EFFECT OF DIFFERENT MULCHES ON YELLOW LEAF CURL DISEASE OF TOMATO AND ITS IMPACT ON YIELD

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CERTIFICATE

This is to certify that the thesis entitled ***"EFFECT OF DIFFERENT MULCHES ON YELLOW LEAF CURL DISEASE OF TOMATO AND ITS IMPACT ON YIELD",*** *Sher-e-Bangla Agricultural University (SAU), Dhaka in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (MS) IN PLANT PATHOLOGY,*** *embodies the results of a piece of bonafide research work carried out by* ***S. M. NAZMUS SAKIB SHAHIN, Registration no. 10 - 04103*** *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.

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ABSTRACT

The present investigation was initiated to evaluate relative effectiveness of several mulches such as Rice straw, Blue, Transparent and Red Polyethylene sheets for the management of *TYLCV* in the field. In this experiment two popular tomato varieties of BARI Tomato-14 and BARI Tomato-16 were used. The experiment was set up at the field of Sher-e-Bangla Agricultural University, during October 2016 to March 2017. *TYLCV* was prevalent between two tomato varieties in different treatments and the average *TYLCV* infection varied from 8.33 % to 66.67 % and 52.32 % to 74.09 % in disease incidence and severity, respectively. Maximum prevalence (Disease incidence 66.67 % and disease severity 74.09 %) was found in T_1 (Control plot) and minimum prevalence (Disease incidence 8.33% and disease severity 52.32%) was observed on T_3 (Blue Polyethylene) in the same variety. Significant reduction was observed in case of different growth and yield contributing characters between two tomato varieties due to application of different mulches. The correlation and regression analysis revealed that % reduction of growth and yield contributing characters due to *TYLCV* infection had pronounced effect on yield reduction of tomato and it was observed in all cases depending on varieties, treatments, whitefly population and weather. The results of the study suggested that, none of the treatments had significant effect against *TYLCV* infection. Although treatment T_3 (Blue Polyethylene) performed better as compared to other treatments on all over consideration. None of the varieties had impressive level of tolerance against *TYLCV* infection but BARI Tomato -14 performed better than BARI Tomato -16.

LIST OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
Agric.	=	Agriculture
BBS	=	Bangladesh Bureau of Statistics
BSMRAU	=	Bangabandhu Sheikh Mujibar Rahman Agricultural University
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAT	=	Days After Transplanting
et al.,	=	And others
FAO	=	Food and Agricultural Organization
Fig.	=	Figure
g	=	Gram (s)
ha	=	Hectare
Int.	=	International
J.	=	Journal
Kg	=	Kilogram (s)
K	=	Potassium
LSD	=	Least Significant Difference
M.S.	=	Master of Science
No.	=	Number
Na	=	Sodium
P	=	Phosphorus
pH	=	Negative logarithm of hydrogen ion concentration
SAU	=	Sher-e-Bangla Agricultural University
Sci.	=	Science
TYLCV	=	Tomato yellow leaf curl virus
USA	=	United States of America
Virol.	=	Virology
Ca	=	Calcium
L	=	Litre
µg	=	Microgram
%	=	Percentage

CHAPTER I

INTRODUCTION

Tomato (*Lycopersicon esculentum* L.) which belongs to the family Solanaceae is one of the most popular commercial vegetable crops grown worldwide (Prior *et al*. 1994). It is one of the important, popular and nutritious vegetables grown in Bangladesh in both winter and summer season around all parts of the country (Haque *et al*. 1999). It is originated in South American Andes and its use as a food originated in Mexico. It ranks next to potato and sweet potato in the world vegetable production and top of the list of canned vegetables (Choudhury, 1979).

The estimated worldwide tomato production was 163 million mt annually (FAOSTAT, 2014). In Bangladesh, the recent statistics shows that tomato was grown in 29765 ha of land and the total production was approximately 413610 metric tons during the year 2014-2015 and the average yield of tomato was 2154 kg/ha (BBS, 2015*)*.

The leading tomato producing countries are China, United States of America, India, Egypt, Turkey, Iran, Mexico, Brazil and Indonesia (FAOSTAT, 2014). In Bangladesh, tomato is cultivated all over the country due to its adaptability to wide range of soil and climate (Ahmad, 1995). The best growing areas of tomato in Bangladesh are Rajshahi, Cumilla and Chattagram and it ranks fourth in respect of production and third in respect of area (BBS, 2014-2015).

Tomato is a popular vegetable with high anti-oxidant. They are sweet, juicy and healthy. Tomatoes are also an excellent source of vitamin C, biotin, molybdenum and vitamin K. They are also a good source of copper, potassium, manganese, dietary fiber, Lycopene, vitamin A, vitamin B6, foliate, vitamin E, and phosphorus.

The yield of tomato in our country is not satisfactory in comparison to its requirement (Aditya *et al.* 1999*)*. The low yield of tomato in Bangladesh is not an indication of low yielding ability of this crop, but of the fact that low yielding variety, poor crop management practices and lack of improved technologies. The average yield of tomato in Bangladesh is very low as compared to world average. Average yield of tomato in the world is 32.8 t/ha whereas in Bangladesh it is around 14 t/ha (FAO, 2014).

Among the yield limiting factors of tomato, virus diseases play an important role all over the world. So far 36 different virus diseases have been recorded in tomato (Jones *et al*., 1991). Among the viral diseases, *tomato mosaic* and *tomato yellow leaf curl virus* (*TYLCV*) are considered as the most important ones. In fact, *TYLC* disease is one of the most devastating *begomovirus* infecting cultivated tomatoes in tropical and sub-tropical regions.

Whitefly (*Bemisia tabaci*, Homopetra: Aleyrodidae) is an important insect pest which causes direct feeding damage, as well as indirect damage as vector of numerous *Gemini viruses* such as *TYLCV* which is a threatening virus for tomato production (Delatte *et al*. 2005). *Bemisia tabaci* beside its role as tomato leaf curl virus disease vector also excretes honey dew. This sweet and sticky excrete substances attracts both saprophytic fungi and ants, the potential dispersal agents of fungal spores (Yassin *et al*. 1990).

Yield loss could be as high as 50-100% and 63-95% respectively due to *TYLCV* depending on variety and stage of infection and it is the most damaging disease of tomato (Pico *et al*. 1998 and Gupta, 2000). Farmers usually rely on frequent application of insecticides against the vector whitefly for the management of *TYLCV*. However it does not give satisfactory results and also cause environmental pollution.

In Bangladesh, *TYLCV* was first reported by Akanda (1991). Since then efforts have been made to characterize the virus systematically, manage the disease through manipulation of sowing dates, growing seedlings in net house and application of insecticides (Paul, 2002; Rahman, 2003; Gupta, 2000; Azam, 2001; Akhter, 2003 and Sultana, 2001). Farmers usually depend on frequent application of insecticides against the vector whitefly for the management of *TYLCV*. Insecticides were considered indispensable for sustainable agriculture production but, their increasing and irrational use has become a source of great concern because of their possible effect on human health and non-target components of the environment. This concern is heightened by the non-specificity and high toxicity of some pesticides and development of resistant strains of microorganisms against other ones. So for the management of *TYLCV* to ensure profitable cultivation of high quality tomatoes, the prime importance has to be given on effective management strategy for the diseases. In this case use of different mulches such as straw and plastic mulches in order to delay virus disease has been proved to be successful in many situations (Cohen and Melamed-Madjar, 1978, Suwwan *et al.* 1988, Csizinszky *et al*. 1996 and Malla *et al.* 2002).

However, there are not so many reports on the effect of straw and color mulches on *TYLCV* disease of tomato in Bangladesh. The present investigation was initiated to evaluate relative effectiveness of several mulches for the management of *TYLCV* in the field.

In consideration with the fact stated above, the present research work was designed to meet the following objectives:

1. To evaluate the incidence and severity of Yellow Leaf Curl disease of tomato;

2. To find out a suitable mulch as an effective management option against Yellow Leaf Curl disease; and

3. To evaluate the effect of different mulches in yield and yield attributes of tomato.

CHAPTER II
REVIEW OF LITERATURE

The studies with respect to effect of mulching on *Tomato Yellow Leaf Curl Virus* (*TYLCV*) and its impact on yield are taken into consideration while reviewing the literature. Therefore, the literatures, which are most relevant and available to the present study, have been reviewed here under the following heads.

2.1. Nutritional value of tomato

Tomato (*Lycopersicon esculentum* Lin.) is an important vegetable crop in our country as well as in the world. In Bangladesh it is the fourth most important vegetable crop in terms of production and third in terms of area. Tomato is classified as group 2 on food production efficiency in terms of nutrition. The food value content of tomato are Water- 93.5 %, Potassium- 0.244 %, Phosphorus- 0.27 %, Ascorbic acid- 0.023 %, Calcium- 0.013 %, Iron- 0.0005 %, Carbohydrates -4.7 %, Proteins- 1.2487 %, Amino acids- 0.00080 % (Mahmud, 1984).

It is prone to cumulative infection by fungi, bacteria and viruses. Virus diseases have been recognized as a limiting factor in tomato production. The successful production of tomato for nutrition and seed purposes demands the control of these viruses which cannot be sufficiently attained by any physical or chemical barrier. Among Virus diseases *TYLCV* is one of the most devastating viral diseases of cultivated tomato (*Lycopersicon esculentum*) in tropical and subtropical regions of the world causing losses up to 100 per cent (Moriones and Navas, 2000)

2.2. Viral diseases in tomato

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 Y* (*PVY*), *Broad bean wilt virus* (*BBWV*), *Tomato rattle virus* (*ToRV*) and *Alfa-alfa mosaic virus* (*AMV*) were identified on the basis of symptoms, electron microscope 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 two viruses as *TYLCV* causing yellow mosaic symptom and *Tomato purple vein virus* (*TPVV*) causing purple vein symptom for the first time in Bangladesh.

Alam (1995) reported 7 virus diseases on tomato in Bangladesh. The viruses are *Cucumber mosaic virus* (*CMV*), *Tomato yellow leaf curl virus* (*TYLCV*), *Tomato leaf curl virus* (*TLCV*), *Tomato mosaic virus* (*TMV*), *Tomato purple vein virus* (*TPVV*), *Potato leaf roll virus* (*PLRV*) and *Tomato spotted wilt virus* (*TSWV*). Among these *TYLCV* and *TPVV* were found to be most damaging and widely distributed.

2.3. Tomato Yellow Leaf Curl disease

2.3.1. Historic perspective

Plant viruses, like all viruses, are obligate intracellular parasites that do not have the molecular machinery to replicate without a host. During the 1960s a new disease reported in the Jordan valley in Israel caused severe damages to a newly introduced tomato variety to the market. This disease was later called *Tomato yellow leaf curl virus* disease (Cohen and Nitzany, 1966). *Tomato yellow leaf curl virus* (*TYLCV*) was found to be the causative agent of this disease and was associated with outbreaks of the whitefly *Bemisia tabaci* populations nearby cotton fields, which were newly grown in this area. These cotton fields helped *B. tabaci* populations to build up to high levels, and outbreaks of the disease were seen afterwards. Although symptoms of *TYLCV* on plants were observed as early as the 1930s but outbreaks of the disease were not observed until *B. tabaci* populations greatly increased.

TYLCV was observed as having geminate shape in 1980 (Russo *et al.*, 1980) and a few years later the viral genome was fully cloned and sequenced, and the virus was shown to be a monopartite *Gemini virus* (Navot *et al*. 1991). Since the late 1990s research regarding TYLCV focused on understanding the interactions between TYLCV, plants that it infects, and its only vector, *B. tabaci*.

