EFFECT OF DIFFERENT PLANTING TIME ON *TOMATO YELLOW LEAF CURL VIRUS* (*TYLCV*) OF TOMATO AND ITS IMPACT ON YIELD

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JUNE, 2017

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REGISTRATION NO.: 10-04017

A Thesis
Submitted to the Department of Plant Pathology
Sher-e-Bangla Agricultural University, Dhaka
In partial fulfillment of the requirements
for the degree of

MASTER OF SCIENCE (MS)
IN
PLANT PATHOLOGY

SEMESTER: JANUARY-JUNE, 2017

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CERTIFICATE

This is to certify that the thesis entitled "***EFFECT OF DIFFERENT PLANTING TIME ON TOMATO YELLOW LEAF CURL VIRUS (TYLCV) OF TOMATO AND ITS IMPACT ON YIELD***" submitted to the Department of Plant Pathology, 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 ***ARMAN HASAN ANIK***, ***Registration No. 10-04017*** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

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

Dated: June, 2017
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Dedicated To

My Beloved Parents &
Respected Research
Supervisor

ACKNOWLEDGEMENTS

The author seems it a much privilege to express his enormous sense of gratitude to the Almighty Allah for the ever ending blessings for the successful completion of the research work.

The author feels proud to express his deep sense of gratitude, sincere appreciation and immense indebtedness to his supervisor Associate Professor Dr. Fatema Begum, Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka, for her continuous guidance, cooperation, constructive criticism, helpful suggestions and valuable opinions in carrying out the research work and preparation of this thesis, without her intense co-operation this work would have not been possible.

The author likes to thank his co-supervisor Professor Dr. F. M. Aminuzzaman, Department of Plant Pathology, SAU, Dhaka, for his scholastic and continuous guidance during the entire period of course, research work and preparation of this thesis.

The author expresses his sincere respect to Prof. Khadija Akhter, Chairman, Prof. Mrs. Nasim Akhtar, Prof. Dr. Md. Rafiqul Islam, Prof. Dr. M. Salahuddin M. Chowdhury, Prof. Dr. Nazneen Sultana, Prof. Dr. Nazmoon Nahar Tonu, Assoc. Prof. Dr. Md. Belal Hossain, Assoc. Prof. Abu Noman Faruq Ahmmed, Assist. Prof. Shukti Rani Chowdhury, Assist. Prof. Md. Ziaur Rahman Bhuiyan, Assist. Prof. Sayed Mohammad Mohsin and Assist. Prof. Hosna Ara Chowdhury Nisha, Department of Plant Pathology, SAU, Dhaka, for their contributing suggestions and cooperations during the study period and also expresses his heartfelt thanks to all the teachers of the Department of Plant Pathology, SAU, for their valuable teachings, suggestions and encouragements during the period of the study.

The author also likes to thank officer and staff of the Department of Plant Pathology, SAU, for their cooperation during the entire period of course and research work.

The author expresses his sincere appreciation to his beloved parents and all of his well-wishers for their continuous contribution in the whole education journey.

The Author

EFFECT OF DIFFERENT PLANTING TIME ON *TOMATO YELLOW LEAF CURL VIRUS* (*TYLCV*) OF TOMATO AND ITS IMPACT ON YIELD

ABSTRACT

A study was carried out at the Department of Plant Pathology, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh during the period of October' 2016 to May' 2017 in order to find out the effect of different planting time on *Tomato yellow leaf curl virus* (*TYLCV*) of tomato and its impact on the yield. Two collected BARI released variety namely BARI Tomato-14 and BARI Tomato-16 were used in this study that was transplanted at three different planting time (1st planting time on 1st November, 2nd planting time on 15th November 2016 and 3rd planting time on 1st December 2016). The lowest percent disease incidence (12.42%) and percent disease severity (15.37%) were found in 3rd planting (1st December planting) and BARI Tomato-16 variety. Under the present study, considering the percentage of *TYLCV* disease incidence and severity, whitefly population infestation, growth and yield contributing characters as well as the yield of two tomato varieties in three different planting time; the 3rd planting (1st December planting) and BARI Tomato-16 variety was found having the highest yield (77.23 ton/ha) and promising the lowest level of percentage of disease incidence (12.42%) and disease severity (15.37%) against *TYLCV*. The percent disease incidence and severity were found positively correlated with temperature. A strong positive correlation was obtained between the whitefly population and (%) disease incidence of *TYLCV*. Whitefly population and yield of tomato were negatively correlated with each other. The yield was also found significant negatively correlated with the percentage of *TYLCV* disease incidence.

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ABBREVIATIONS AND ACRONYMS

AEZ	=	Agro-Ecological Zone
BBS	=	Bangladesh Bureau of Statistics
BCSIR	=	Bangladesh Council of Scientific and Industrial Research
cm	=	Centimeter
CV %	=	Percent Coefficient of Variation
DAS	=	Days After Sowing
DMRT	=	Duncan's Multiple Range Test
et al.,	=	And others
e.g.	=	exempli gratia (L), for example
etc.	=	Etcetera
FAO	=	Food and Agricultural Organization
g	=	Gram (s)
i.e.	=	id est (L), that is
Kg	=	Kilogram (s)
LSD	=	Least Significant Difference
m_2	=	Meter squares
ml	=	Milliliter
M.S.	=	Master of Science
No.	=	Number
SAU	=	Sher-e-Bangla Agricultural University
var.	=	Variety
^oC	=	Degree Celsius
%	=	Percentage
NaOH	=	Sodium hydroxide
GM	=	Geometric mean
mg	=	Milligram
P	=	Phosphorus
K	=	Potassium
Ca	=	Calcium
L	=	Liter
µg	=	Microgram
USA	=	United States of America
WHO	=	World Health Organization

CHAPTER I

INTRODUCTION

Tomato (*Solanum lycopersicum* L.) belongs to Solanaceae family which is normally a self-fertilized annual crop. It is a popular vegetable crop in Bangladesh as well as many countries of the world. All cultivated type of tomato belongs to *Solanum lycopersicum* and is native to Central, South and Southern North America. Tomato fruit is rich in vitamins and minerals (Hobson and Davis 1971). Tomato is an important source of vitamin A and C. Lycopene, one of nature's most powerful antioxidants present in tomatoes which can protect people from free radical injury and has been found beneficial in preventing prostate cancer. It is even present when tomatoes are cooked. The nutritive value and versatile use make it popular worldwide. It is cultivated in almost all kitchen gardens and also in the field due to its adaptability to wide range of soil and climate (Ahmed, 1976). In world vegetable production, it has great contribution. It ranks third in the worlds vegetable production next to potato and sweet potato (FAO, 2003) but as a processing crop ranks first among the vegetables (Choudhury, 1979 and Shanmugavelu, 1989). Its food value is very rich because of higher contents of vitamins A, B and C including calcium and carotene (Bose and Som, 1990). It has multipurpose demand both in home and industry use.

About 170.8 million tons of tomatoes were produced in the world in 2017. The largest producer China (52.6 million tons), accounted for more than one third of the global production followed by India (18.7 million tons) and United states of America (14.5 million tons) (WORLDATLAS, 2017). In 2015-16 the average production of tomato in our country was 368 thousand metric tons (Anon.2017). The low yield of tomato in Bangladesh is not an indication of the low yielding potentiality of this crop, but the fact that the lower yield may be attributed to a number of reason like use of low yielding variety, unavailability of quality seeds of improved varieties, disease infection, improper irrigation, fertilizer and other horticultural management etc. The increase of tomato yield per hectare should be the most important consideration in a country like Bangladesh where efficient land use should have given first priority. However, among the various constraints, viral disease of tomato is one of the major problem of the tomato production.

Among the factors responsible for low yield of tomato, diseases are considered the most important ones. Lukyanenko (1991) reported that tomato is susceptible to more than 200 diseases and losses of yield due to the disease as high as 71-95%. Among these diseases 40 different virus disease have been reported to be prevalent on tomato of which *Tobacco mosaic virus* (*TMV*), *Tomato leaf curl virus* (*TLCV*) and *Tomato yellow leaf curl virus* (*TYLCV*) caused 80, 90 and 100%, yield loss of tomato, respectively (Martelli and Quacquarelli, 1982). So far 16 different tomato viruses have been recorded on tomato in Bangladesh (Akanda and Rahman, 1993, Akanda,1994, Akand *et al.*, 1994).

Tomato yellow leaf curl virus, better known as *TYLCV*, has become a major problem for tomato growers in recent years, as it has infected tomato crops worldwide. A virus causing yellow leaf curl symptom of tomato was introduced by Cohen and Harpez (1964) from Israel which was extensively studied by Cohen and Nitzany (1966) and named the virus as *Tomato yellow leaf curl virus* (*TYLCV*). They studied the symptoms, host range, transmission etc. and concluded that the virus is mechanically non-transmissible, transmitted by whitefly *(Bemisia tabaci)* in the field and belong to geminivirus group. At present, *TYLCV* is reported to be a major menace, which limits the tomato cultivation in all tomato growing areas of the world (Green and Kalloo 1994, Brunt *et al*. 1990 and Kalloo 1991). *TYLCV* alone could cause 100% yield loss of the crop as reported by Martelli and Quacquarelli (1982). Among the virus diseases of tomato *TYLCV* is considered to be the major ones in respect to prevalence, severity and damage to the crop in all tomato growing areas in the world (Kalloo, 1991). In Bangladesh the prevalence of *TYLCV* was first noted by Akanda (1991). The prevalence, symptoms, varietal response, transmission, serology, response to DNA hybridization test including the effect of the virus on various growth and yield contributing characters of tomato (Akanda and Rahman 1993; Akanda, 1994; Alam, 1995 and Gupta, 2000).

