plants, the lowest weight of fruits/plant was found from T_4 (Neemax)

4.6.4 Single fruit weight

The TYLCV transmitted by whitefly had significant influence on single fruit weight of tomato against different treatments applied (Table 7). The treatment, T_6 (Silver mulch) produced highest single fruit weight (95.68 g) followed by T_1 (Imidacloprid) which was significantly different from all other treatments. The lowest single fruit weight (76.75 g) was produced from the Control treatment (T_7) which was also significantly different from all other treatments. Among the treated plants, the lowest single fruit weight (90.25 g) was found from T_4 (Neemax) which was statistically identical with T_3 (Subicron).

4.6.5 Average fruit diameter

Whitefly transmitted virus, *TYLCV* significantly influenced the average fruit diameter of tomato against different treatments (Table 7). The treatment, T_6 (Silver mulch) exhibited the highest average fruit diameter (14.57 cm) followed by T_1 (Imidacloprid) which was significantly different from all other treatments. The lowest average fruit diameter (8.04) was found from the Control treatment (T_7). Among the treated plants, the lowest single fruit weight (10.15 cm) was found from T_4 (Neemax) which was statistically identical with T_5 (Multineem).

Table 7. Effect on yield and yield contributing parameters of tomato through management of tomato yellow leaf curl virususing different treatments

	Yield and yield contributing parameters				
	Number of flowers/ plant	Number of fruits/plant	Weight of fruits/plant (kg)	Single fruit weight (g)	Average fruit diameter (cm)
T_1	32.12b	29.39 b	2.74 b	93.17 b	13.67 b
T_2	30.63b	28.10 c	2.57 c	91.57 c	12.91 c
T_3	27.24c	25.80 d	2.34 d	90.52 d	11.47 d
T_4	23.22d	20.93 f	1.89 f	90.25 d	10.15 e
T_5	24.73d	22.26 e	2.03 e	91.43 c	10.49 e
T_6	34.60a	31.84 a	3.08 a	95.68 a	14.57 a
T_7	21.36e	16.08 g	1.24 g	76.75 e	8.04 f
$LSD_{0.05}$	1.617	0.614	0.116	0.327	0.415
CV (%)	8.636	6.421	4.713	8.334	6.528

T_1 =ImidaclopridT_2 = ACmix, T_3 = Subicron, T_4 = Neemax, T_5 = Multineem, T_6 = Silver colored mulch, T_7 = Control

5. Fruit yield

Fruit yield/ha performed best from the treatment, T_6 (Silver colored mulch) against *TYLCV* and found signification variation among all the treatments (Fig. 4 and Appendix X). Results exposed that the treatment, T_6 (Silver colored mulch) gave highest fruit yield (53.35 t/ha) where the lowest fruit yield (21.41 t/ha) was produced from Control treatment (T_7). The second highest and third highest fruit yield (47.49 and 44.51 t/ha respectively) was achieved from T_1 (Imidacloprid) and T_2 (ACmix) respectively. Among the treated plants, the lowest fruit yield (10.15 t/ha) was found from T_4 (Neemax) which was statistically identical with T_5 (Multineem)).