2.3.2. Distribution and economic importance of TYLC disease

The first report of the occurrence of *TYLCV* causing damage in tomatoes was from Israel in late 1930s (Pico *et al*. 1996). The causal agent was described in 1964 and named *Tomato yellow leaf curl virus* (Cohen and Harpaz, 1964). The virus was isolated in 1988 (Czosnek *et al*. 1988) and the genome was sequenced in 1991 (Navot *et al*. 1991, Cohen and Antignus, 1994, Pico *et al.* 1996).

Polizzi *et al.* (1994) reported that *Tomato yellow leaf curl bigeminivirus* (*TYLCV*) is a limiting factor for tomato production in Italy. Yield loss ranges from 25-80%. *TYLCV* is a whitefly transmitted *Gemini virus*. It has been a major limiting factor for tomato production over the last 30 years in many tropical and subtropical areas causing yield loss as high as 50- 99% (Pico *el al.* 1998).

Abou - Jawdah *et al.* (1999) reported that *Tomato yellow leaf curl virus* (*TYLCV*), transmitted by the whitefly, and is epidemic in Africa, Middle East and South-East Asia. It is also reported in some European countries and the American continent. In Lebanon, it is the major limiting factor for summer and autumn production of tomato. Comparisons of the nucleotide sequence in the intergenic region with other reported leaf curl viruses showed the Lebanese *TYLCV* isolates (94-96% identity) but not closely related to isolates from Sardinia, Spain and Thailand, or to tomato leaf curl isolates from India, Taiwan and Australia.

Kung (1999) described that *TYLCV* is one of the most devastating virus diseases of cultivated tomato.

Lapidot *et al.* (2001) described *TYLCV* as one of the most devastating *begomoviruses* of cultivated tomato in the tropical and subtropical region. *TYLCV* has long been known in the Middle East, the North and Central Africa and the Southeast Asia. It has been spread to southern Europe; *TYLCV* has also been identified in the Caribbean region, Mexico and the United States. *TYLCV* epidemics tend to be associated with high population of whitefly. In the Mediterranean region yield loss can be upto 100%. In many tomato growing areas *TYLCV* has become a limiting factor for production in the field. *TYLCV* is a *Gemini virus* transmitted by whitefly (*B. tabaci).*

TYLCV causes most destructive disease of tomato throughout the Mediterranean region, the Middle East and the tropical regions of Africa and

Central America. It is also reported from Japan, Australia and the USA. In many cases yield loss can be up to 90% (Gafni, 2003).

Polston *et al.* (2005) reported that *TYLCV* causes 90% reduction marketable yield if infected within 8 weeks after transplanting and 45% if infection occurs between 8-14 weeks after transplanting. Tomato plant are susceptible to *TYLCV* disease at all stages of their growth (Sikia and Muniy-appa, 1989), but yield reductions were determined to a great extent by the stage at which tomato plants become infected. Yield losses caused by *TLCV* vary from 50% to 82% depending on the strain of the virus, the tomato cultivar and the growth stage at which plants become infected (Ioannou, 1985). Yield losses of 100% are common, particular when plants are infected at early stage of development (Cohen and Antignus, 1994; Nakhla and Maxwell, 1998).

It was reported that the virus incidence results in more than 70% yield reduction and even causes losses up to 100% in tomato in tropical, subtropical regions as well as Bangladesh (Ahmed *et al*. 2001).

Luckyanenko (1991) pointed out that *TYLCV* transmitted by whitefly is 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%. Whitefly transmitted *Gemini viruses* cause over 40 diseases of vegetables and fiber crops worldwide were reviewed by Brown and Bird (1992). During the past decade both prevalence and distribution of whitefly transmitted plant viruses 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 the

TYLCV was one of the most damaging viruses of tomato prevalent worldwide.

Alam *et al.* (1994) studied on its effects on cellular components of infected leaves and revealed that the virus infection caused 44% and 50% of chlorophyll and β- carotene reduction, respectively compared to healthy plant. They also observed 25% reduction of phosphorus in infected leaves while nitrogen, 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.

Pico *et al.* (1996) stated that *TYLCV* is one of the most devastating diseases of cultivated tomato crops that causes economic losses up to 100% in many tropical and subtropical regions, and is spreading towards new areas. They also suggested that the increasing economic importance of *TYLCV* has resulted in the need for accurate detection and identification procedures, stimulating intensive research efforts focused on virus biology, diversity, and epidemiology to develop successful management strategies.

2.3.3. Host Range

Tomato yellow leaf curl virus (*TYLCV*) (*Begomovirus, Geminiviridae*) is the type member and representative of the complex of viruses associated with the *Tomato yellow leaf curl* disease with ssDNA genome, a plant-infecting group of viruses that have single or double genomic components enveloped by an icosahedra coat protein. These viruses infect tomatoes and other vegetable and ornamental crops and cause severe losses estimated by billions of dollars each year. *Begomoviruses* are exclusively transmitted by the whitefly (*Bemisia tabaci*) in a persistent circulative manner. Epidemics were often associated with the presence of whiteflies. Since then, extensive research in many laboratories in the world was conducted to better understand the interactions between *TYLCV*, the tomato plant and its only vector is *B. tabaci* (Abdullah, 2014).

Whiteflies are pests which affect agricultural crops and ornamental plants, both in greenhouses and outdoors, and are vectors of many viruses. The tobacco whitefly (*Bemisia tabaci* Genn.) is the insect vector of *TYLCV,* a Gemini virus with a single genomic component (Czosnek *et al.* 1988; Navot *et al.* 1991).

The *TYLCV* known to affects tomato crops (*Lycopersicon esculentum* Lin.) in the Middle East and in many other tropical and subtropical regions (Czosnek *et al.* 1990).

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

Fifteen species of the families Solanaceae, Compositae, Leguminosae, Malvaceae and Plantaginaceae became systemically infected by *TYLCV* following artificial inoculation by means of viruliferous whiteflies (Ioannou *et al*. 1987).

2.3.4. Symptoms of TYLC disease

TYLCV was first studied by Cohen and Harpaz (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*).

Severely attacked tomatoes by the disease are easily recognizable in the field and the new growth of plants with *TYLCV* has reduced internodes, giving the plant a stunted appearance (Yassin and Nour, 1965). The new leaves as well are greatly reduced in size, wrinkled, and yellowed between the veins and have margins that curl upward giving them a cup-like appearance. Flowers may appear but usually will drop before**.**

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.

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.

Aboul-Ata *et al*. (2000) studied some epidemiological aspects of *TYLCV* in the field. It was found that *TYLCV* intensity is related to proportion of viruliferous whitefly rather than total number of whitefly. Five percent of viruliferous vector density as detected by cDNA hybridization led to 46.4% *TYLCV* in the field and same percentage as determined by bioassay led to 67.9% infection.

Gafni (2003) reported that *TYLCV* is an ssDNA plant virus, a member of *geminiviridae* of the genus *begomovirus*. *TYLCV* like all members of *geminiviridae* has geminate (twinned) particle, 18-20 nm in diameter and 30 nm long with 22 metameric capsomeres and 110 identical protein units. Symptoms become visible in tomato in approximately 2-3 weeks after infection. Leaf symptoms include chlorotic margins, small leaves that are cupped, thick and rubbery. The majority (90%) of flowers abscises after infection and therefore few fruits are produced.

2.3.5. TYLC disease incidence and severity

Malla *et al.* (2002) evaluated effectiveness of mulching (rice straw) and muslin tunnel to manage *TYLCV* in Nepal. Mulching reduced *TYLCV* incidence as compared to control. But the reduction was not very effective in reducing *TYLCV* incidence.

In open field production in Florida, reflective plastic mulches are used successfully to reduce incidences of *TYLCV* infected tomatoes. The most effective reflective mulches are entirely or partially aluminized and reflect a lot of daylight. These are believed to reflect both visible and UV light which disorients whiteflies and decreases the landing of whiteflies on plants in the field. Like other mulches, the effectiveness decreases as the tomato canopy increases and covers the mulch. Reflective mulches are effective even when whitefly populations are expected to be high. This approach has the added benefit of interfering with other virus vectors (aphids and thrips) and is associated with lower incidences of several other tomato viruses (Zaks, 1997).

In addition to reducing incidences of whitefly-transmitted viruses such as TYLCV, reflective mulches can also reduce incidences of aphid- and thrips transmitted viruses (Csizinszky *et al.* 1996, 1999).

Ahmed *et al.* (2001) studied the effect of imidacloprid on incidence of *TYLCV* by using two applications at four different rates (47.6, 71.4, 95.2, and 119 g a.i./ha) under field conditions and found that the repeated rates of imidacloprid reduced disease incidence at all the dosage and the disease incidence was reduced to 2.2 to 17% and the treated plots consistently had higher yields than control plots.

Rashid *et al.* (2002) screened 32 varieties of tomato against *TYLCV*. None of them were found to be free from infection. Disease incidence varied from 3 to 100%. They use following scale for grading the varieties. R= Resistant (1-25%), MR= Moderately Resistant (26-50%), MS= Moderately susceptible (51-75%) and S= Susceptible (76-100%). Out of 32 varieties they graded 12 as resistant which included Ratan, BARI -7, 10, 11 and BARI- 13.

Muqit *et al*. (2006) evaluated effectiveness of mulching (Blue, transparent and yellow colored polyethylene) to manage *TYLCV* in Bangladesh. Mulching reduced 15-45% *TYLCV* incidence as compared to control.

2.3.6. Management Strategies

Several methods have been developed to control *TYLCV*, such as the use of healthy transplants, chemical and physical control of the vector, crop rotation, and breeding for resistance to *TYLCV* (Nakhla & Maxwell, 1998). The most effective and environmentally sound management remains planting of resistant or tolerant varieties. Thus, breeding for *TYLCV* resistance is probably the most important long term goal for lasting *TYLCV* management (Lapidot and Friedmann, 2002). At present, only partially resistant F_1 hybrids are commercially available. Moreover, a prevalent Problem is associated with the definition of resistance. As stated by Lapidot and Friedmann (2002), a host plant is resistant to *TYLCV* if it can suppress its multiplication and consequently suppress the development of disease symptoms. Lower virus accumulation in a resistant host has been associated with the latter's resistance, as well as with the effect of infection on total yield and yield components (Lapidot *et al.* 1997).

Classical breeding has attempted to introduce *TYLCV* resistance in tomato cultivars. However, resistance appears to be controlled by one to five genes and crosses have produced only tolerant hybrids which is unfortunate after over 25 years of breeding. Moreover, the best commercially available cultivars show only tolerance to the virus and meanwhile, the disease continues to spread. Therefore, the production of transgenic tomato plants appears to be a more promising way of obtaining resistance to *TYLCV*. Several strategies have been used to engineer plants resistant to viral pathogens, based on the concept that the introduction and expression of viral sequences in plants can interfere with the virus's life cycle. This strategy is also referred to as pathogen derived resistance (Lapidot *et al.* 1997).

Pilowsky and Cohen (2000) screened 25 wild *Lycopersicon* accessions 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 or 4 accessions of *L. pimpinellifolium* were highly susceptible. Plants of accessions CIAS 27(*L. pimpinellifolium)* showed moderate resistance to *TYLCV*.