The virus is mechanically non-transmissible, graft transmitted, transmitted by whitefly (*Bemisia tabaci*) in the field. DNA hybridization test proved that *TYLCV* isolates of Bangladesh is strongly positive to the *TYLCV* isolates of different tropical and sub-tropical countries (Gupta, 2000). In Bangladesh this virus is highly damaging which may reach even up to 100% depending on the varieties and stage of infection. The distribution of *TYLCV* in Bangladesh seems to be countrywide and none of the cultivated tomato varieties has appreciable amount of resistance against the virus.

During last two decades this virus has emerged as devastating one causing economic loss of up to 100% in many tropical and subtropical regions including Bangladesh (Lukyanenko, 1991; Akanda 1994; Peterschmit *et al*.,1999; Moriones and Castillo 2000; Varma and Malathi, 2003).

In many cases *TYLCV* epidemics lead to abandonment of the crop, particularly in seasons/periods favoring whitefly population buildup (Pico *et al.* 1996). Recently, *TYLCV* has become the prime limiting factor in tomato production in Bangladesh (Anon., 2015). For the last few years it appeared in epidemic form. 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, Sultana 2001). Although the efforts generated a number of information regarding *TYLCV* and its management in Bangladesh including yield loss pattern, but none of the efforts could provide conclusive information about *TYLCV*. The frequent development of disease epidemic and high yield loss even leading to a total crop failure have drawn attention of the scientists to develop effective management program against *TYLCV* for profitable tomato production in many countries.

Various strategies have been pursued to control the disease. Developing resistant variety is the best option for the control of *TYLCV*, but none of the tomato varieties cultivated in our country is found to have resistance or tolerance to the virus (Rahman *el al.* 2006). So the management of *TYLCV* in Bangladesh is immensely important to reduce the crop loss and also to minimize the deterioration quality, so that the cultivation of tomato could be profitable. It needs in depth investigation on the prevalence of the virus in different tomato varieties, the crop damage in respect to stage of plant infected by the virus etc. Moreover, the growing of tomato seedlings in protected conditions have been reported as a management practice by different investigators (Polston and Anderson, 1997, Azam *et al.*, 1997, Cohen *et al.*, 1998 and Antignus *et al.*, 1998). As the disease caused heavy loss to tomato in many countries, development of suitable management practices is of utmost importance. Considering the importance of the above background, the present research programme was designed to know the effect of different planting times on prevalence of *TYLCV* and whitefly association in tomato.

The proposed research work was carried out to achieve the following specific objectives:

- To evaluate the incidence and severity of *Tomato yellow leaf curl virus* (*TYLCV*) against two popular cultivars of tomato.
- To find out a suitable planting time for the reduction of *TYLCV* incidence and severity of tomato; and
- To evaluate the effect of *TYLC* disease incidence on yield of tomato.

CHAPTER II

REVIEW OF LITERATURE

Tomato (*Solanum lycopersicum* L.) is the second most important vegetable crop. Tomato suffers from many diseases of which yellow leaf curl is considered as the most important and widely distributed disease throughout the world, wherever tomato is grown. The studies with respect to effect of different planting time on *Tomato yellow leaf curl virus* (*TYLCV*) and its impact on yield are taken into consideration while reviewing the literature. Accordingly, the literature pertaining to the above aspects is presented here.

Historical background of *TYLCV*

TYLCV was first reported in Israel in 1939-40 associated with outbreak of *Bemisia tabaci*. The causal agent was described in 1964 and named *Tomato yellow leaf curl virus* (*TYLCV*) Cohen and Harpez (1964). Cohen and Nitzany (1966) reported that in nature the virus mainly infects tomato. The experimental host range of *TYLCV* is narrow. It mainly infects some species of Solanaceae, Composite and Caprifoliaceae.

Tomato yellow leaf curl virus (*TYLCV*) has been a major constraint to tomato production in the Near East since 1966. It is the best-characterized virus causing yellowing and leaf curl disease of tomato Green and Kalloo (1994). Czosnek and Laterrot (1997) published worldwide survey report on *TYLCV*. They pointed out that the name *TYLCV* has been given to several whiteflies transmitted gemeniviruses. Affecting tomato cultures in many tropical and subtropical regions. Their result based on DNA and protein sequence revealed that tomato geminiviruses fall into three main clusters representing viruses from 1. The Mediterranean / the Middle East / the African regions 2. India / the Far East Australia 3. The Americans. They also pointed out that *TYLCV* diseases increase considerably between 1990 and 1996. Early diagnosis of

TYLCV is essentially based on symptom observation, although symptoms vary greatly as a function of soil, growth conditions and climate.

Semi-persistent transmission of the virus by whitefly (*Bemisia tabaci*) and no availability of tomato cultivars makes the situation more vulnerable in respect to the management of *TYLCV* Martalli and Quaequarelli 1982 and Polston and Anderson (1997). Sanchez *et al.* (2000) reported that the yellow leaf curl disease of tomato was caused by a complex of virus species, two of which, tomato yellow leaf curl virus (*TYLCV*) Sar and *TYLCV* Is, were involved in epidemics of southern Spain. Plants of *Murcularies ambigua* and *Solatium luteum* showing abnormal upward leaf curling and leaf distortion collected in the vicinity of tomato crops were found to be naturally infected with *TYLCV*-Is and *TYLCV* Sar respectively this was the first report of *M. ambigua* and *S. luteum* as host of *TYLCV*.

Geographical distribution and economic importance

The first assessment of the worldwide distribution of *TYLCV* was made by Czosnek *et al.* (1990). *Tomato yellow leaf curl geminivirus* was diagnosed in tomatoes collected in Mediterranean countries, America, Western Africa and Southeast Asia by hybridizing tomato leaflets squashed onto a nylon membrane with a virus-specific DNA probe. Sample positive for *TYLCV* were counted. The results revealed the worldwide distribution of *TYLCV*.

Pilowsky *et al.* (1993) reported that *Tomato yellow leaf curl gemininivirus* transmitted by the vector *Bemisia tabaci,* is spreading towards the west of the Mediterranean basin and South East Asia.

According to Polizzi *et al.* (1994) *Tomato yellow leaf curl geminivirus* is a limiting factor for tomato production in Italy.

Pico *et al.* (1996) reported that *Tomato yellow leaf curl virus* (*TYLCV*) is a whitefly transmitted geminivirus. It has been recognized as a major limiting factor for tomato production over the last 30 years in many tropical and sub-tropical areas causing yield loss as high as 50-99%.

Peterschmit *et al.* (1999) observed shortened internodes, reduced leaf size, leaf curling, and bushy plants in tomato crops in the coastal region near Casablanca, Morocco. The symptoms were similar to those described for *Tomato yellow leaf curl virus* (*TYLCV*) disease. During September, the disease was present in more than 130 ha of outdoor and protected crops. Economic losses ranged between 20 and 100%. Similar symptoms were observed in tomato crops in the northeastern region of Morocco.

Abou-Jawdah *et al.* (1999) reported that *Tomato yellow leaf curl virus* (*TYLCV*), transmitted by whitefly is endemic in Africa, the Middle East and South 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. Comparison of the nucleotide sequence in the intergenic region with other reported leaf curl viruses showed the Lebanese *TYLCV* isolate to be closely related to the Egyptian, Israeli and Jamaican isolates (94-96% identified) but not closely related to isolates from Sardinia, Spain and Thailand, or to tomato leaf curl isolates from India, Taiwan and Australia.

Peterschmit *et al.* (1999) observed stunting, reduced leaf size, leaf curling and yellow margins on tomato plants in a farm on the South Coast of Reunion. These symptoms appeared to be characteristic of a *Tomato yellow leaf curl bigeminivirus* (*TYLCV*) infection. Diseased plants gave positive reactions with a TAS-ELISA, using ADGEN antibodies specific for begomoviruses. Infected plants were detected by TAS-ELISA in 52 of the 123 locations visited. Severe economic losses were observed as 14 locations with 60-100% yield reduction and 11 locations with 40 to 60% yield reduction.

Tomato yellow leaf curl virus (*TYLCV*) is one of the most devastating virus diseases of cultivated tomato. Most commercial cultivars are susceptible to the disease and losses in some regions can reach up to 100%. The disease has a worldwide distribution i.e. from Taiwan to the Far East, the Middle East, Tropical and Subtropical Africa, the Mediterranean basin to the Americas (Kung 1999).