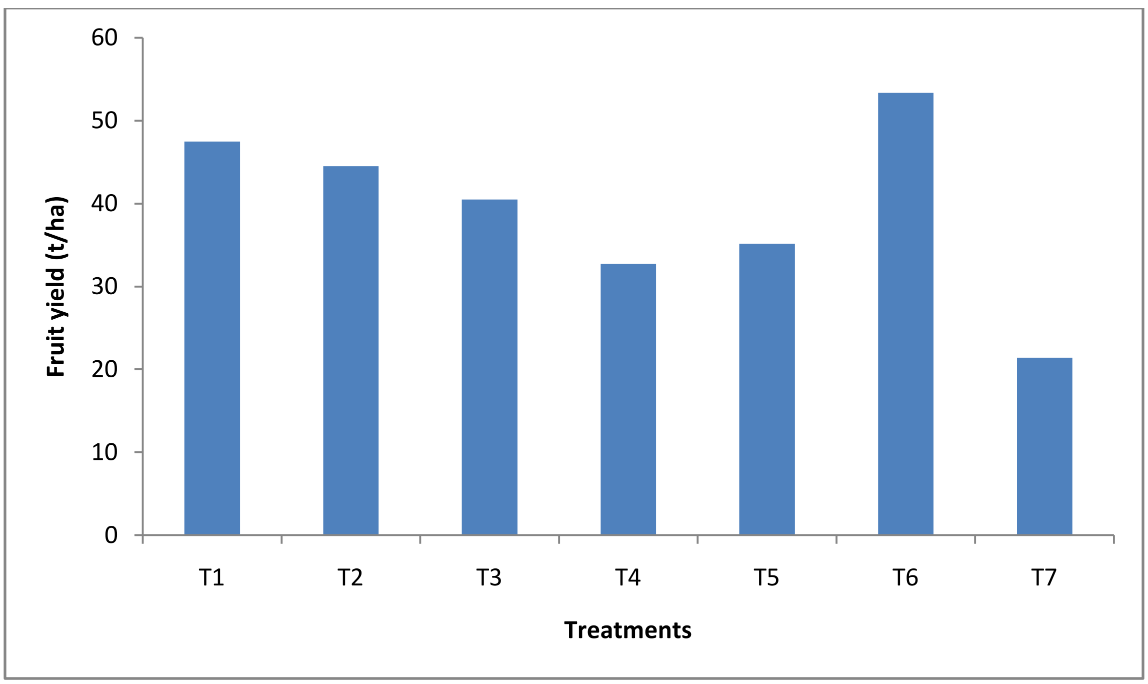

Fig. 8. Effect on yield of tomato using different treatmentsagainst *Tomato Yellow Leaf Curl Virus*

T_1 =Imidacloprid, T_2 = ACmix, T_3 = Subicron, T_4 = Neemax, T_5 = Multineem, T_6 = Silver colored mulch, T_7 = Control

DISCUSSION

The present study was undertaken to study the management of *tomato Yellow Leaf Curl Virus* through insecticides, botanicals and Silver colored mulch. Considerable control of *Tomato Yellow Leaf Curl Virus* was observed through different management practices. Different treatment were used *viz*. T_1 =Imidacloprid, T_2 = ACmix, T_3 = Subicron, T_4 = Neemax, T_5 = Multineem, T_6 = Silver colored mulch, T_7 = Control for the management of *Tomato Yellow Leaf Curl Virus*. Under the present study, T_6 (Silver colored mulch) gave the best performance against *Tomato Yellow Leaf Curl Virus*.

5.1 Disease incidence and severity (%): In this study,it was noticed that the disease incidence (%) due to *Tomato Yellow Leaf Curl Virus*was found in almost all the plots at 80 DAS. The highest percentage disease incidence was recorded in the T_7 (control treatment) followed by T_4, T_5, T_3, T_2, T_1 and T_6 respectively. Among the treatments, the lowest disease incidence (%) was found in T_6 (Silver colored mulch).The results regarding the percent disease incidence of *TYLCV* in tomato that observed in this study is almost similar as observed by Sastry and Singh (1973), Al-Musa (1982), Green and Kalloo (1994) and Ali *et al*. (2005). Azam *et al.* (1997) investigated that insecticides (carbofuran, endosulfan, Dimethoate, buprofezin and triazophos) and cultural methods are most effective for the control of whitefly and *TYLCV* in tomatoes. Ahmed *et al.* (2001) used Imidacloprid insecticide, for indirectly controlling *TYLCV t*hrough control of its vector whitefly.

Vani *et al.* (1989) evaluated that different type of mulches reduced the incidence of viral diseases and also found that mulching increased plant growth and yield. Mulching with polyethylene sheets of deferent colours (black, transparent, white, and aluminum) had significant effect on *Bemisia tabaci* and spread of *TYLCV*. Polyethylene mulching reduced whitefly and *TYLCV* infection. But mulching with aluminum colour was found to be most effective in reducing number of whiteflies and delay the infection of *TYLCV* (Davino *et al.,* 1996).Azam *et al.* (1997) and also investigated that insecticides (carbofuran, endosulfan, Dimethoate, buprofezin and triazophos) and cultural methods (covering the plants with polyester for 30, 45 or 60 days) are most effective for the control of whitefly and *TYLCV* in tomatoes.

5.2. Morphological features

5.2.1. Number of, flowers and fruits per plant

The yield of individual treatment depends on the number of flowers and fruits per plant. The highest number of flower and fruits per plant were recorded in T_6(Silver colored mulch) (followed by T_1, T_2 and T_3. But considering the economic condition/cost-benefit ratio T_5 (Multineem)was the best in both block, because there was no significant different among T_4 (Neemax), regarding these mentioned parameters. The lowest number of leaves, flowers and fruits per plant were recorded in the T_7 (control treatment). The same results were found in the previous study that was conducted by Sayed *et al.,* (2018). The finding of the previous work was Imidacloprid gave the better results regarding the flowers and fruits/plant than Sobicron.