Yang *et al.* (2004) tested 8 different constructs of *TYLCV* replication associated protein and C4 gene sequence in the transformed inbred line. Transgenic plants were screened for resistance to *TYLCV* using viruliferous whiteflies (*B. tabaci*). No symptom was observed and no *TYLCV* DNA was detected by hybridization or PCR in the progenies of the plants transformed with 3 constructs.

Many chemicals are used primarily in field production against *TYLCV*. The most effective and widely used class of insecticides to reduce whitefly populations is the neonicotinoids of which at least three (thiomethoxam, imidacloprid, and dinotefuron) have been used to reduce incidence of *TYLCV* infected tomato plants (*Ahmed et al.* 2001; Cahill *et al.* 1996; Polston & Anderson, 1997).

In Florida and in Israel neonicotinoids applied as drenches and less often as sprays, is the main line of *TYLCV* management. Neonicotinoids are used at reduced rate in the plant house on tomato transplants for protection for the first 2 weeks in the field, and then are applied at higher rates in the setting water at the time of transplant. The setting water application is applied at a rate that gives approximately 8 weeks of whitefly control. Once whiteflies begin to develop on the tomato plants then a rotation of non 20 neonicotinoid insecticides such as insect growth regulators, oils and soaps, and several contact insecticides can be employed through final harvest. Resistance to neonicotinoids has been shown in several locations around the world (Schuster & Gilreath, 2003).

Sastry (1989) observed that the incidence of *TYLCV* was minimized by initial root dip of tomato seedlings (cv. Pusa ruby) in 0.1% carbofuran solution for 1 h followed by 2 foliar sprays at 20 and 30 days after transplanting.

Azam *et al.* (1997) conducted an experiment for the management of whitefly (*Bemisia tabaci*) over a two-year period in Oman. Each experiment had a total of 10 treatment, including six insecticidal treatment with carbofurn (two different dosages), endosulfan, Aflix (endosulfan+ dimethoate), buprofezin and triazophos; three cultural treatments covering the plants with Agril. (a polyster material) for 30, 45, and 60 days after transplanting in all the treatments. The plant covered with Agril. (a polyster material) had a lower incidence of egg and nymphal population of whitefly and of *TYLCV* in the two year study. There was a significant increase in the yield of plants under the three Agril cover treatments with an average ranging from 44 to 49 t/ha as compared to the average in the control treatment with 26.5 t/ha over the two year period.

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 Di-methioate (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.

Nakhla *et al.* (1991) found that covering the seedbed with insect proof muslin net cloth gave the best result for controlling *Bemisia tabaci* vector.

Physical barriers such as fine-mesh screens have been used in the Mediterranean Basin since 1990 to protect crops from *TYLCV* (Berlinger & Lebiush Mordechi, 1996; Berlinger *et al.* 2002; Cohen & Antignus, 1994). Net houses covered by 50- mesh screens became a necessity due to the spread of *TYLCV* and its whitefly vector. The 50-mesh whitefly-proof screens decreased dramatically the number of invading whiteflies into covered net or greenhouses combined with a few insecticide sprays.

New plantings should not be located near old plantings. New tomato plantings should not be placed near any crops known to be hosts of *TYLCV* nor should they be located next to older fields of tomato, older fields of known susceptible crop species or any crop species where whiteflies are not managed. This is especially true of resistant tomato cultivars which may not show symptoms but may still act as sources of *TYLCV* for susceptible cultivars (Lapidot *et al.* 2001).

Polston and Anderson (1997) observed that the whitefly borne *Gemini virus* could be successfully managed through integrated pest management approach in which the cultural management practices like manipulation of sowing date use of trap crops and growing of seedling in whitefly free netting. Among all cultivation of crop under protective netting might be the major components.

Simone and Momol (2001) reported that to identify early symptoms of TYLCV and rogue infected and infected-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 whiteflies to healthy plants should be prevented.

2.3.6.1. Straw and Plastic mulches

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

Monci *et al.* (2002) reported that the prevalence of *TYLCV* is the major limiting factor for the production of tomato in the South of Spain and the successful tomato production in the area depends on the control of whitefly borne *TYLCV*. They observed that the use of UV blocking plastic covers in growing tomato crops resulted in a significant reduction of *TYLCV* incidence and increased tomato fruit yield.

The use of yellow plastic mulch to protect open-field tomato plants from the whitefly-borne *TYLCV* is a common practice in Israeli agriculture (Zaks, 1997). Interestingly, yellow plastic mulches were not found to be effective in Florida (Csizinszky *et al.* 1996 and Csizinszky *et al.* 1999). The reason for this may be due to the very high level of humidity in Florida. Whiteflies which are attracted to the yellow mulch probably are not dehydrated as quickly in Florida as they were in Israel, where relative humidity is much lower. Whiteflies attracted to the yellow mulch in Florida were still able to fly to a plant and feed on it. In a climate with high relative humidity the yellow mulch may actually attract whiteflies to the crop rather than protect it from whiteflies. Although the yellow plastic mulches were ineffective in Florida, reflective or aluminized plastic mulches have been used very successfully to reduce incidences of *TYLCV* infected plants (Csizinszky *et al.* 1996 and Csizinszky *et al.* 1999).

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

Five different mulch types, i.e. silver (aluminium-treated, reflective) plastic, black plastic, paper, white/black plastic and black/white plastic, were evaluated by Suwwan *et al.* (1988) in terms of their effect on growth, yield, fruit quality and incidence of *TYLCV*. The highest early marketable yields were obtained with the silver, white/black and black/white plastic mulches. Total marketable yields were significantly increased by all mulch treatments. Both the silver and white/black plastic mulches were superior to other treatments in early and total fruit counts. Average weight per fruit was similar for all treatments and was acceptable in the local market. Incidence of *TYLCV* was reduced by the silver plastic mulch.

Mauromicale *et al.* (1996) studied the effect of mulching with polyethylene sheets of different colours (black, transparent white and reflecting aluminum color) on *Bemisia tabaci*, and the spread of *TYLCV*. Polyethylene mulching reduced whitefly population and spread of *TYLCV*. But mulching with aluminum colored polyethylene sheets was found to be most effective in reducing the number of whiteflies and delay in *TYLCV* infection.

Muqit *et al.* (2006) studied the effect of mulching with polyethylene sheets of different colours (blue, transparent and yellow color) on *Bemisia tabaci*, and the spread of *TYLCV*. Among the polyethylene mulches, yellow colored mulch caused the highest disease reduction (45.52%) and increase in yield (14.54%).

2.3.7. Research works done in Bangladesh

Alam (1995) reported 7 virus diseases on tomato in Bangladesh. The viruses are *Cucumber mosaic virus* (*CMV*), *Tomato yellow leaf curl virus* (*TYLCV*), *Tomato leaf curl virus* (*TLCV*), *Tomato mosaic virus* (*TMV*), *Tomato purple vein virus* (*TPVV*), *Potato leaf roll virus* (*PLRV*) and *Tomato spotted wilt* *virus* (*TSWV*). Among these *TYLCV* and *TPVV* were found to be most damaging and widely distributed.

Gupta (2000) worked on identification, symptom expression and yield loss due to *TYLCV* in Bangladesh. Identification by DNA hybridization proved the presence of *TYLCV* in the field. Symptoms include yellowing and upward curling of leaves and stunting of the tomato plants. Due to *TYLCV* infection all the growth parameters were found to be reduced. Yield reduction varied from 63-95% depending on variety Positive and significant correlation was found between no. of whitefly and spread of *TYLCV*.

Rashid *et al*. (2001) reported that *TYLCV* is one of the most damaging diseases of tomato in Bangladesh. They screened several tomato entries against *TYLCV*. Tomato accessions ATY-14 and 17 were found to be resistant which might be helpful in breeding program. Wild tomato accession ATY-10, 11 and 22 were found to be resistant.

Muqit *et al.* (2006) screened 15 varieties of tomato against *TYLCV*. None of them were found to be free from infection. Disease incidence varied from 28 to 66%. He graded the tomato varieties as highly susceptible, susceptible and moderately resistant on the basis of their reactions on disease incidence, severity and yield loss. Out of 15 varieties he graded five as highly susceptible which included BARI -5, 7, 10 and E6. Six varieties namely BARI – 3, 4, 6, 9, 12 and BINA -2 were graded as susceptible. Four varieties namely BINA- 3, BARI- 1, 2 and 11 were found to be moderately resistant.

CHAPTER III

MATERIALS AND METHODS

Required materials and methodology are described below under the following heading:

3.1. Experimental site

The experiment was conducted at the research field of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207. The experimental site was situated at latitude 23˚46′ N and longitude 90˚23′E with an elevation of 8.45 meter from the sea level (Appendix -I).

3.2. Soil type

The area represents the Agro-Ecological Zone of Madhupur tract (AEZ-28)

Whose pH and CEC are 5.45-5.61 and 25.28, respectively (Appendix -I). Soil of the study site was silty clay loam in texture belonging to series (Appendix II).The soil represents the shallow red brown terraces (Shaheed, 1980). The soil texture was silt loam, non-calcareous, dark grey soil of Tejgaon soil series. Soil compositions of the experimental plots were collected from the Soil Resources Development Institute (SRDI), Farmgate, Dhaka (Appendix -II).

3.3. Weather condition

The weather condition of the experimental site was under the sub-tropical monsoon climate, which is characterized by heavy rainfall during Kharif season (May-September) and scanty in the Rabi season (October-March). There was no rainfall during the month of December, January and February. The average maximum temperature during the period of investigation was

33.33^0 C and the average minimum temperature was 19.11^0 C. Details of the meteorological data in respect of temperature, rainfall and relative humidity the period of experiment were collected from Bangladesh Meteorological Department, Agargaon, Dhaka (Appendix -III).

3.4. Experimental period

The present study was conducted during the period from October' 2016 to March' 2017. At first tomato seedlings were raised in nursery bed and after 30 days, healthy seedlings were transplanted to the main field.

3.5. Seed Collection

A total of 2 varieties of tomato released by Bangladesh Agricultural Research Institute (BARI) were used namely BARI tomato-14 and BARI tomato-16. The seeds of tomato varieties were collected from vegetable division, Horticulture Research Centre (HRC), Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur.

3.6. Raising of seedlings in seedbed

Tomato seedlings of the two varieties were raised separately in a well-drained open nursery bed. Proper care was taken to ensure good and healthy seedlings development. Desired amount of compost and fertilizers were mixed properly with the soil of the nursery bed before sowing. After well preparation of the nursery bed the seeds of tomato varieties were sown on November 1st, 2016 (Plate 1).

(A) Variety BARI Tomato-14 (B) Variety BARI Tomato-16

Plate 1: Raising of seedlings on seedbed

3.7. Field Preparation

The experimental field was properly ploughed to obtain a good tilth on November 15, 2016. Manures and fertilizers were used as per recommendation (Rahman *et al.* 1998). Cowdung (15 ton/ha) was applied during final land preparation, Urea, Triple Super Phosphate (TSP), Murate of Potash (MP), Sulpher and Boron were applied at the rate of 200, 100, 150, 20 and 2 kg/ha, respectively. At the time of final land preparation total cowdung, TSP and MP, half of the urea were mixed with the soil. After two weeks of seedlings transplantation the rest of the urea was applied in two splits at 15 days interval.

3.8. Design of Experiments

The experiment was conducted in Randomized complete block design (RCBD) with 3 replications. Individual plot size 2.3 m × 2.3 m and plot to plot distance was 0.5 m. Each plot was prepared followed by a good tillage.