Montasser *et al.* (1999) studied a naturally occurring viral disease causing devastating yield reduction of field-grown tomato crops in Kuwait. An outbreak of the disease was observed during the growing seasons of 1993-99, causing a major loss in tomato fruit yield. Transmission studies revealed that the disease was transmitted by the whitefly (*Bemisia tabaci*). Based on electron microscopy, dot blot hybridization and polymerase chain reaction (PCR), the causal virus was identified as *Tomato yellow leaf curl geminivirus* (*TYLCV*).

In Summer or Autumn, 1999 severe outbreaks of tomato leaf curl disease occurred in tomatoes in the Vecindario Region of Gran Canaria, Canary Islands (Spain) and Agadir, Morocco. Monci *et al.* (2000) identified the causal virus as *TYLCV* using molecular techniques. This was the first report of *TYLCV*-Sar in the Canary Islands and Morocco.

Lapidot *et al.* (2001) stated that *Tomato yellow leaf curl virus* (*TYLCV*) is one of the most devastating virus diseases of cultivated tomato in the tropical and sub-tropical region. Tomato leaf curl disease has long been known in Middle East, North and Central Africa and South East Asia which also spread to Southern Europe. *TYLCV* has also been identified in the Caribbean region, Mexico and in the United States. *TYLCV* epidemics tend to be associated with high population of whitefly.

Tomato yellow leaf curl virus is a geminivirus transmitted by whitefly (*Bemisia tabaci*). It 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 USA. In many cases yield losses may be up to 90% (Gafni 2003).

Disease symptoms

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 chlorosis 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 *Tomato yellow leaf curl virus* (*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.

Gallitelli *et al.* (1991) observed sever outbreaks of stunting, yellowing and curl in tunnel grown tomatoes, accompanied by heavy infestation of whitefly.

Abdel Salam (1991) stated that tomato leaf curl virus, causing various symptoms of leaf curl inter veined 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.

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 *Solanum* could be infected experimentally and showed clear typical symptoms of *TYLCV*.

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.

Green and Kallo (1994) in their review described many aspects of *TYLCV*. Infected tomato plants stunted, branches and petioles tend to assume erect position, leaflets are smaller than those of healthy plants, puckered and often show upward curling, margins with or without yellowing. The virus is transmitted by whitefly *(B. tabaci)* in a semi persistent (circulative) manner. A single viruliferous whitefly is able to transmit the diseases to a healthy plant and the rate of transmission increases with the increased population density of the vector. Particle of *TYLCV* is geminate and 20x30 nm in size.

As reported by Mc Glashan *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.

Aboul-Ata *et al.* (2000) studied some epidemiological aspects of *TYLCV* in the field. It was found *TYLCV* intensity is related to proportion of viruliferous whitefly rather than total number of whitefly. Lapidot *et al.* (2001) used 0-4 scale to evaluate tomato plants against *TYLCV*, Where, 0= no visible symptom, 1= very slight yellowing of leaflet margins on apical leaf, 2= some yellowing and minor curling of leaflet ends, 3= a wide range of leaf yellowing, curling and cupping with some reduction in size, yet plants develop and 4= very severe plant stunting and yellowing, pronounced leaf cupping and curling, plants stop growing.

Vector and transmission of virus

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

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

Makkoub (1978) found two different *TYLCV* isolates on the basis of symptoms produced on tomato and stated that both the isolates were transmitted by *Bemisia tabaci*.

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

Goodman (1981) mentioned in his review paper on geminiviruses infecting different crops that *TYLCV* is a whitefly transmitted geminivirus and it is highly prevalent in the Mediterranean region.

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 was a viral disease associated with a non-mechanically transmissible by virus.

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

Ioannou (1985) reported that *TYLCV* was detected as the most frequently occurring whitefly transmitted virus causing *TYLCV* disease of tomato in Cyprus.

Al-Hitty and Sharif (1987) reported that cucumber could be the best host of *Bemisia tabaci* 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.

Singh (1989) mentioned that *TYLCV* is transmitted by an insect vector called whitefly (*Bemisia tabaci*).

Verma *et al.* (1989) stated that the incidence of *Tomato yellow leaf curl virus* 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 is 20 nm in diameter and 30 nm in length and these are phloem or phloem restricted in the host.

Lukyanenko (1991) pointed out that *TYLCV* transmitted by whitefly is the most serious virus disease of tomato in tropical and sub-tropical Asian countries and part of Africa. Kheyr-pour *et al.* (1991) worked on *TYLCV* from Sardinia, Italy and detected that the virus is a whitefly transmitted monopartite gemini-virus.

Mansour and Al-Musa (1992) reported that the *Bemisia tabaci* is an efficient vector. A single whitefly is able to transmit the virus. The minimum acquisition and the inoculation feeding period were 60 and 30 minute, respectively, and the latent period was 11 days.

Brown and Bird (1992) published review or whitefly transmitted gemini-virus in which they noted that plant viruses transmitted by whiteflies cause over 40 diseases of vegetable, and fiber crops worldwide. Depending on the crop, season, whitefly prevalence and other factors, the yield losses ranged from 22-100%.

Davino *et al.* (1994) reported that under favorable environmental condition *TYLCV* early transmitted to Jimson weed *(Datura stramonium)* and tomato by its vector *Bemisia tabaci.*

Kheyr-pour *et al.* (1994) reported that the *TYLCV* was transmitted by whitefly *(Bemisia tabaci).* The causal agent of tomato leaf curl was transmitted by grafting and by *Bemisia tabaci* tomato seedlings. The virus was identified on the basis of symptoms, transmission, cytopathology, particle morphology and molecular hybridization using a cDNA probe.

Mehta *et al.* (1994) reported that *Bemisia tabaci* transmitted *TYLCV* after a minimum acquisition-access period of 15 minute, and rate of transmission increased as the acquisition access period was lengthened and reached a maximum after 24 hours. A minimum inoculation-access period was observed with the rate of transmission increasing as the inoculation access period was lengthened, reaching a maximum after a 12-hour inoculation access period.

McGrath and Harrison (1995) compared the cultures of *B. tabaci* from Ivory Coast (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 (*TYLCV*-Ind) and tomato yellow leaf curl geminiviruses 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.

Ghanim *et al.* (1998) reported that whitefly (*B. tabaci*) is the only vector of *TYLCV*. which transmits the virus in a persistent (circulative) manner.

Khan (2000) reported that detection of geminivirus by conventional methods is very difficult due to low titer of virus in their vector and hosts. Difficulty in purification of geminiviruses, non-chemical transmission of most of them and restricted host range make their characterization rather slow. He suggested that PCR (polymerase chain reaction) method is the most ideal approach to detect geminiviruses.

Disease incidence and severity

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.

Considering the prevalence and severity of *TYLCV*, 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 B-carotene, 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.

Rashid *et al.* (2001) 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 used the 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 include Ratan, BARI-7, BARI-10, BARI-11 and BARI-13.

Akhter (2003) reported the incidence of *TYLCV* on tomato varieties in respect to time of planting. Planting of tomato in the first and third week of December as well as first week of January caused 62-66, 72-75, and 75-80% disease incidence, respectively. Yield reduction varied from 19-74% depending on variety. The shoot weight, root length and yield contributing characters like fruits/plant and fruit length were significantly reduced in diseased plants as compared to healthy.

Effects of planting time on disease incidence & severity and its impact on yield

Verma *et al.* (1989) reported that the incidence of *Tomato leaf curl virus* on tomato was directly related to the population density of the vector, *B. tabaci*. The vector population developed during January when incidence of the disease also began to increase.

Whitefly transmitted geminiviruses 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 that *TYLCV* was one of the most damaging viruses of tomato prevalent worldwide.

Traboulsi (1993) reviewed the essential aspect of the biology of the whitefly (*Bemisia tabaci*) and the economic damage it causes, particularly as a vector of plant disease and examined in detail major crops attack and available control methods. It has been suggested that the control of whitefly is a must to control of whitefly-borne Geminiviruses in various crops. It has also been suggested that the control measures such as manipulation of date of sowing might be useful components of integrated management of whitefly, which ultimately help to control the virus disease vectored by whitefly.

Polston and Anderson (1997) observed that the whitefly borne Geminivirus 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.

An experiment was conducted by Ahammad *et al* (2009) at Jessore to observe the effect of planting date and variety on the yield of late planting tomato. The Effects of planting time were evaluated for BARI tomato 4, 5, 6 and 12 by planting December 01, December 16, January 01, January 16 and February 01. A combination of December 01 planting with BARI Tomato 5 variety performed better in respect of yield (57.07 t/ha).

Hossain *et al* (2013) investigate the effect of different sowing dates on yield of tomato genotype conducted at Agricultural Research Station, Thakurgaon, Bangladesh during October 2009 to March 2010. Three sowing dates viz. October 1, October 15 and October 30 were considered as factor A and tomato variety viz., BARI Tomato-2, BARI Tomato-3, BARI Tomato-4, BARI Tomato-9 and BARI Hybrid Tomato-4 considered as factor B. Seed sowing of October 1 was found better in respect of yield (74.75 tha-1) compared to October 15 (58.55 tha-1) and October 30 (24.60 tha-1) sowing. Among the variety, BARI Tomat-2 produced the highest (68.12 tha-1) marketable yield followed by BARI Tomato-9 (56.16).