5.3. Yield and yield contributing characters

The highest yield per plant and plot was recorded in T_6 (Silver colored mulch) followed by the treatment T_1, T_2,T_3,T_5 ,T_4 and T_7 (control treatment). But considering the economic condition/cost-benefit ratio $T_5$was the best in the study, because there was no significant different among T_4, T_5, regarding yield per plant and plot. Where the lowest yield per plant/plot was founded in T_7 (control treatment). The same results were found in the previous study that was conducted by Sayed *et.al*, (2018). There is no more previous report over yield of okra against *YVMV* in our country.

5.4. Growth promoting parameters

5.4.1. Number of branches per plant

The highest number of branches were recorded in T_6 (Silver colored mulch) followed by T_1, T_2 and T_3. But considering the economic condition/cost-benefit ratio T_5 (Multineem) was the best in both block, because there was no significant different among T_4 (Neemax) regarding these mentioned parameters. The lowest number of leaves, flowers and fruits per plant were recorded in the T_7 (control treatment). The same results were found in the previous study that was conducted by Sayed *et al.*, (2018). The finding of the previous work was Imidacloroprid better than Sobicron.

5.4.2. Plant height

The highest height of plant was recorded in T_6 (Silver colored mulch) followed by T_1, T_2 and T_3. But considering the economic condition/cost-benefit ratio T_5 (Multineem) was the best in both block, because there was no significant different among $T_{4,}$(Neemax) regarding these mentioned parameters. The lowest number of leaves, flowers and fruits per plant were recorded in the T_7 (control treatment). The same results were found in the previous study that was conducted by Sayed *et al.*, (2018). The finding of the previous work was Imidacloroprid better than Sobicron.

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conductedto manage the*Tomato Yellow Leaf Curl Virus* through selected insecticides, botanicals and Silver colored mulch. The study was conducted in the field allowed for the Department of Plant Pathology of Sher-e-Bangla Agricultural University, Dhaka during winter season. High yielding tomato variety BARITomato-14 was used. The field experiment was carried out in randomized complete block design with three replications.In total 7 treatments including control were considered viz. T_1 = Imidachloroprid, T_2 = ACmix, T_3 = Subicron, T_4 = Neemax, T_5 =Multineem, T_6 = Silver metallic plastic mulch and T_7 = Control.

In case of % disease incidence of *TYLCV*, the lowest disease incidence was recorded 11.11%, 13.33% and 13.33% at 30, 45 and 60 DAT respectively was recorded in T_6. The highest disease incidence 33.33, 40.00 and 46.67% at 30, 45 and 60 DAT respectively was recorded in T_7 (control). In case of disease severity, the lowest disease severity (1.96%, 2.01% and 1.72% at 30, 45 and 60 DAT respectively was also recorded in T_6 (Silver mulch) and the highest disease severity 25.80, 27.43, 46.22%) was also found in T_7 treatment. All the selected treatments used in the study for controlling the insect vector, whitefly of *TYLCV* were showed significant influence on different assayed parameters in the test crop tomato. Among the set treatments, T_6 (Silver mulch) was gave the best performance in all regards of assayed parameter, the best performance was the reduced whitefly association in remarkable level. In case of insect vectors, whitefly association, the whitefly association was the lowest in T6 treatment (Sliver mulch) there were 2.0, 4.0 and 2.0 at 30, 45 and 60 DAT respectively. The highest whitefly association was recorded in T_7 (control treatment) that was 19, 23 and 18 at 30, 45 and 60 DAT respectively.

Among the set treatments, T_6 (Silver mulch) gave the best results regarding growth promoting characters, yield and yield attributes. The highest plant height (74.93, 94.05 and 99.21 cm at 30, 45 and 60 DAT respectively), number of healthy leaves/plant (34.07, 98.31 and 95.50 at 30, 45 and 60 DAT respectively), number of branches/plant (6.20, 7.21 and 8.07 at 30, 45 and 60 DAT respectively), number of flowers/plant (0.37, 5.31 and 34.60 at 30, 45 and 60 DAT respectively), number of fruits/plant (31.84), weight of fruits/plant (3.08 kg), single fruit weight (95.68 g), average fruit diameter (14.57 cm) and fruit yield (53.35 t/ha) were obtained from the treatment, T_6 (Silver mulch). Again, the lowest plant height (60.87, 75.76 and 79.99 cm at 30, 45 and 60 DAT respectively), number of healthy leaves/plant (27.20, 51.75 and 45.15 at 30, 45 and 60 DAT respectively), number of branches/plant (7.00, 7.33 and 5.22 at 30, 45 and 60 DAT respectively), number of flowers/plant (0.13, 3.44 and 21.36 at 30, 45 and 60 DAT respectively), number of fruits/plant (16.08), highest weight of fruits/plant (3.08 kg), weight of fruits/plant (1.24 kg), single fruit weight (76.75 g), average fruit diameter (8.04) and fruit yield (21.41 t/ha) were obtained from control treatment ($T_{7)}$.