3.9. Treatment of the experiment

In this study in total five treatments combinations were arranged including control treatment. Different mulches viz. straw, blue, transparent and red polyethylene sheet were used as mulching treatments to see the effect of *TYLCV* in tomato plant. The treatments combinations were as follows:

T_1 =	Control
T_2 =	Rice straw
T_3 =	Blue Polyethylene sheet
T_4 =	Transparent Polyethylene sheet
T_5 =	Red Polyethylene sheet

3.10. Application of the mulches

Blue, white and red polyethylene was bought from Karwan bazar and straw was collected from SAU farm. After final land preparation and making of unit plot all the mulches were put on the field 2-3 days before the transplantation. Then a hole was made for each of the seedlings and total 16 holes were made to transplant 16 seedlings in each plot. The treatments were used randomly in the field (Plate 2).

A

B

C

D

E

Plate 2: Different mulches applied in the field with control plots, (A) Rice straw, (B), Blue Polyethylene sheet (C), Transparent Polyethylene sheet (D), Red Polyethylene sheet, and (E) Control plot

3.11. Transplantation of seedlings

The seedlings of two tomato varieties grown in open nursery bed were carefully uprooted and transplanted in the main field on December 1st, 2016. 16 seedlings of each variety were transplanted in 2.3 m× 2.3 m unit plot.

3.12. Cultural practices

After transplanting, a light irrigation was given. Subsequent irrigation was applied in all the plots as and when needed. After 15 days of transplanting a single healthy seedling and luxuriant growth per pit was allowed to grow discarding the others, propping of each plant by bamboo stick was provided on about 1m height from ground level for additional support and to allow normal creeping. Weeding, gap filling, irrigation and other intercultural operation were done in the plot were, whenever necessary.

3.13. Identification of the Virus

The *Tomato yellow leaf curl virus* (*TYLCV*) was identified on the basis of field symptoms as described by Akanda (1991), Alam (1995), and Gupta (2000). The incidence and severity of *TYLCV* was calculated by counting the plants infected everyday on the basis of typical symptoms caused by the virus. The plants were inspected everyday morning to note the appearance and development of the symptoms of *TYLCV* starting from transplantation to harvest. The tomato plants remained asymptomatic until the last harvest was designed as healthy plants (Plate 3).

(A) **(B)**

(C) **(D)**

Plate 3: Healthy Tomato plant and TYLCV symptoms on tomato plant

(A) Healthy plant **(B) Mild symptom**

(C) Medium symptom **(D) Severe symptom**

3.14. Whitefly counting in the field

Adult whitefly was counted from infested tomato plant manually. Four plants were selected in each plot for whitefly observation. No. of whitefly population per plant was counted from the sample plants and it was started after 20 DAT and continued up to 60 DAT. The number of whiteflies fallen on the leaves were counted at 10 days interval at 9 to 10 AM up to the date of last harvesting.

Figure1: Whitefly on lower surface of tomato leaf (Zoom view)

3.15. Data Collection and Calculation

For data collection four plants per plot were randomly selected and tagged. Data collection was started at 20 days after transplanting (20 DAT) the seedlings and continued up to fruit set. All the data were collected once in a 10 days interval. The data on the percent incidence and severity of TYLCV, growth and yield contributing characters of tomato plants were collected. The parameters were as follows:

1. No. of branch /plant
2. No. of leaves/plant

3. No. of infected leaves/plant

4. No. of flower/plant

5. No. of fruit/plant

6. Plant height (cm)

7. Individual fruit weight (gm)

8. Fruit yield /plant (kg)

9. Fruit yield /plot (kg/ha)

10. Total yield (ton/ha)

11. No. of whitefly/plant

3.16. Disease incidence (%)

The disease incidence was expressed in percentage on the basis of infected plant per plot. The percent disease incidence was calculated using the following formula:

$$\% \text{ Disease Incidence} = \frac{\text{Number of plants infected}}{\text{Total number of plants observation}} \times 100$$

3.17. Disease Severity

Percent disease severity was calculated by using 0-4 scale (Lapidot and Friedmann, 2002).

- 0 = No visible disease symptoms (0%);
- 1 = very slight yellowing of leaflet margins on apical leaf (1-25%);
- 2 = some yellowing and minor curling of leaflet ends (26-50);

- 3 = a wide range of leaf yellowing, curling and cupping, with some reduction in size, yet plants continue to develop (51-75%) and
- 4 = very severe plant stunting and yellowing, pronounced leaf cupping and curling; plants stop growth (76-100%).

Percentage of disease severity of tomato leaf curl virus in treated and untreated plots was calculated by using standard formula (McKinney, 1923).

$$\text{PDI} = \frac{\text{Sum of all numerical rating}}{\text{Maximum disease grade} \times \text{Total number of plants observed}} \times 100$$

3.18. Statistical Analysis

The data obtained for different characters were statistically analyzed by using the analysis of variance (ANOVA) and STATISTICS 10 software for proper interpretation to find out the incidence of whitefly, disease incidence, diseases severity and *TYLCV* effect on the growth and yield of tomato. The significance of the difference among the treatment combinations means were determined by LSD at 5% level of probability. Tables, bar diagram, linear graphs and photographs were used to present the data as and when required. Correlation and regression were performed to find out the relationship between different parameters.

CHAPTER IV

RESULTS

The present study was conducted to see the effect of different mulches against *Tomato yellow leaf curl virus* (*TYLCV*) and its impact on yield of tomato. This chapter contains the explanation and description of the results obtained from the experiment. The results have been presented and possible interpretations have been given under the following headings:

4.1. Effect of different mulches on TYLC disease incidence (%) and disease severity (%) on tomato

Significant differences were found in average disease incidence and severity due to use of different mulches between two tomato varieties against *TYLCV* during experimental period. The percentages of *Tomato yellow leaf curl* disease incidence and severity in five treatments of two different varieties (BARI Tomato-14 and BARI Tomato-16) are presented in table 1.

4.1.1. Disease incidence (%)

Appreciable variations were found among different treatment in two tomato varieties ranging from 8.33 to 66.67 %. The highest average *TYLCV* incidence was recorded in T_1 (control plot) treatment of BARI Tomato-16 (66.67 %) followed by BARI Tomato-14 (62.50%). On the other hand, the lowest incidence was recorded in treatment T_3 (Blue polyethylene) of both of BARI Tomato-14 & 16 (8.33%).

4.1.2 Disease severity (%)

There were significant variations found among different treatment in two tomato varieties. Average disease severity of *TYLCV* was ranged from 52.32 to 74.09 %. On the basis of severity index values the highest average severity was observed in T_1 (control plot) of BARI Tomato-14 (74.09%)

followed by BARI Tomato-16 (71.13%) of the same treatment. On the contrary, the lowest disease average severity index was found in BARI Tomato-16 (52.32%) of T_3 (Blue polyethylene) followed by BARI Tomato-16 (56.06%) of T_2 (Rice straw).

Table 1: Effect of different mulches on Tomato yellow leaf curl disease incidence (%) and disease severity (%) on two tomato varieties

Treatment	Average Disease Incidence (%)		Average Disease Severity (%)	
	BARI Tomato -14	BARI Tomato - 16	BARI Tomato -14	BARI Tomato -16
T_1	62.50 a	66.67 a	74.09 a	71.13 ab
T_2	33.33 b	31.25 b	59.08 bd	56.06 cd
T_3	8.33 d	8.33 d	60.46 bd	52.32 d
T_4	12.50 cd	14.58 cd	66.96 ac	59.64 bd
T_5	20.83 bd	25 bc	62.68 ad	57.73 cd
LSD (0.05)	14.38		13.34	
CV (%)	17.35		7.35	

T_1= Control plot, T_2= Rice straw, T_3= Blue Polyethylene sheet, T_4= Transparent Polyethylene sheet, T_5= Red Polyethylene sheet

*Means followed by same letters not significantly different at 5% level of significance

4.2. Effect of different mulches on growth and growth contributing character between two tomato varieties against *Tomato yellow leaf curl virus* (*TYLCV*)

Growth and growth contributing character of tomato were affected due to *TYLCV* infection under different mulches. Growth contributing characters such as average number of leaves/plant, average number of branch/plant, average number of flowers/plant, average plant height showed significant differences under different mulches in two tomato varieties. The effect of growth and growth contributing characters of tomato due to *TYLCV* infection are shown in table 2.

4.2.1. Number of leaves per plant

Average number of leaves of tomato showed significant difference due to *TYLCV* infection among different mulches in two tomato varieties. The range of leaves number per plant varied from 39.33 to 68.67. Maximum no. of leaves per plant was found in T_3 (Blue polyethylene) of BARI Tomato-14 (68.67) followed by BARI Tomato-16 (66.33) of the same treatment. On the other hand, minimum no. of leaves per plant was recorded in T_1 (control plot) of BARI Tomato-14 (39.33) followed by BARI Tomato-16 (39.67) of the same treatment.

4.2.2. Number of branch per plant

Significant variations were found in average number of branch/plant of two tomato varieties due to TYLCV infection among different mulches in field. The range of branch per plant varied from 8.33 to 16.33. The highest no. of branch per plant was recorded in T_3 (Blue polyethylene) of BARI

Tomato-14 (16.33) followed by BARI Tomato-16 (15.33) of the same treatment. The lowest no. of branch per plant was found in BARI Tomato-14 & 16 (8.33) in T_1 (control plot) followed by BARI Tomato-14 (12.00) in T_4 (Transparent polyethylene) and T_5 (Red polyethylene).

4.2.3. Number of flower per plant

In case of average number of flower per plant there were found appreciable differences at different mulches in two tomato varieties due to *TYLCV* infection. The range of average flower per plant varied from 42.33 to 83.67. Maximum number of flower per plant was recorded in T_3 (Blue polyethylene) of BARI Tomato-14 (83.67) followed by BARI Tomato-16 (80.00) of the same treatment. Minimum no. of flower per plant was found in BARI Tomato-16 (42.33) in T_1 (control plot) followed by BARI Tomato-14 (44.67) of the same treatment.

4.2.4. Plant height (cm)

Plant height is an important growth contributing character of tomato. Average plant height of tomato showed significant variations due to *TYLCV* infection among different mulches in two tomato varieties. The range of average plant height varied from 77.10 to 118.03 cm while the tallest plant was found in T_3 (Blue polyethylene) of BARI Tomato-16 (118.03 cm) followed by BARI Tomato-14 (117.47 cm) of the same treatment. On the contrary, the shortest plant (77.10 cm) was recorded in T_1 (control treatment) of BARI Tomato-14 followed by BARI Tomato-16 (81.57 cm) of the same treatment.