Review on correlation-coefficient analysis

A combination of control approaches (Integrated Pest Management) was suggested by Singh and Reddy (1993) for the management of *TYLCV* under field condition. The yield reduction was correlated with the percent incidence of *TYLCV* in the field.

Aboul *et al*. (2000) studied a positive correlation between the incidence of *TYLCV* and whitefly population.

Gupta (2000) studied a negative correlation between the whitefly population and yield of tomato

Rashid *et al* (2008) studied a negative correlation between the incidence of *TYLCV* and yield of tomato.

Research works conducted in Bangladesh

In Bangladesh seven different virus diseases are observed and reported on tomato by Alam (1995). These 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. Yield reduction varied from 63-95% depending on variety. Positive and significant correlation was found between number of whitefly and spread of *TYLCV*.

Tomato yellow leaf curl virus (*TYLCV*) was reported as one of the most damaging virus causing severe damage to tomato in Bangladesh by Rashid *et al.* (2001). They screened several tomato lines against *TYLCV*. Tomato accessions ATY-14 and 17 were found no symptom which found to be resistant.

Shih *et al.* (1998) did PCR base molecular characterization of *TYLCV* isolates from several Asian countries including Bangladesh. They found that *TYLCV* isolates from Bangladesh contained DNA B component i.e.it is a geminivirus which is different from *TYLCV*-Is isolate. The report confirmed that there is great genetic diversity of geminivirus infecting tomato in Asia.

Rashid *et al.* (2001) 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 used the 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 include Ratan, BARI-7, BARI-10, BARI-11 and BARI-13.

Akhter (2003) reported the incidence of *TYLCV* on tomato varieties in respect to time of planting. Planting of tomato in the first and third week of December as well as first week of January caused 62-66, 72-75, and 75-80% disease incidence, respectively. Yield reduction varied from 19-74% depending on variety. The shoot weight, root length and yield contributing characters like fruits/plant and fruit length were significantly reduced in diseased plants as compared to healthy.

CHAPTER III

MATERIALS AND METHODS

The details of the materials and methods of this research work were described in this chapter. It consists of a short description of experimental site & duration, weather, experimental design, layout, materials used for experiment, raising of seedling, treatments, land preparation, manuring and fertilizing, transplantation of seedlings, intercultural operations, harvesting, collection of data and statistical analysis which are given below:

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 location of the site was $23^{0}74'$ N latitude and $90^{0}35'$ E longitude with an elevation of 8.2 meter from sea level (Appendix I).

3.2 Experimental period

The experiment was carried out during the Rabi season from October' 2016 to May' 2017.

3.3 Soil type

The experimental site was situated in the subtropical zone. The soil of the experimental site lies in agro-ecological regions of "Madhupur Tract" (AEZ No. 28). Its top soil is clay loam in texture and olive grey with common fine to medium distinct dark yellowish brown mottles. The pH 4.47 to 5.63 and organic carbon contents is 0.8 (Appendix II).

3.4 Weather

The monthly mean of maximum & minimum temperature and relative humidity, at the experimental site during the period of the study have been collected. (Appendix III).

3.5 Materials used for experiment

Two most popular tomato varieties namely BARI Tomato-14 and BARI Tomato-16, released by Bangladesh Agricultural Research Institute (BARI) were used for the experiment. Seeds of two varieties were collected from vegetable division, Horticulture Research Centre (HRC), BARI, Joydevpur, Gazipur-1701.

3.6 Raising of seedling

Seedlings of tomato were raised in six seed beds of 1m x 1m size plot were used for seedling raising. The soil was well prepared and converted into loose friable condition in obtaining good tilt. All weeds, stubbles and dead roots were removed from seed bed. Ten grams of each varieties seeds were sown in each seedbed. The seeds were sown in the seedbed on 01st October 2016; 15th October 2016 and 01st November 2016, respectively. After sowing, seeds were covered with finished light soil. Then shading was provided by bamboo mat (chatai) to protect young seedlings from scorching sunshine and rainfall. Light watering, weeding and mulching were done as and when necessary to provide seedlings with a good condition for growth.

3.7 Factors and Treatments

This experiment consisted of two factors, three levels of planting time and two levels of variety as BARI Tomato-14 and BARI Tomato-16. The factors were as follows:

Factor A: Planting time	Factor B: Variety
P_1: 1st Planting	V_1: BARI Tomato-14
P_2: 2nd Planting	V_2: BARI Tomato-16
P_3: 3rd Planting	

3.8 Experimental design and layout

Field layout was done after final land preparation. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications. Layout of the whole plot was divided into three blocks each containing six (6) plots of 2.45 m x 2.30 m size, giving 18 unit plots. The drain was kept 1.0 m between the blocks and 0.5 m between the plots were kept. The distance between row to row and plant to plant was 65 cm and 60 cm, respectively.

3.9 Land preparation

The experimental field was thoroughly ploughed and cross ploughed and cleaned prior to seedling transplant. Finally, the land was properly levelled before transplanting and plots were prepared as per the design.

3.10 Application of manure and fertilizers

The sources of N, P_2O_5, K_2O as Urea, TSP and MP were applied, respectively as recommended dose (BARI, 2005). The entire amounts of TSP and MP were applied during the final land preparation. Urea was applied in three equal instalments at 25, 35 and 45 days after seedling transplanting (DAT). Well-rotten cow dung 10 t ha^{-1} also applied during final land preparation.

Table-1. Application of fertilizer and manure per hectare applied for the experimental field preparation

Manure / Fertilizers	Rate/ha	Application (%)			
		Basal	25 DAT	35 DAT	45 DAT
Cow dung	20 ton	100	-	-	-
Urea	100 kg	-	33.33	33.33	33.33
TSP	200 kg	100	-	-	-
MP	220 kg	100	-	-	-

Manure and fertilizers were used as recommended by BARI (2005).

3.11 Transplanting of seedlings

Healthy and uniform 30 days old seedlings were uprooted separately from the seed bed and transplanted in the experimental plots in the afternoon. Seedlings were 1st planting time on 1st November, 2nd planting time on 15th November 2016 and 3rd planting time on 1st December 2016 maintaining a spacing of 65 cm x 60 cm between the rows and plants, respectively. This allowed an accommodation of 16 plants in each plot. The seedbed was watered before uprooting the seedlings from the seedbed so as to minimize damage of the roots. The seedlings were watered after transplanting. Seedlings were also planted around the border area of the experimental plots for gap filling.

3.12 Gap filling

Gap filling was done as and when needed.

3.13 Intercultural operation

After transplanting of seedlings, various intercultural operations such as irrigation, weeding, stalking and top dressing etc. were accomplished for better growth and development of the tomato seedlings.

3.13.1 Irrigation and drainage

Over-head irrigation was provided with a watering cane to the plots once immediately after transplanting seedlings in every alternate day in the evening up to seedling establishment. Further irrigation was provided when needed. Excess water was effectively drained out at the time of heavy rain.

3.13.2 Stalking

When the plants were well established, stalking was given to each plant by bamboo sticks to keep them erect.

3.13.3 Weeding

Weeding was done to keep the plots clean and easy aeration of soil which ultimately ensured better growth and development. The newly emerged weeds were uprooted carefully. Mulching for breaking the crust of the soil was done when needed.

3.14 Control of soil borne pathogen

Furadan 10 G was applied during final land preparation for control soil borne pathogen.

3.15 Identification of symptom

The *Tomato yellow leaf curl virus* (*TYLCV*) was identified on the basis of typical field symptoms as described by Akanda (1991), Alam (1995) and Gupta (2000). The plants were inspected at 20, 30, 40, 50 and 60 days after planting to observe the appearance and development of the symptoms of *TYLCV* at three planting time.

a. Healthy plant

b. Early TYLCV symptoms

c. Severe TYLCV symptoms

Plate 1:(a) Heathy Tomato plant, (b-c) *TYLCV* Symptoms at different stage

3.16 Harvesting

Fruits were harvested at 5 days' intervals during maturity to ripening stage. The maturity of the fruit was determined on the basis of red colouring of fruits. Harvesting was started from 20 February, 2017 and completed by 30 May, 2017.

3.17 Collection of data

Eight plants were selected randomly from each unit plot for data collection in such a way that the border effect could be avoided at the highest precision. Data on the following parameters were recorded from the sample plants during the course of experiment.

3.17.1 Number of leaves/plant

Number of leaves was measured from the sample plants and recorded from 20, 30, 40, 50 and 60 days after planting to observe the growth rate of the plants at three planting time.

3.17.2 Number of infected leaves/plant

Number of infected leaves was measured from the sample plants and recorded from 20, 30, 40, 50 and 60 days after planting to observe the growth rate of the plants at three planting time.

3.17.3 Number of infected plants

Number of infected plants was measured from all the plants and recorded from 20, 30, 40, 50 and 60 days after planting to observe the growth rate of the plants at three planting time.