Among the treated plants, the results on different parameters, achieved lower performance from botanical treatment T_4 (Neemax) and T_5 (Multi Neem) in most of the cases where the treatment T_1 (Imidacloprid) showed comparatively better performance next to treatment T_6 (Silver mulch). From the above findings on different parameters studied, it can be concluded that the treatment T_6 (Silver colored mulch) was best against whitefly association in test crop tomato against *TYLCV* for tomato cultivation compared to other considering treatments including control treatment.

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APPENDICES

Appendix I. Agro-Ecological Zone of Bangladesh showing the experimental location

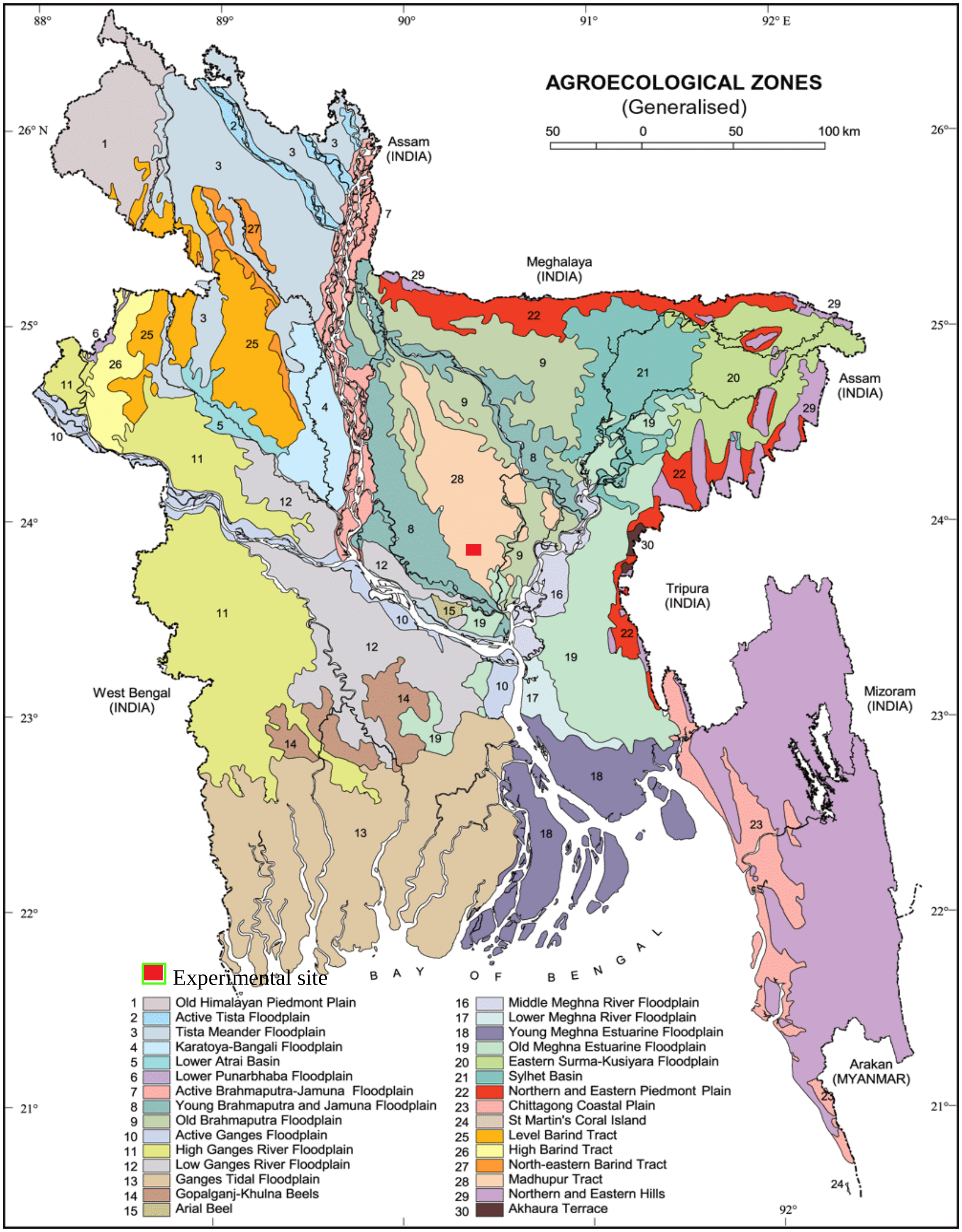

Fig. 10. Experimental site

Appendix II. Monthly records of air temperature, relative humidity, rainfall and sunshine hours during the period from October 2016 to March 2017