Table 2: Effect of different mulches on growth and growth contributing character between two tomato varieties against Tomato yellow leaf curl disease

Treatment	Average leaves/ plant (no.)		Average branch/plant (no.)		Average flower/ plant (no.)		Average plant height (cm)	
	BARI Tomato -14	BARI Tomato -16	BARI Tomato -14	BARI Tomato - 16	BARI Tomato -14	BARI Tomato -16	BARI Tomato -14	BARI Tomato -16
T_1	39.33 c	39.67 c	8.33 d	8.33 d	44.67 b	42.33 b	77.10 d	81.57 d
T_2	52.33 bc	60.67 ab	12.67 bc	13.67 ac	66.67 a	70.33 a	89.87 cd	90.37 cd
T_3	68.67 a	66.33 ab	16.33 a	15.33 ab	83.67 a	80 a	117.47 a	118.03 a
T_4	57 ab	59.33 ab	12 c	13 bc	66.67 a	69 a	106.10 ac	112.23 ab
T_5	52.67 bc	61.67 ab	12 c	13 bc	74. 67 a	69.67 a	93.70 bd	97.50 ad
LSD (0.05)	15.39		3.32		17.96		21.14	
CV (%)	9.43		9.09		9.19		7.34	

T_1= Control plot, T_2= Rice straw, T_3= Blue Polyethylene sheet, T_4= Transparent Polyethylene sheet, T_5= Red Polyethylene sheet

*Means followed by same letters not significantly different at 5% level of significance

4.3. Effect of different mulches on yield and yield contributing character between two tomato varieties against *Tomato yellow leaf curl virus* (*TYLCV*)

Yield and yield contributing character of tomato were affected due to *TYLCV* infection under different mulches. Yield contributing characters such as average number of fruits/plant, average fruit weight/plant (kg), average fruit weight/plot (kg), total yield (ton/ha) showed significant differences among different mulches between two tomato varieties. The effect of yield and yield contributing characters due to *TYLCV* infection are shown in table 3.

4.3.1. Number of fruit per plant

In case of average number of fruit per plant, there were found appreciable differences in different mulches between two tomato varieties. The average range of fruit per plant varied from 23.67 to 52.67. The maximum number of fruit per plant was recorded in T_3 (Blue polyethylene) of BARI Tomato-14 (52.67) followed by BARI Tomato-16 (50.33) of the same treatment. The minimum number of fruit per plant was found in BARI Tomato-16 (23.67) of T_1 (control plot) followed by BARI Tomato-14 (27.00) of the same treatment.

4.3.2. Fruit weight per plant (Kg)

Fruit weight is an important yield contributing character of tomato. Fruit weight per plant of tomato showed significant result due to *TYLCV* infection among different mulches in two tomato varieties. The range of average fruit weight per plant varied from 1.52 to 2.79 kg. The highest average fruit weight per plant was found in T_3 (Blue polyethylene) of BARI Tomato-14 (2.79 kg) followed by BARI Tomato-16 (2.58 kg) of the same treatment. On the other hand, the lowest average fruit weight per plant was recorded in T_1

(control plot) of BARI Tomato-14 (1.52 kg) followed by BARI Tomato-16 (1.65 kg) of the same treatment.

4.3.3. Fruit weight per plot (Kg)

Fruit weight per plot of tomato showed significant result due to *TYLCV* infection among different mulches between two tomato varieties. The range of average fruit weight per plot varied from 24.27 to 44.64 kg. Maximum fruit weight per plot was observed in T_3 (Blue polyethylene) of BARI Tomato-14 (44.64 kg) followed by BARI Tomato-16 (41.33 kg) of the same treatment. On the contrary, minimum fruit weight per plot was observed in T_1 (control plot) of BARI Tomato-14 (24.267 kg) followed by BARI Tomato-16 (26.40 kg) of the same treatment.

4.3.5. Fruit yield (ton/ha)

Fruit yield of tomato showed appreciable differences due to *TYLCV* infection among different mulches in two tomato varieties. The range of fruit yield differed from 45.863 to 84.370 ton/ha. The highest fruit yield was found in T_3 (Blue polyethylene) of BARI Tomato-14 (84.370 ton/ha) followed by BARI Tomato-16 (78.120 ton/ha) of the same mulch. On the other hand the lowest fruit yield was recorded in T_1 (control plot) of BARI Tomato-14(45.863 ton/ha) followed by BARI Tomato-16 (49.897 ton/ha) of the same treatment.

Table 3: Effect of different mulches on yield and yield contributing character between two tomato varieties against Tomato yellow leaf curl disease

Treatment	Average fruits/plant (no.)		Average fruit weight/plant (kg)		Average yield/plot (kg)		Yield (ton/ha)	
	BARI Tomato-14	BARI Tomato-16	BARI Tomato-14	BARI Tomato-16	BARI Tomato-14	BARI Tomato-16	BARI Tomato-14	BARI Tomato-16
T_1	27 d	23.67 d	1.52 c	1.65 c	24.27 c	26.40 c	45.86 c	49.89 c
T_2	39 c	41.33 bc	1.88 bc	1.94 ac	30.03 bc	31.04 ac	56.75 bc	58.67 ac
T_3	52.67 a	50.33 ab	2.79 a	2.58 ab	44.64 a	41.33 ab	84.37 a	78.12 ab
T_4	41 bc	42.33 ac	1.70 bc	2.02 ac	27.14 bc	32.27 ac	51.30 bc	60.97 ac
T_5	45.33 ac	42.33 ac	1.97 ac	2.14 ac	31.52 ac	34.19 ac	59.57 ac	64.61 ac
LSD (0.05)	11.19		0.8960		14.34		27.09	
CV (%)	9.44		15.17		15.18		15.18	

T_1= Control plant, T_2= Rice straw, T_3= Blue Polyethylene sheet, T_4= Transparent Polyethylene sheet, T_5= Red Polyethylene sheet

*Means followed by same letters not significantly different at 5% level of significance

4.4. Whitefly infestation in tomato against different mulches between two tomato varieties

The average number of whitefly populations per plant against different mulches is presented in table 4. The table showed us appreciable differences of whitefly population among different mulches between two tomato varieties. The range of whitefly/plant varied from 19.00 to 55.33. Maximum whitefly population per plant was observed in T_1 (control plot) of BARI Tomato-14 (55.33) followed by BARI Tomato-16 (51.33) of the same treatment. On the contrary, minimum whitefly population per plant was observed in T_3 (Blue polyethylene) of BARI Tomato-14 (19.00) followed by BARI Tomato-16 (23.67) of the same treatment.

Table 4: Whitefly infestation at different treatments between two tomato varieties

Treatment	Average no. of adult whitefly/plant	
	BARI Tomato -14	BARI Tomato -16
T_1	55.33 a	51.33 ab
T_2	35.33 cd	35.67 cd
T_3	19 e	23.67 de
T_4	38.67 bc	39.33 bc
T_5	44 ac	41 bc
LSD (0.05)	14.14	
CV (%)	12.60	

T_1= Control plot, T_2= Rice straw, T_3= Blue Polyethylene sheet, T_4= Transparent Polyethylene sheet, T_5= Red Polyethylene sheet

*Means followed by same letters not significantly different at 5% level of significance

4.5. Yield loss (%)

The % yield reduction of the two tomato varieties due to *TYLCV* infection against different mulches are presented in table 5. In case of BARI Tomato-14 reduction of yield varied from 19.30 to 45.46 % among different treatments. The highest yield reduction (45.46 %) was observed in T_1 (control plot) followed by T_4 (Transparent Polyethylene) which was 28.11% while the lowest yield reduction (19.30 %) observed in T_3 (Blue polyethylene) treatment followed by T_5 (Red Polyethylene) and which was 26.07%. In case of BARI Tomato-16 reduction of yield varied from 24.14 to 42.56 % among different treatments. The highest yield reduction (42.56 %) was observed in T_1 (control plot) followed by T_4 (Transparent Polyethylene) which was 25.79 % while the lowest yield reduction (24.14 %) observed in T_3 (Blue polyethylene) treatment followed by T_2 (Rice Straw) and which was 24.34 %.

Table 5: Reduction of yield due to *TYLCV* infection in different treatments

Treatments	**Yield (kg/plant)**							
	BARI Tomato - 14				**BARI Tomato - 16**			
	Healthy	**Diseased**	**% Reduction**	**T-test**	**Healthy**	**Diseased**	**% Reduction**	**T-test**
T_1	2.31	1.26	45.46	**	2.42	1.39	42.56	**
T_2	2.12	1.55	26.88	**	2.26	1.71	24.34	**
T_3	2.85	2.30	19.30	**	2.61	1.98	24.14	**
T_4	2.17	1.56	28.11	**	2.21	1.64	25.79	**
T_5	2.30	1.70	26.07	**	2.33	1.76	24.46	**

T_1= Control plot, T_2= Rice Straw, T_3= Blue Polyethylene sheet, T_4= White Polyethylene sheet, T_5= Red Polyethylene sheet

(**: Significant, P= 0.01)

4.6. Relationship between whitefly populations and weather parameters

Temperature and humidity plays an important role in *TYLCV* disease incidence and severity increase whereas temperature and humidity act as a catalyst of whitefly infestation in the field condition of tomato. Field epidemiology of *TYLCV*, the effect of prevailing temperature and relative humidity on the whitefly population build up as well as the spread of the disease were studied and the results are presented in the Figure 2 and 3.The results obtained in the present study revealed that the presence of increased number of whitefly population increased the number of *TYLCV* infected plants in the tomato field. With an exception the no. of whitefly population gradually increased up to 68 and then decreased down to 39, this might be due to temperature. Whitefly population increased up to 65 with the relative humidity ranged from 80-90%. Then again the whitefly population decreased to 42 with the relative humidity of 70%. All this might be due to the maturity of the plant, which did not favour for whitefly. Whereas a steady increasing trends from first to last was observed in respect of disease spread. This is due to increasing the population of viruliferous whitefly and continuous symptom expression of susceptibility of plants in the field.

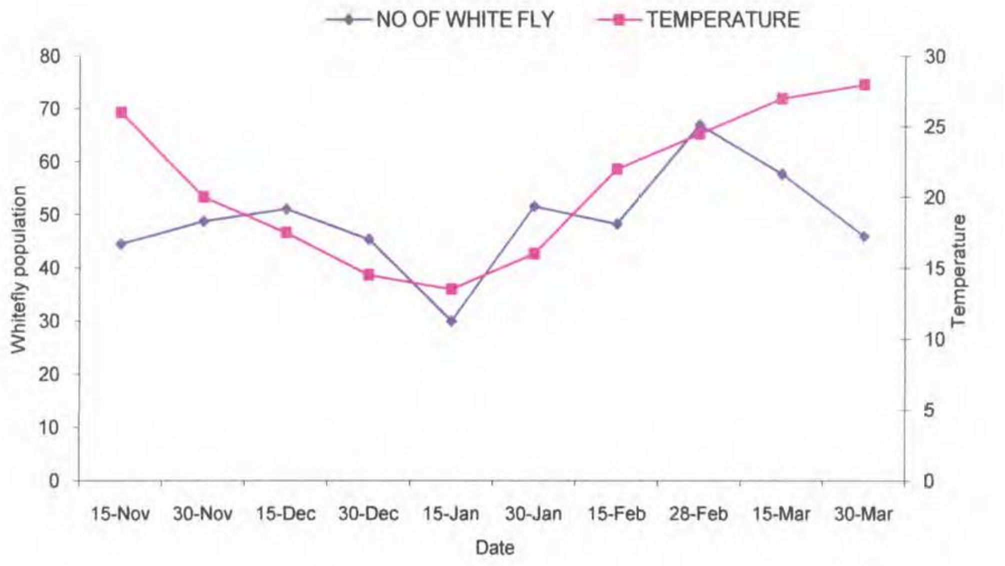


Fig. 2: Relation between average no. of whitefly populations and temperature in tomato field