3.17.4 Number of branch/plant

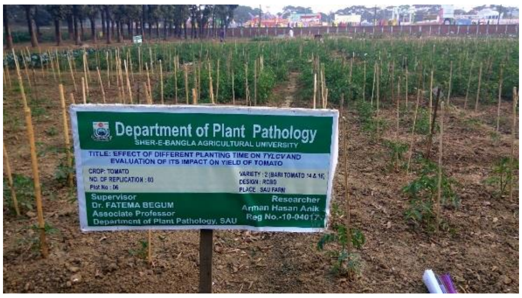
Number of branch per plant was measured from the sample plants and recorded from 20, 30, 40, 50 and 60 days after planting to observe the growth rate of the plants at three planting time.

a. Seedbed preparation

b. Seedling

c. Preparing main field

d. Transplanting seedling to main field



e. Field view of research plot

f. View of fruiting

g. Data collection

h. Harvesting

Plate 2 (a-h): Different steps of tomato plantation in experimental field

3.17.5 Number of flowers/plant

Number of flowers was measured from the sample plants and recorded from 20, 30, 40, 50 and 60 days after planting to observe the growth rate of the plants at three planting time.

3.17.6 Plant height

Plant height was measured from the sample plants in centimetre from the ground level to the tip of the longest stem and means value was calculated. Plant height was recorded 20, 30, 40, 50 and 60 days after planting to observe the growth rate at three planting time.

3.17.7 Number of fruits/plant

The number of fruits/plant was recorded from the sample plants.

3.17.8 Fruit weight/plant (kg)

Fresh fruit weight (kg)/plant of plant was taken by an electric balance after harvest and was recorded.

3.17.9 Fruit weight/plot (kg)

An electric balance was used to take the fruit weight per plot. It was measured by totalling of fruit yield from each unit plot during the period from first to final harvest and was recorded in kilogram.

3.17.10 Fruit yield (kg/ha)

It was measured by the following formula:

$$\text{Fruit Yield per hectare (kg)} = \frac{\text{Fruit yield per plot (kg) x } 10000\text{m}^2}{\text{Area of plot in square meter (m}^2\text{)}}$$

3.17.11 Fruit yield (ton/ha)

It was measured by the following formula:

$$\text{Fruit Yield per hectare (ton)} = \frac{\text{Fruit yield per plot (kg) x 10000m}^2}{\text{Area of plot in square meter (m}^2\text{) x l000kg}}$$

3.17.12 Number of whitefly/plant

Number of whitefly per plant was counted from the sample plants and recorded from 20, 30, 40, 50 and 60 days after planting to observe the occurrence of whitefly.

3.17.13 Disease incidence

Percent disease incidence was calculated using the following formula which was used by Ashrafuzzaman (2016):

$$\text{Disease incidence (\%)} = \frac{\text{Number of diseased plant /leaves}}{\text{Number of total plants/leaves observed}} \text{ x 100}$$

Table 2: Disease rating scale of *TYLCV*

Rating	Scale	Incidence Range (%)
0	Immune	0
1	Highly resistant	1
2	Moderate resistant	1
3	Tolerant	2
4	Moderate susceptibility	5
5	Susceptibility	6
6	High susceptibility	7

Source: Ali *et al.*, (2005)

3.17.14 Disease severity

Percent disease severity was calculated using the following formula which was used by Ashrafuzzaman (2016):

$$\text{Disease Severity (\%)} = \frac{\text{Amount of tissue infected}}{\text{Total area inspected}} \times 100$$

3.18 Analysis of data

Randomized Completely Block Design (RCBD) was followed for field experiments. The data obtained for different characters were statistically analyzed using MSTAT-C software. To calculate the level of significant difference and to separate the means within the parameters Duncan's Multiple Range Test (DMRT) and Least Significant Difference (LSD) test were performed at 5% level of significance. Tables, graphs and charts were used for interpretation of different parameters.

CHAPTER IV

RESULTS

This chapter comprises the explanation and presentation of the results obtained from the experiment on effect of different planting time on *Tomato yellow leaf curl virus* (*TYLCV*) of tomato and its impact on yield of tomato.

4.1 Effect of planting time on disease incidence (%) & severity (%) of *TYLCV* in tomato

Significant differences were found in disease incidence (%) and severity (%) of *TYLCV* in tomato plant during experimental period. The percent disease incidence and severity at different planting times are presented in Table 3.

4.1.1 Disease incidence (%) of *TYLCV*

Disease incidence (%) of *TYLCV* in three planting time of two tomato varieties (BARI Tomato-14 and BARI Tomato-16) were showed significant differences. The *TYLCV* disease incidence (%) was ranged from 12.42 to 76.83 among all planting time. The highest disease incidence was observed in 1st planting in BARI Tomato-14 (76.83%) followed by BARI Tomato-16 (62.50%). On the other hand, the lowest *TYLCV* incidence (%) was found in 3rd planting in BARI Tomato-16 (12.42) followed by same planting time in BARI Tomato-14 (21.67).

4.1.2 Disease severity (%) of *TYLCV*

Statistical significant differences were found among three planting time in two different tomato varieties. Disease severity (%) of *TYLCV* was ranged from 15.37% to 69.22%. The highest *TYLCV* severity (%) was observed in 1st planting in BARI Tomato-14 (69.22) followed by BARI Tomato-16 (57.19) and the lowest *TYLCV* severity (%) was found in 3rd planting in BARI Tomato-16 (15.37) followed by in BARI Tomato-14 (23.56) in same planting time.

Table-3: Effect of three planting time on disease incidence (%) & disease severity (%) of *TYLCV* in two tomato varieties

Treatment	Variety	Disease Incidence (%)	Disease Severity (%)
1st Planting	BARI Tomato-14	76.83 a *	69.22 a
	BARI Tomato-16	62.50 b	57.19 b
2nd Planting	BARI Tomato-14	39.33 c	42.05 c
	BARI Tomato-16	30.00 cd	35.28 d
3rd Planting	BARI Tomato-14	21.67 de	23.56 e
	BARI Tomato-16	12.42 e	15.37 f
$LSD_{(0.05)}$		10.01	5.77
CV (%)		8.74	5.04

1st planting=1st November; 2nd Planting=15th November; 3rd Planting= 1st December

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

4.2 Effect of three planting time on growth and growth contributing characters in two tomato varieties against *Tomato yellow leaf curl* (*TYLC)* disease

Growth and growth contributing characters of tomato were affected due to *TYLCV* infection at different planting time. Growth contributing characters like number of leaves/plant, number of branch /plant, number of flower/plant, plant height showed significant difference at three planting time in two tomato varieties. The effects of growth and growth contributing characters due to *TYLCV* are presented in Table 4.

4.2.1. Number of leaves/plant

Number of leaves of tomato showed significant differences due to *TYLCV* infection at different dates of planting time in two tomato varieties. The range of leaves number per plant were varied from 73.67 to 80.33. The maximum number of leaves per plant (80.33) was observed at 2nd and 3rd planting time in BARI Tomato-16 followed by 1st planting in same variety (79.00). The minimum number of leaves/plant (73.67) was found in 1^{st} planting in BARI Tomato-14 followed by 2^{nd} and 3^{rd} planting in BARI Tomato-16 (75.33).

4.2.2 Number of branch/plant

Number of branch per plant of tomato differed significantly from different dates of planting time of two different tomato varieties (BARI Tomato-14 and BARI Tomato-16) in respect of growth contributing performance under field condition. The range of branch number per plant was varied from 5.33 to 10.67. The highest number of branch per plant (10.67) was observed at 3^{rd} planting in BARI Tomato-16 followed by BARI Tomato-14 (79.00). The lowest number of branch /plant (5.33) was found at 1^{st} planting in BARI Tomato-14 followed by same planting time in BARI Tomato-16 variety.

4.2.3. Number of flower/plant

In case of number of flower/plant there were significant differences found at different planting time in two tomato varieties. The range of flower number per plant varied from 41.00 to 76.00 The maximum number of flower per plant (76.00) was observed in 3^{rd} planting in BARI Tomato-16 followed by 2^{nd} planting in BARI Tomato-16 (70.00). The minimum number of flower /plant (41.00) was found in 1^{st} planting in BARI Tomato-14 followed by BARI Tomato-16 (54.33) in same planting.

4.2.4. Plant height (cm)

The plant height differed significantly from different dates of planting time of two tomato varieties (BARI Tomato-14 and BARI Tomato-16) in respect of growth contributing performance under field condition. The plant height ranged from 68.17 cm to 95.20 cm, while the tallest plant (95.20 cm) was found in 3^{rd} planting in BARI Tomato-14 followed by same planting time in BARI Tomato-16 (88.77 cm). The lowest plant height (68.17 cm) was recorded in 1^{st} planting of BARI Tomato-16 followed by BARI Tomato-14 (73.80 cm).