Month	RH (%)	Air temperature (C)			Rainfall (mm)
		Max.	*Min.*	*Mean*	
October, 2016	68.48	30.42	16.24	23.33	52.60
November, 2016	56.75	28.60	8.52	18.56	14.40
December, 2016	54.80	25.50	6.70	16.10	0.0
January, 2017	46.20	23.80	11.70	17.75	0.0
February, 2017	37.90	22.75	14.26	18.51	0.0
March, 2017	52.44	35.20	21.00	28.10	20.4

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1212.

Appendix III. Characteristics of experimental soil analyzed at Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

A. Morphological characteristics of the experimental field

Morphological features	**Characteristics**
Location	Agronomy Farm, SAU, Dhaka
AEZ	Modhupur 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	Not Applicable

Source: Soil Resource Development Institute (SRDI)

B. Physical and chemical properties of the initial soil

Characteristics	**Value**
Partical size analysis % Sand	27
%Silt	43
% Clay	30
Textural class	Silty Clay Loam (ISSS)
pH	6.7
Organic carbon (%)	0.45
Organic matter (%)	0.78
Total N (%)	0.03
Available P (ppm)	20
Exchangeable K (me/100 g soil)	0.1
Available S (ppm)	45

Source: Soil Resource Development Institute (SRDI)

Appendix IV. Layout of the experiment field

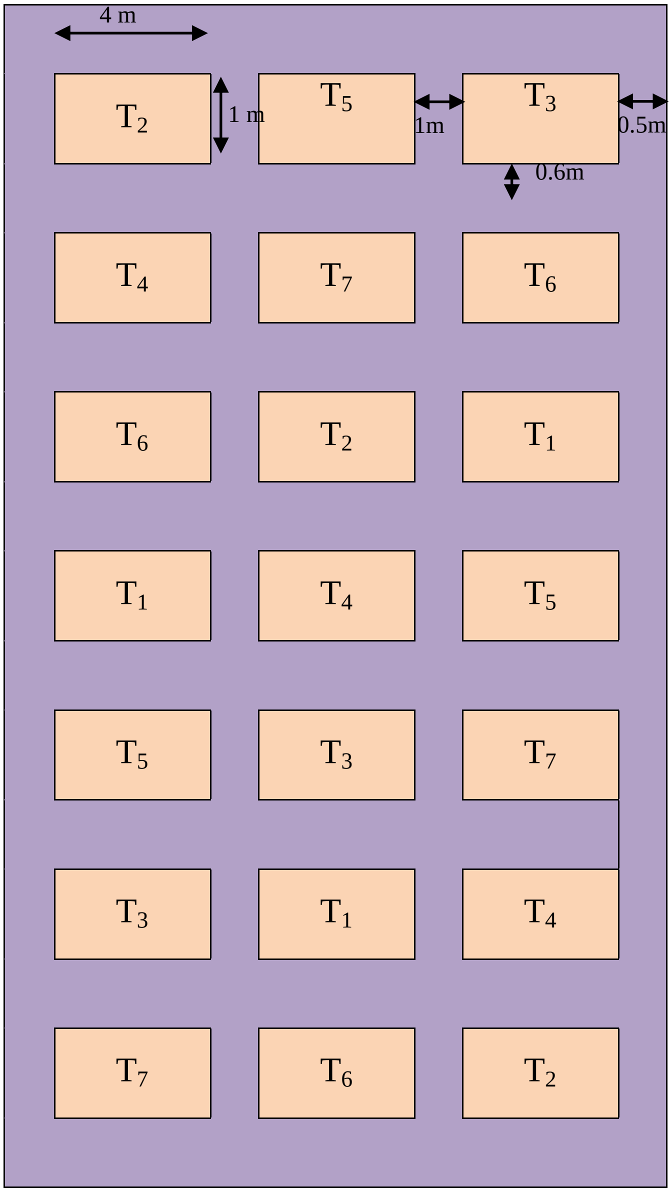

Fig. 11. Layout of the experiment field

Appendix v. Pictorial view of treatment plots

Fig 12. Plot treatment with silver mulch material