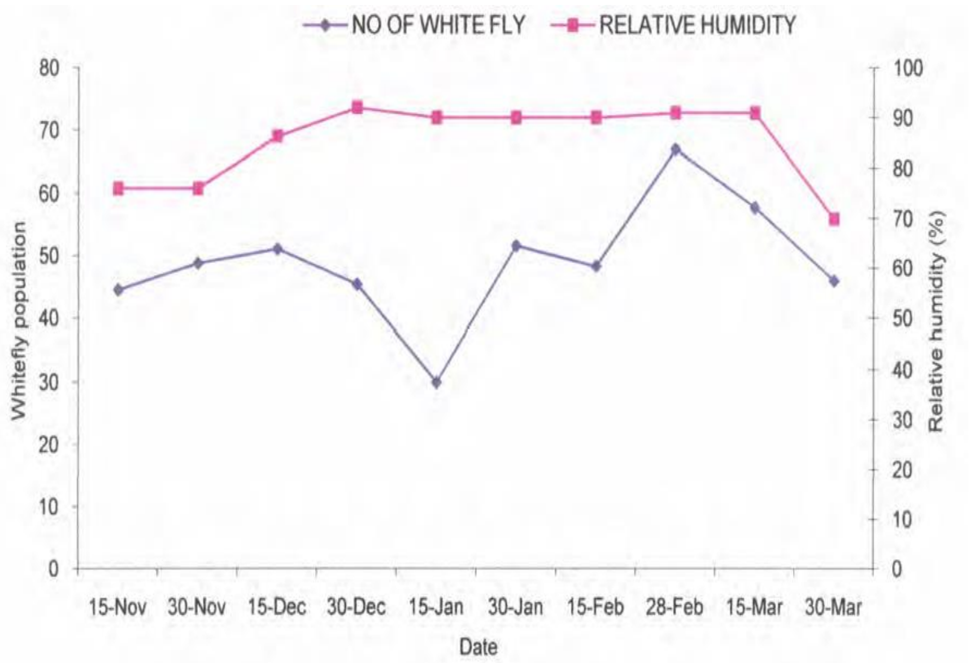
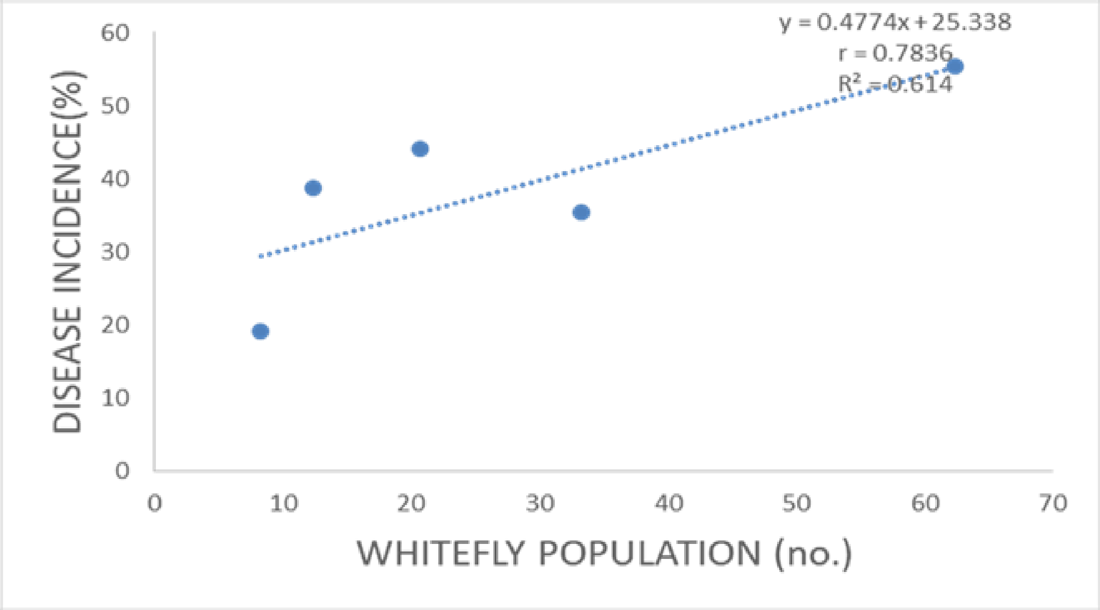


Fig.3:Relation between average no. of whitefly populations and Relative humidity in tomato field

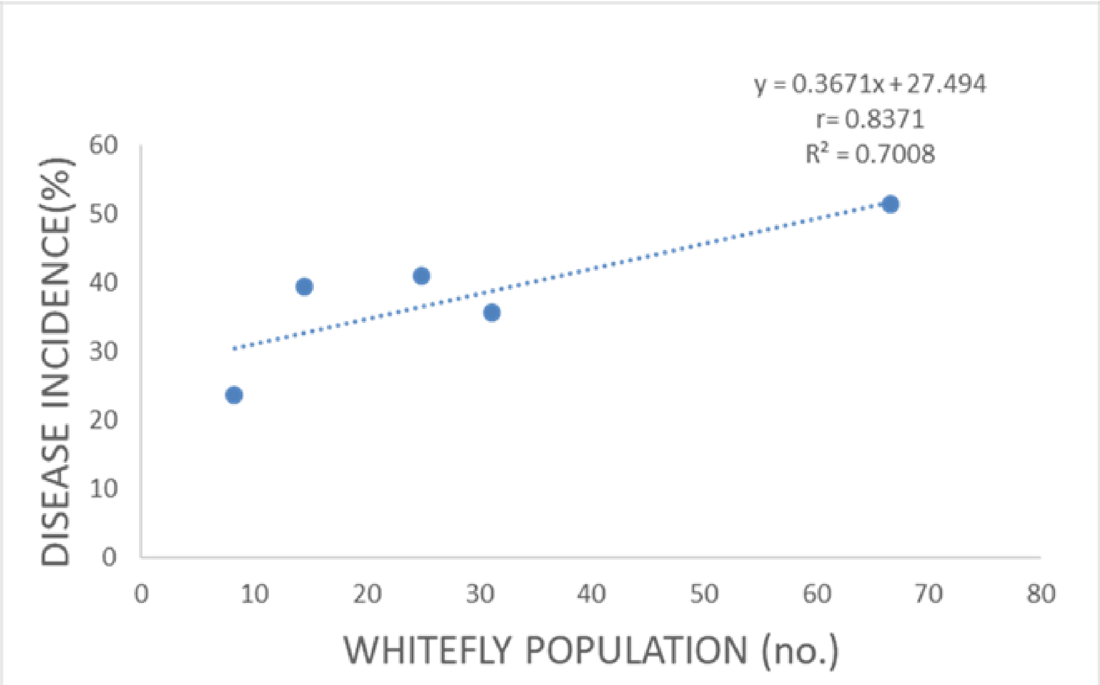
4.7. Correlation regression of different parameters

4.7.1. Relationship between the whitefly populations and % leaf curl disease incidence of tomato

Relation between whitefly populations and % disease incidence of *TYLCV* in the field condition are shown in figure 4. This figure showed a strong positive correlation between disease incidence (%) of *TYLCV* infection and whitefly populations. With the increase of whitefly populations, *TYLCV* infection also increased. A regression line was fitted between whitefly populations & % disease incidence of *TYLCV*. In case of BARI Tomato -14 the correlation coefficient (r) was 0.7836 and the contribution of the regression (R^2 = 0.614) indicated that 61.4 % *TYLCV* infection increased due to whitefly infestation. In case of BARI Tomato -16 the correlation coefficient (r) was 0.8371 and the contribution of the regression (R^2 = 0.7008) indicated that 70.08 % *TYLCV* infection increased due to whitefly infestation.



BARI Tomato- 14

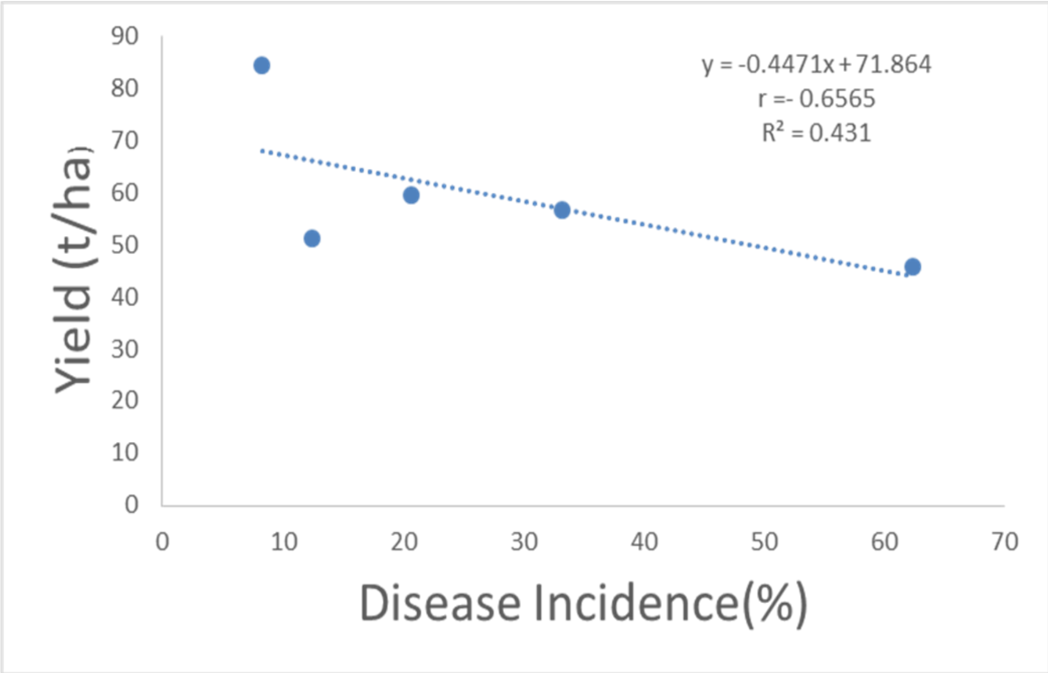


BARI Tomato- 16

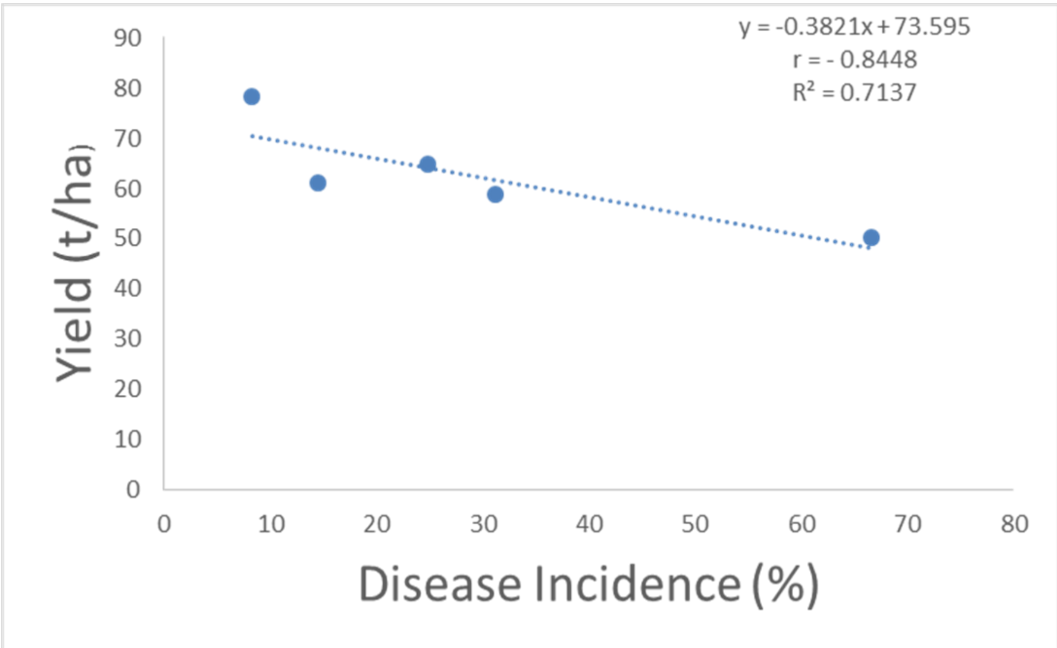
Figure 4: Relation between whitefly populations and % disease incidence caused by *TYLCV* of tomato

4.7.2. Relationship between % leaf curl disease incidence and yield (ton/ha) of tomato

A negative correlation was found between % disease incidence of *TYLCV* and yield (ton/ha) of tomato are shown in the figure 5. This figure showed that with the increase of % disease incidence of *TYLCV* between two tomato varieties in different treatment, yield (ton/ha) of tomato decreased. A regression line was fitted between % disease incidence of *TYLCV* and yield of tomato. In case of BARI Tomato- 14 the correlation coefficient (r) was -0.6565 and the contribution of the regression (R^2 = 0.431) indicated that 43.1 % yield in tomato would be affected by *TYLCV* infection. In case of BARI Tomato- 16 the correlation coefficient (r) was -0.8448 and the contribution of the regression (R^2 = 0.7137) indicated that 71.37 % yield in tomato would be affected by *TYLCV* infection.