Table-4: Effect of three planting time on growth and growth contributing character in two tomato varieties against *Tomato yellow leaf curl virus* (*TYLCV*)

Treatment	**Variety**	**Leaves/ plant (no)**	**Branch/ plant (no)**	**Flower/ plant (no)**	**Plant height (cm)**
1st Planting	BARI Tomato-14	73.67 b*	5.33 d	41.00 e	73.80 e
	BARI Tomato-16	79.00 a	5.67 d	54.33 d	68.17 f
2nd Planting	BARI Tomato-14	75.33 b	7.67 c	57.00 cd	84.50 c
	BARI Tomato-16	80.33 a	8.67 bc	70.00 b	78.93 d
3rd Planting	BARI Tomato-14	75.33 b	10.33 ab	60.67 c	95.20 a
	BARI Tomato-16	80.33 a	10.67 a	76.00 a	88.77 b
$LSD_{(0.05)}$		2.53	1.69	4.29	2.51
CV (%)		1.16	7.40	2.53	1.09

1st planting=1st November; 2nd Planting=15th November; 3rd Planting= 1st December

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

4.3 Effect of different planting time on yield and yield contributing character in two tomato varieties against *Tomato yellow leaf curl virus* (*TYLCV*)

Yield and yield contributing characters of tomato were affected due to *TYLCV* infection at different planting time. Yield contributing characters like number of fruits/plant, fruit weight/plant, fruit yield (kg/plot), fruit yield (ton/ha) showed significant difference at three planting time in two tomato varieties. The effects of yield and yield contributing characters due to *TYLCV* are presented in Table 5.

4.3.1 Number of fruits/plant

Significant differences were found in three planting time in two tomato varieties against *TYLCV*. The range of fruit number per plant varied from 21.33 to 40.00. The highest number of fruits per plant (40.00) was found in 3rd planting in BARI Tomato-16 followed by 2nd planting in BARI Tomato-16 (37.33). The lowest number of fruits/plant (21.33) was found in 1st planting in BARI Tomato-14 followed by same planting time in BARI Tomato-16 (28.33).

4.3.2 Fruit weight/plant (Kg)

Fruit weight/plant (kg) varied greatly among the different dates of planting time of two tomato varieties (BARI Tomato-14 and BARI Tomato-16). The range of fruit weight/plant varied from 1.67 kg to 2.72 kg. The maximum fruit weight/plant (2.72 kg) was observed in 3rd planting in BARI Tomato-16 followed by BARI Tomato-14(2.52 kg). The minimum fruit weight/plant (1.67 kg) was found in 1st planting of BARI Tomato-14 followed by same planting time in BARI Tomato-16 (1.93).

4.3.3 Fruit yield (kg/plot)

Fruit yield (kg/plot) differed significantly in different dates of planting time in two different tomato varieties (BARI Tomato-14 and BARI Tomato-16). Fruit yield (kg/plot) of two tomato varieties at three planting time ranged from 26.67 kg to 43.52 kg. The highest fruit yield (43.52 kg) was found in 3rd planting in BARI Tomato-16 followed by 2nd planting in BARI Tomato-16 (40.64 kg). On the contrary the lowest fruit yield was recorded in 1st planting in BARI Tomato-14 (26.67) followed by same planting time in BARI Tomato-16(30.83).

4.3.4 Fruit yield (kg/ha)

There were significant differences were found in fruit yield (kg/ha) at different planting time in two different tomato varieties. Fruit yield (kg/ha) of two tomato varieties at three planting time ranged from 47323 kg to 77232 kg, while the maximum fruit yield (77232 kg/ha) was found in 3rd planting in BARI Tomato-16 followed by 2nd planting in BARI Tomato-16 (72121 kg/ha). The minimum fruit yield (kg/ha) was recorded in 1st planting in BARI Tomato-14 (47323 kg/ha) followed by same planting time in BARI Tomato-16 (54706 kg/ha).

4.3.5 Fruit yield (ton/ha)

There were significant differences were found in fruit yield (ton/ha) at different planting time in two different tomato varieties. Fruit yield (ton/ha) of two tomato varieties at three planting time ranged from 47.32 ton to 77.23 ton, while the maximum fruit yield (77.23 ton/ha) was found in 3rd planting in BARI Tomato-16 followed by 2nd planting in BARI Tomato-16 (72.12 ton/ha). The minimum fruit yield (ton/ha) was recorded in 1st planting in BARI Tomato-14 (47.32 ton/ha) followed by same planting time in BARI Tomato-16 (54.71 ton/ha).

Table-5: Effect of different planting time on yield and yield contributing character in two tomato varieties against *Tomato yellow leaf curl virus* (*TYLCV*)

Treatment	**Variety**	**Fruits/ plant (no)**	**Fruit weight / plant (kg)**	**Yield (kg/plot)**	**Yield (kg/ha)**	**Yield (ton/ha)**
1st Planting	BARI Tomato-14	21.33 e*	1.67 e	26.67 e	47323 e	47.32 e
	BARI Tomato-16	28.33 d	1.93 d	30.83 d	54706 d	54.71 d
2nd Planting	BARI Tomato-14	29.67 d	2.31 c	37.01 c	65685 c	65.69 c
	BARI Tomato-16	37.33 b	2.54 b	40.64 b	72121 b	72.12 b
3rd Planting	BARI Tomato-14	32.33 c	2.52 b	40.32 b	71553 b	71.55 b
	BARI Tomato-16	40.00 a	2.72 a	43.52 a	77232 a	77.23 a
$LSD_{(0.05)}$		2.00	0.15	2.33	4135.1	4.14
CV (%)		2.24	2.25	2.25	2.26	2.26

1st planting=1st November; 2nd Planting=15th November; 3rd Planting= 1st December.

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

4.4 Whitefly infestation at three planting time in two tomato varieties

The number of whitefly/plant in different dates of planting time (from 1st November 2016 to 1st December 2016) in two different tomato varieties (BARI Tomato-14 and BARI Tomato-16) are presented in Table 6. There were significant differences were found between different planting time in two different tomato varieties. The range of whitefly number per plant varied from 20.67 to 48.67. The maximum number of whitefly per plant (48.67) was observed in 1st planting in BARI Tomato-14 followed by BARI Tomato-16 (44.00). The minimum number of whitefly/plant (20.67) was found in 3rd planting of BARI Tomato-16 followed by same planting time in BARI Tomato-14(27.67).

Table-6: Whitefly infestation at three planting time in two tomato varieties

Treatment	Variety	Average population/plant
1st Planting	BARI Tomato-14	48.67 a*
	BARI Tomato-16	44.00 b
2nd Planting	BARI Tomato-14	41.33 b
	BARI Tomato-16	34.33 c
3rd Planting	BARI Tomato-14	27.67 d
	BARI Tomato-16	20.67 e
$LSD_{(0.05)}$		2.95
CV (%)		2.89

1st planting=1st November; 2nd Planting=15th November; 3rd Planting= 1st December

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

4.5 Temperature and Humidity

Temperature (°C) and relative humidity (%) during the eight-week period after transplanting at different planting times are presented in Fig.1 and Fig.2. temperature was significantly higher at the first planting than in the second or third. At 1st planting temperature varied from 29.5 (°C) to 20 (°C) with an average of 23.75 (°C), at 2nd planting temperature varied from 25 (°C) to 14 (°C) with an average of 20.44 (°C) and at 3rd planting temperature varied from 21 (°C) to 11 (°C) with an average of 17.19 (°C).

Average relative humidity (%) followed an increasing trend with respect to planting time but the variation was insignificant (73.5%,73.75%,74.38%).

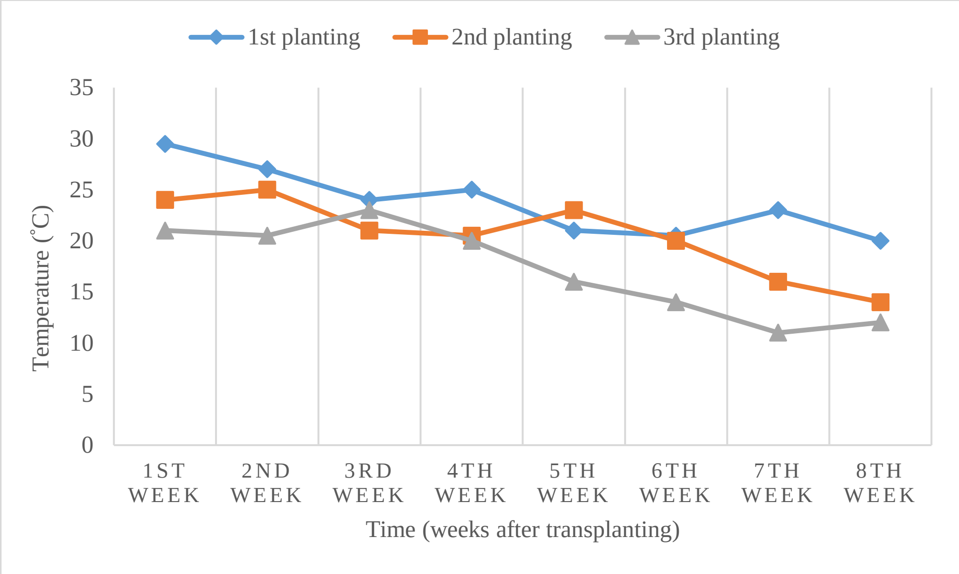


Fig.1: Average temperature (˚C) during eight weeks after transplanting at different planting time

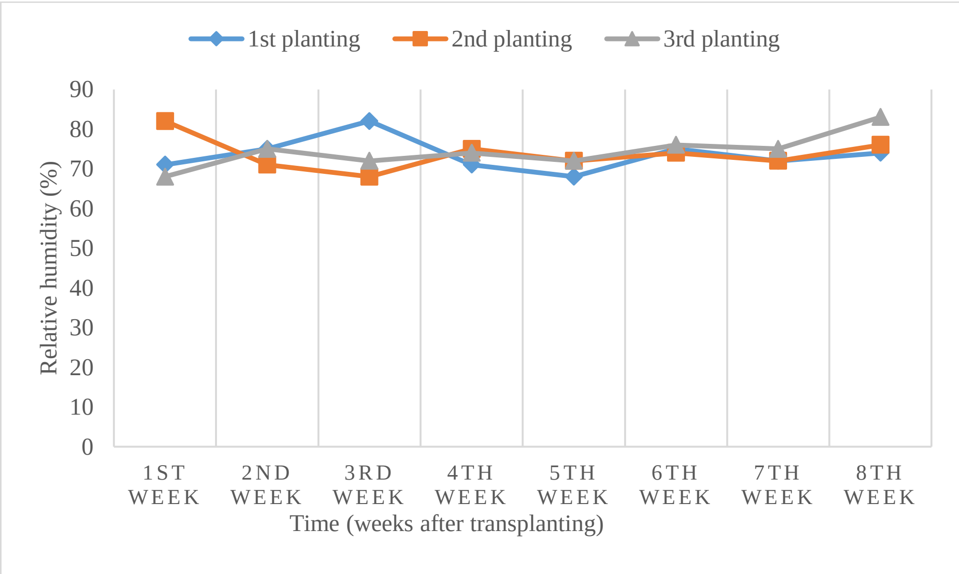


Fig. 2: Average relative humidity (%) during eight weeks after transplanting at different planting time

4.6 Correlation co-efficient between different parameters

4.6.1. Relationship between the average whitefly population and disease incidence (%) of *TYLCV* in the tomato

Relation between average whitefly population and disease incidence (%) of *TYLCV* in three planting time of two tomato varieties in field condition is shown in Figure 3. During experiment, a strong positive correlation was found between the average whitefly population and *TYLCV* disease incidence (%). This figure showed that the disease incidence (%) was increase with the increase of average whitefly population. A regression line was fitted between average whitefly population and disease incidence (%) of *TYLCV*. The correlation coefficient (r) was 0.9435 and the contribution of the regression (R^2= 0.8902) indicated that 89.02% *TYLCV* infection increased by whitefly.

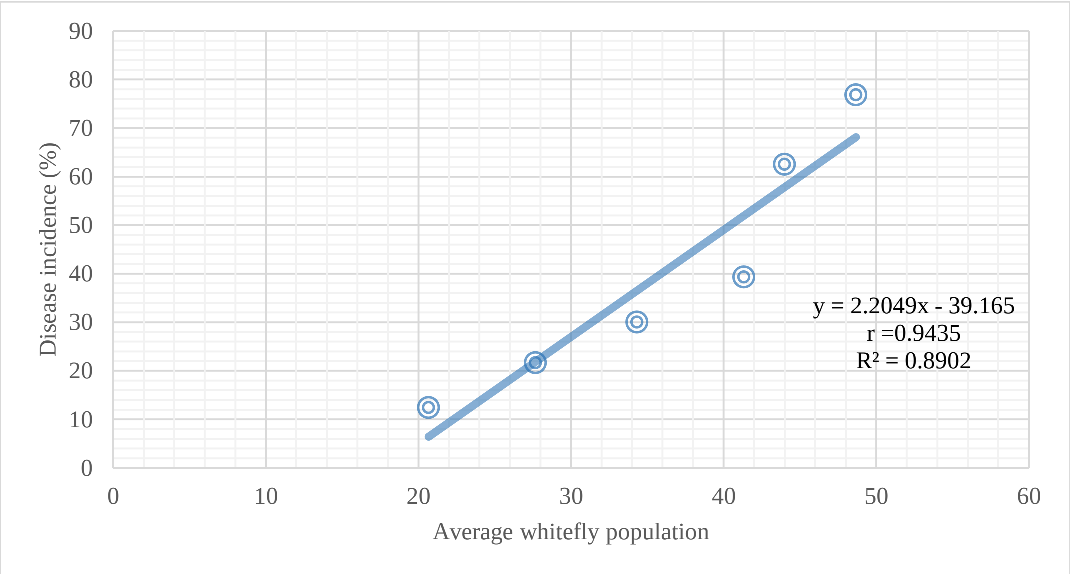


Fig. 3: Relation between the average whitefly population and disease incidence (%) of *TYLCV* in the tomato

4.6.2 Relation between disease incidence (%) of *TYLCV* and yield (ton/ha) of tomato

A significant negative correlation was found between disease incidence of *TYLCV* (%) and yield (ton/ha) of tomato in three planting time of two tomato varieties in field condition are shown in Figure 4. From the figure it is revealed that yield (ton/ha) of tomato decreased with the increased of TYLCV disease incidence. A regression line was fitted between % incidence of *TYLCV* and yield of tomato. The correlation coefficient (r) was -0.9918 and the contribution of the regression (R^2 = 0.9837) indicate that 98.37 % yield in tomato would be affected by *TYLCV* infection.

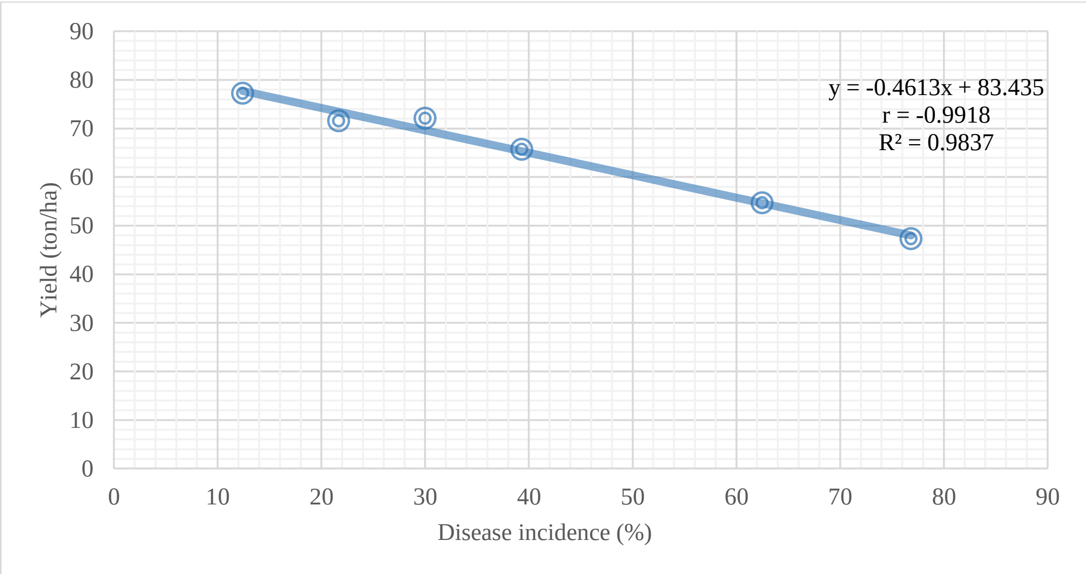


Fig.4: Relation between disease incidence (%) of *TYLCV* and yield (ton/ha) of tomato

4.6.3 Relation between the average whitefly population and yield(ton/ha) of tomato

Figure-5 showed a negative correlation between the average whitefly population and yield (ton/ha) of tomato in three planting time of two tomato varieties. Figure showed that with the increase of average whitefly population in tomato field, yield (ton/ha) of tomato decreased. A regression line was fitted between average whitefly population and yield (ton/ha) of tomato. The correlation coefficient (r) was -0.9139 and the contribution of the regression (R^2 = 0.8353) indicate that 83.53% yield in tomato would be affected by whitefly.