BARI Tomato- 14

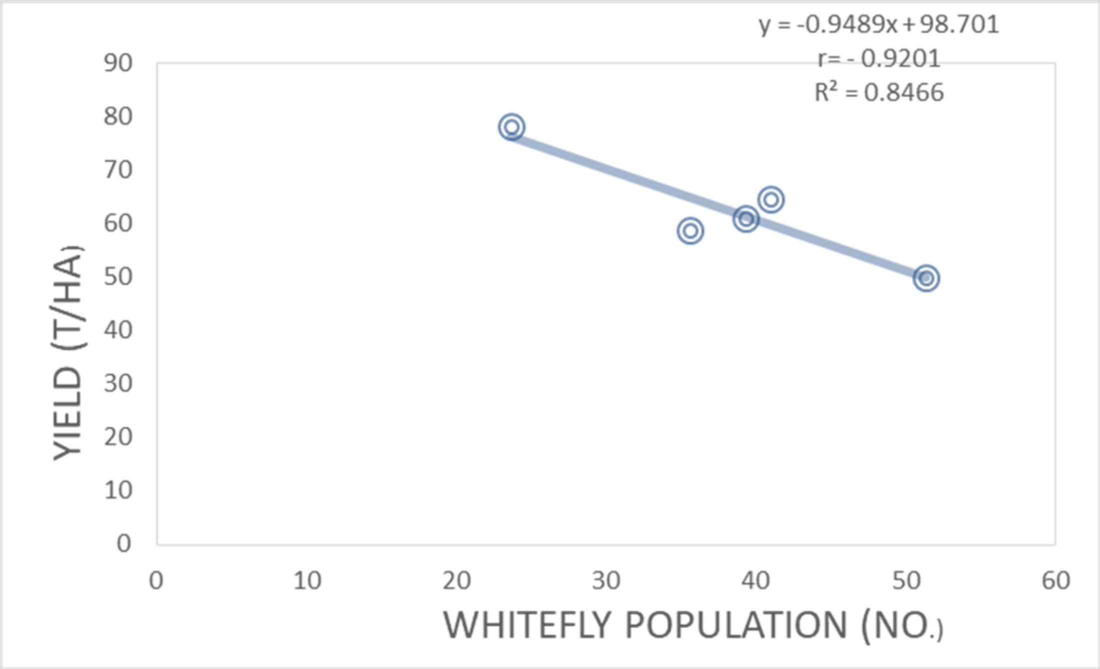


BARI Tomato- 16

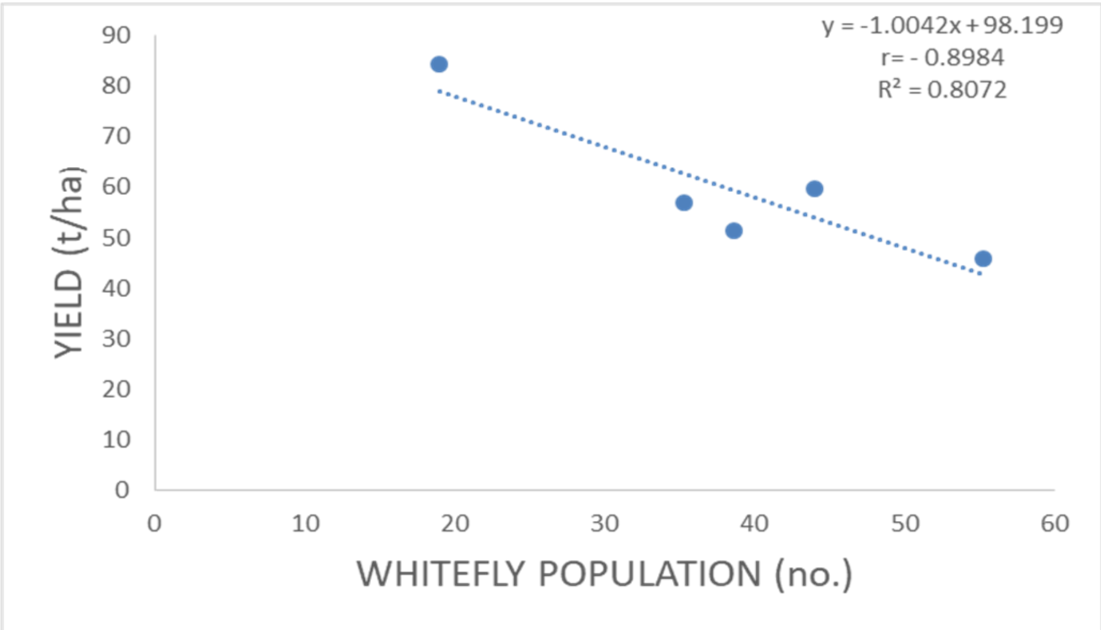
Figure 5: Relation between disease incidence of TYLC (%) and yield (t/ha) of tomato

4.7.3. Relationship between whitefly populations and yield (ton/ha) of tomato

A negative correlation was observed between whitefly populations and yield (ton/ha) of tomato are shown in the figure 6. This figure showed that with the increase of whitefly populations in the tomato field, yield of tomato decreased. A regression line was fitted between whitefly populations and yield of tomato. In case of BARI Tomao-14 the correlation coefficient (r) was –0.9201 and the contribution of the regression (R^2 = 0.8466) indicated that 84.66 % yield in tomato would be affected by whitefly populations. In case of BARI Tomao-16 the correlation coefficient (r) was –0.8984 and the contribution of the regression (R^2 = 0.8072) indicated that 80.72 % yield in tomato would be affected by whitefly populations.



BARI Tomato- 14



BARI Tomato- 16

Figure 6: Relation between whitefly populations and yield (ton/ha) of tomato

CHAPTER V

DISCUSSION

Tomato is considered as one of the most important vegetable crop grown worldwide mainly to be used either fresh or cooked mixed with other vegetables. The crop suffers important losses from infection by yellow leaf curl virus disease which considered as a major problem affecting tomato production in many of the old world, tropical and subtropical countries (Jawdah and Shebaro, 1993).

The aim of this study was to evaluate the effect of different mulches on Tomato yellow leaf curl disease and its impact on yield of tomato. The study was conducted at the research farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period of October 2016 to March 2017. Two recent popularly cultivated varieties BARI Tomao-14 and 16 and four different mulches (rice straw, blue, transparent and red polyethylene sheet) were used in the experiment.

The result of this study revealed that treatment T_3 (Blue polyethylene) & BARI Tomato-14 showed better performance between two varieties against *TYLCV* in case of all the parameters of disease incidence (%), Disease severity (%), growth and yield contributing characters. The average TYLC disease incidence (%) ranged from to 8.33 66.67 % and average TYLC severity ranged from 52.32 to 74.09 % among different mulches. The highest TYLC incidence and severity were 66.67 % and 74.09 % respectively. On the other hand, the lowest incidence and severity were 8.33 % and 52.32 % respectively. Almost such type of investigation on different mulches and varietal performance against TYLC disease incidence (%) and severity (%) in tomato field was observed by Csizinszky *et al.* (1996, 1999);

Davino *et al,* (1996); Gupta (2000); Rashid *et al.* (2002) and Muqit *et al.* (2006).

In case of growth contributing characters, average leaves number per plant varied from 39.33 to 68.67. Maximum no. of leaves per plant was found in T_3 (Blue polyethylene) of BARI Tomato-14 (68.67) and minimum no. of leaves per plant was recorded in T_1 (control plot) of BARI Tomato-14 (39.33). Average number of branch per plant varied from 8.33 to 16.33. The highest no. of branch per plant was recorded in T_3 (Blue polyethylene) of BARI Tomato-14 (16.33) and the lowest no. of branch per plant was found in BARI Tomato-14 & 16 (8.33) in T_1 (control plot). Average number of flower per plant varied from 42.33 to 83.67. Maximum no. of flower per plant was recorded in T_3 (Blue polyethylene) of BARI Tomato-14 (83.67) and minimum no. of flower per plant was found in BARI Tomato-16 (42.33) in T_1 (control plot). Average plant height varied from 77.10 to 118.03 cm while the tallest plant was found in T_3 (Blue polyethylene) of BARI Tomato-16 (118.03 cm). On the contrary, the shortest plant (77.10 cm) was recorded in T_1 (control plot) of BARI Tomato-14.

In case of yield contributing characters, average fruit weight/plant ranged from 1.52 to 2.79 kg. The highest fruit weight/plant (2.79 kg) was recorded in T_3 treatment (Blue polyethylene) of BARI Tomato-14 while the lowest fruit weight per plant was recorded in T_1 (control plot) of BARI Tomato-14 (1.52 kg). From the above results it can be concluded that average fruit weight/plant was more in T_2 treatment (Blue Polyethylene) than other treatment. Fruit yield (ton/ha) varied from 45.86 to 84.37 ton/ha whereas the highest fruit yield was found in T_3 (Blue polyethylene) treatment of BARI Tomato-14 (84.37 ton/ha). The lowest fruit yield was recorded in T_1 (control plot) of BARI Tomato-14 (45.86 ton/ha). Results of the present study showed that in case of BARI Tomato- 14 the highest yield reduction (45.46 %) was observed in T_1 (control plot) and the lowest yield reduction (19.30 %) observed in T_3 (Blue polyethylene) treatment and in case of BARI Tomato- 16 the highest yield reduction (42.56 %) was observed in T_1 (control plot) and the lowest yield reduction (24.14 %) observed in T_3 (Blue polyethylene) treatment. The incumbent investigation revealed that higher severity of TYLC disease was one of the reasons for reduction of fruit yield of tomato. Similar findings were also reported by Lukayanenko (1991) and Polston *et al*. (2005). They reported that TYLC disease caused 90% reduction of marketable yield and pointed out that *TYLCV* transmitted by whitefly is 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%. According to Pico *et al*. (1998) and Gupta (2000) TYLC disease could cause 50-100% and 63-95% yield loss, respectively.

The results indicated that yield of tomato was positively influenced by number of leaves, number of branch, number of flower, plant height, number of fruits and fruit weight. The results of the study are more or less similar with the findings of Mohanty 2002; Mohanty 2003.

In whitefly infestation, average number of whitefly population /plant differed from 19.00 to 55.33. Maximum number of whitefly/ plant was observed in T_1 (control plot) of BARI Tomato-14 (55.33). On the contrary, minimum whitefly/ plant was observed in T_3 (Blue polyethylene) treatment of BARI Tomato-14 (19.00). Verma *et al.* (1989) stated that the incidence of TYLC disease on tomato was directly related to the population density of the vector developed during January when incidence of the disease also began to increase.

Field epidemiology of TYLC disease in view of the effect of prevailing temperature and relative humidity on the whitefly population builds up as well as the spread of the disease was studied. The results obtained in the present study revealed that the presence of increased number of whitefly increased the number of *TYLCV* infected plants in the tomato field with an exception, while the number of whitefly population gradually increased up to 68 and then decreased down to 39, this might be due to the temperature. Whitefly population increased up to 65 with the relative humidity ranged from 80-90%. On the other hand, the whitefly population decreased to 42 with the relative humidity of 70%. This might be due to the maturity of the plant, which did not favour the whitefly. Cohen and Nitzany (1966) reported that TYLC disease show great regional and seasonal variations mainly because of fluctuations in the population density of the whitefly vector. According to Borah and Borodoloi (1998) there is a positive and significant association between disease incidence and whitefly population, temperature and rainfall.

During experiment a strong positive correlation was found between disease incidence (%) of *TYLCV* infection and whitefly population and which was supported by Polizzi *et al*. (1994) and Aboul-Ata *et al*. (2000). The increasing of whitefly population was also found to be positively correlated with the spread of *TYLCV* in the field (Mehta *et al*. 1994; Gupta 2000; Paul 2002; Parvin 2002).

There also a negative correlation between the whitefly population and yield of tomato which was supported by Gupta (2000).There also a negative correlation between the incidence of TYLC disease and yield of tomato was found and which was in accordance with Gupta’s (2000) findings.

CHAPTER VI

SUMMARY AND CONCLUSION

Tomato yellow leaf curl disease is a serious problem of tomato cultivation in the field. Yield loss can be as high as 90% or even more in some cases. No resistant variety is presently available in Bangladesh and also there is a lack of effective method for control this disease. Therefore the present study was initiated to develop an effective management strategy by using different mulching materials. The experiment was aimed at to evaluate the efficacy of different mulches for the management of TYLC disease in field condition and their impact on growth and yield of tomato. The study was conducted at the research farm of Sher-e-Bangla Agricultural University (SAU), Sher-e-Bangla Nagar, Dhaka-1207 during the period from October 2016 to March 2017. Two most popularly cultivated varieties BARI Tomao-14 and 16 were used in this experiment.

Four type of mulches viz Rice straw, Blue polyethylene, Transparent polyethylene and Red polyethylene sheet were used for evaluating their efficacy to manage the TYLC disease in field condition. Data were collected on the disease incidence and severity of TYLC and its impact on growth and yield contributing characters such as leaves/plant, branch/plant, flower/plant, fruit/plant, plant height, fruit weight/plant, fruit weight/plot, whitefly population/plant, yield of fruit under different treatments.

The results of the study revealed that the application of Blue Polyethylene (T_3) and Transparent Polyethylene (T_4) treatment as mulch significantly reduced the TYLC disease incidence and severity. The incidence in case treatment T_5 (Red Polyethylene) and T_2 (Rice straw) did not differ significantly between each other but they were significantly differed from control. Considering average disease incidence, the lowest incidence was observed in T_3 (Blue Polyethylene) while the highest incidence was recorded in T_1 (Control plot) .

The prevalence and spread pf TYLC disease in two tomato varieties was positively coorelated with the whitefly population which indicated that the increase of whitefly population in the tomato field increased the number of *TYLCV* infected plants during the study period.

However, the disease incidence was increased with the increase of whitefly population in the field and the relationship was positive and significant but % disease incidence of TYLC and yield of the tomato was negatively correlated. On the other hand, the whitefly population build up in the field was positively correlated with the temperature and relative humidity. As a result a negative correlation was observed between whitefly population and yield of tomato.

The correlation and regression analysis revealed that the percent reduction of growth and yield contributing characters due to *TYLCV* infection had pronounced effect on yield reduction of tomato as strongly positive and significant effect was observed in all cases.

The results of the study on all growth and yield contributing characters including the virus incidence suggested that, none of the treatments had impressive level of reduction against *TYLCV* infection. Although T_3 (Blue Polyethylene) performed better as compared to other treatments on all over consideration.

The results of the study revealed that the effect of *TYLCV* infection on growth and yield contributing characters, prevalence of the virus and spread and yield varied on tomato varieties. None of the varieties had impressive level of tolerance against *TYLCV* infection. Individual fruit weight, flower per plant, fruit per plant should be taken into consideration. On the basis of the overall consideration BARI Tomato-14 performed better than BARI Tomato-16. However, it needs further investigations before final recommendation.

In view of the results the present study may be concluded as-

- ❖ TYLC disease was prevalent on all the tomato varieties though the infection was varied with varieties and treatment. The maximum prevalence (Average disease incidence and severity were 66.67 % and 74.09 %, respectively) was found in T_1 (Control plot) and the minimum prevalence (Average disease incidence and severity were 8.33 % and 52.32 %, respectively) was observed on T_3 (Blue Polyethylene).
- ❖ There were significant reduction of different growth and yield contributing characters of plants of all the tomato varieties.
- ❖ Whitefly population was positively correlated with temperature and relative humidity. The incidence and severity of TYLC disease in the field was also positively correlated with the whitefly population in tomato field.
- ❖ The yield was found negatively and appreciably correlated with the TYLC disease incidence and severity.
- ❖ Considering the disease incidence and severity, growth and yield contributing characters among the treatment Blue Polyethylene mulch performed better against *TYLCV* and BARI Tomato-14 variety found having highest yield and profound tolerance against *TYLCV*.

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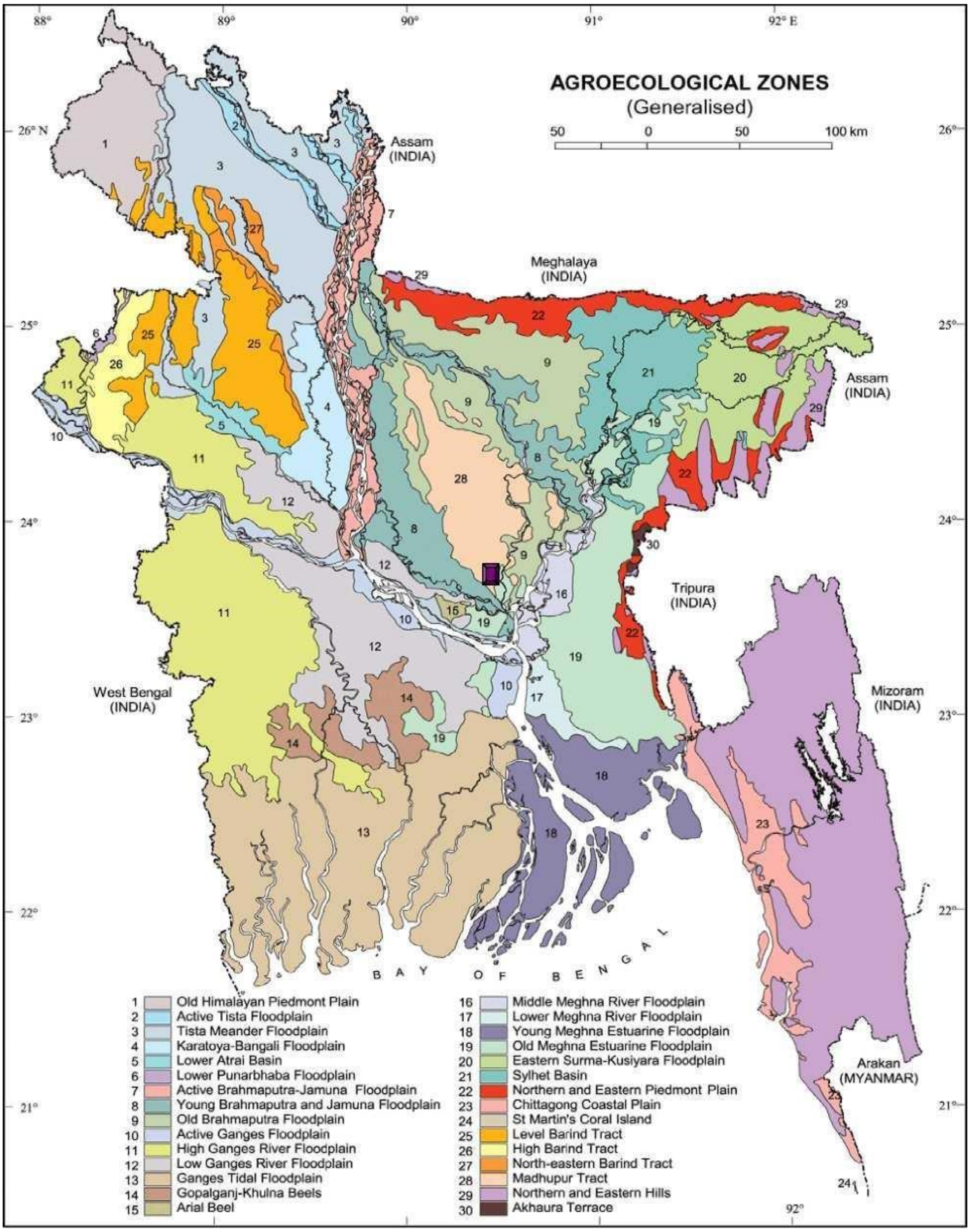
APPENDICES

Appendix I: Experimental site showing in the map under the present study



Appendix II: The Morphological and chemical characteristics of soil of the experimental site as observed prior to experimentation

Morphological characteristics of soil of the experimental plot

Morphological features	**Characteristics**
Location	Research farm, SAU, Dhaka
AEZ	Modhupur Tract (28)
General Soil Type	Shallow Red Brown Terrace Soil
Land Type	Medium high land
Soil Series	Tejgaon fairly leveled
Topography	Fairly level
Flood Level	Above flood level
Drainage	Well drained
Texture	Loamy

Chemical composition

Constituents	0-15cm depth
P^H	5.45-5.61
Total N (%)	0.07
Available P (µ gm/gm)	18.49
Exchangeable K (µ gm/gm)	0.07
Available S (µ gm/gm)	20.82
Available Fe (µ gm/gm)	229
Available Zn (µ gm/gm)	4.48
Available Mg (µ gm/gm)	0.825
Available Na (µ gm/gm)	0.32
Available B (µ gm/gm)	0.94
Organic matter (%)	0.83

Source: Soil Resources Development Institute (SRDI), Farmgate, Dhaka.

Appendix III: Monthly records of meteorological observation at the period of experiment (September, 2016 to May, 2017)

Name of months	Temperature (^0C)		Relative humidity (%)
	Maximum	Minimum	
September, 2016	35	26	82
October, 2016	36	24	75
November, 2016	34	19	71
December, 2016	30	16	68
January, 2017	29	14	71
February, 2016	32	15	76
March, 2016	32	17	83
April, 2016	36	20	72
May, 2016	36	21	71

Source: Time and date.com/weather/bangladesh/dhaka

Appendix IV: Different steps of tomato production in experimental plot

(A) Transplanting of plants

(B) Stalking of plants

(C) Flowering in control plot

(D) Fruiting of tomato

(D) Harvesting of fruits

(E) Field view of tomato plants