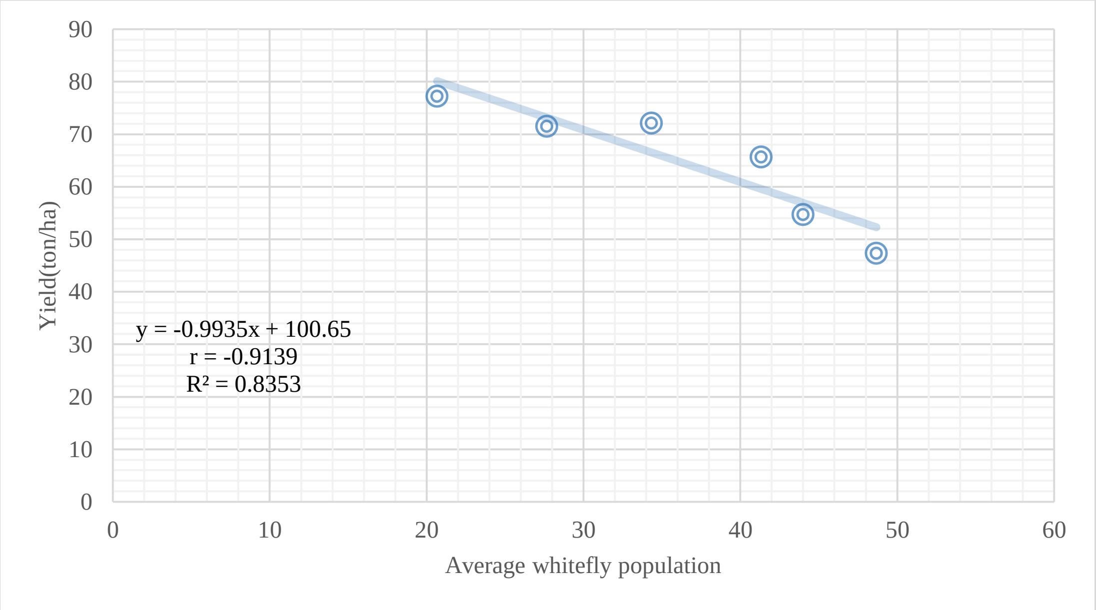


Fig. 5: Relation between the average whitefly population and yield(ton/ha) of tomato

CHAPTER V

DISCUSSION

Tomato (*Solanum lycopersicum* L.) belonging to the family Solanaceae, is one of the most important, popular and nutritious vegetables grown in Bangladesh Haque *et al.,* (1999). Tomato fruit is rich in vitamins and minerals (Hobson and Davis, 1971). Its food value is very rich because of higher contents of vitamins A, B and C including calcium and carotene (Bose and Som, 1990). Tomato has a significant role in human nutrition because of its rich source of lycopene, minerals and vitamins such as ascorbic acid (Vitamin-C) and β-carotene (Vitamin-A) which are anti-oxidants and promote good health (Wilcox *et al*., 2003).

Tomato yield was seriously affected by date of planting, because it has a high sensitivity with temperature for fruit setting, high temperature reduce fruit setting and ultimate yield. So during flowering time tomato need required temperature for better yield. The results of the present study indicated that 3rd planting (1st December planting) and BARI Tomato-16 between two varieties performed better against of disease incidence (%) (12.42) and severity (%) (15.37) of *TYLCV*. On the other hand, the highest *TYLCV* disease incidence (%) (76.83%) and severity (%) (69.22) was found in 1st planting in BARI Tomato-14. Almost similar investigation on different planting time and varietal performance against disease incidence (%) and severity (%) of *TYLCV* in tomato field was obtained by Mazyad *et al.* (1979), Pilowsky *et al.* (1993), Gupta (2000), Azam (2001), Paul (2002), Rashid *et al*. (2008) and Muqit *et al* (2006).

The highest number of leaves/plant (80.33) was recorded in 2nd planting of BARI Tomato-16 and The lowest number of leaves/plant (73.67) was found in 1st planting in BARI Tomato-14. From this result it can be concluded that number of leaves/plant reduced more in the early planting compared to the late planting. Singh and Sastry (1979) stated that *TYLCV* infected plants was characterized by reducing leaf and severe stunting with downward rolling and crinkling of leaves. The newly formed leaves also exhibit chlorotic symptoms whereas older leaves became leathery and brittle.

The highest number of branch/plant (10.67) was observed in 3rd planting in BARI Tomato-16. The lowest number of branch/plant (5.33) was found in 1st planting in BARI Tomato-14. Results of the present study revealed that branch number reduced more in the early planting than the late planting. The results also agreement with the findings of Sinisterra *el al.* (2000).

The highest number of flower/plant (76.00) was observed in 3rd planting in BARI Tomato-16. The lowest number of flower /plant (41.00) was found in 1st planting in BARI Tomato-14. From the above results it can be pointed out that the late planting produced more flowers than the early planting. Similar results also reported by Gupta (2000).

The highest plant height (95.20 cm) was found in 3rd planting in BARI Tomato-14. The lowest plant height (68.17 cm) was recorded in 1st planting in BARI Tomato-16. The results indicated that there were significant differences between the late planting and the early planting. Results indicated that the late planting obtained maximum heights than the early planting This types of findings were also reported by Rahman (2003).

The highest number of fruits per plant (40.00) was observed in 3rd planting in BARI Tomato-16. The lowest number of fruits/plant (21.33) was found in 1st planting in BARI Tomato-14. Results of the present study revealed that fruits number reduced more in the early planting than the late planting due to *TYLCV* infection. The results also agreement with the findings of Sinisterra *el al.* (2000).

Maximum fruit weight/plant (2.72 kg) was observed in 3rd planting in BARI Tomato-16. Minimum fruit weight/plant (1.67 kg) was found in 1st planting in BARI Tomato-14. From the above results it can be pointed out that the late planting had more fruit weight/plant than the early planting. Similar findings also reported by Gupta (2000).

Fruit yield (ton/ha) ranged from 47.32to 77.23, while the highest fruit yield (ton/ha) (77.23) was found in 3rd planting in BARI Tomato-16. The lowest fruit yield (ton/ha) was recorded in 1st planting in BARI Tomato-14 (47.32). The present investigation demonstrates that higher severity of *TYLCV* was one of the reasons for reduction of fruit yield in tomato plants. Similar findings were also reported by Lukyanenko (1991) and Polston *et al.* (2005). They reported that *TYLCV* is caused reduction of the 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.

The results indicated that the yield of tomato was positively influenced by number of leaves, number of flower, plant height, number of fruits, fruit weight. The results of the study are more or less in agreement with the findings of different workers (Mohanty 2002a, 2002b and 2003)

The highest number of whitefly per plant (48.67) was observed in 1st planting in BARI Tomato-14. The lowest number of whitefly/plant (20.67) was found in 3rd planting in BARI Tomato-16. Results of the present study revealed that whitefly number reduced more in the late planting than the early planting. Verma *et al.* (1989) stated that the incidence of *TYLCV* on tomato was directly related to the population density of the vector developed when incidence of the disease also began to increase. 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 and Muqit *et al* (2006).

Cohen (1966) reported that *TYLCV* show great regional and seasonal variations mainly because of fluctuations in the population density of the whitefly vector. Ioannou and Iordanou (1985) observed that incidence of *TYLCV* was less in winter and early spring planting as compared to summer and early autumn when vector population was the highest. Results of the present study are in agreement with the findings of Ioannou and Iordanou (1985) and Muqit *et al* (2006).

The relationship between average whitefly population and incidence (%) of *TYLCV* was investigated. A positive correlation between the incidence (%) of *TYLCV* and average whitefly population (0.9435) was recorded which was supported by Saikia and Muniyappa (1989), Polizzi *et al* (1994), Aboul-Ata *et al.* (2000) and Muqit *et al* (2006).

The present study also revealed the relationship between average whitefly population and yield (ton/ha) of tomato. A negative correlation (r = -0.9139) between the average whitefly population and yield (ton/ha) of tomato was recorded which is an accordance with the findings of Gupta (2000). A negative correlation (r = -0.9918) between the incidence of *TYLCV* and yield (ton/ha) was also obtained that has also been supported by Gupta (2000).

CHAPTER VI
SUMMARY AND CONCLUSIONS

A field experiment was conducted at the research farm of Sher-e-Bangla Agricultural University, Dhaka, during the Rabi season from October 2016 to March 2017 to study effect of different planting time on *Tomato yellow leaf curl virus* (*TYLCV*) and its impact on the yield attribute. The experiment was laid out in a Randomized Complete Block Design (RCBD) with three replications of each treatment. The whole plot was divided into three blocks each containing six (6) plots of 2.45 m x 2.30 m size, giving 18 unit plots. There were two factors in the experiment comprising three levels of planting time (1st November, 15th November and 1st December) and two levels of variety as BARI Tomato-14 and BARI Tomato-16. Data on disease incidence, disease severity, whitefly population, growth and yield contributing parameters were recorded during experiment, and the collected data were statistically analyzed to evaluate the treatment effects.

The results indicated that disease incidence (%) & disease severity (%) of *TYLCV* were lowest in 3rd planting and BARI Tomato-16 variety. It also indicated that higher incidence and severity of *TYLCV* was one of the reasons for reduction of fruit yield in tomato plants which are greatly dependent on planting time.

Among the different planting time 3rd planting and BARI Tomato-16 variety had maximum growth and growth contributing characters like as number of leaves, branch flower and plant height, the results also indicated that the yield of tomato was increased by number of leaves, branch flower and plant height.

Yield and yield contributing characters like as number of fruits, fruit weight/plant, fruit yield (kg/plot), fruit yield (kg/ha) and fruit yield (ton/ha) were highest in 3rd planting and BARI Tomato-16 variety.

The results also revealed that whitefly population reduced more in the late planting than in the early planting.

The present study revealed a positive correlation between the whitefly population and disease incidence (%) of *TYLCV* (0.9435**) was recorded. A negative correlation (r = -0.9918**) between the incidence of *TYLCV* and yield was also obtained in this study. A negative correlation (r = -0.9139**) between the whitefly population and yield of tomato was also recorded.

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

- Disease incidence (%) & disease severity (%) of *TYLCV* were lowest in 3^{rd} planting and BARI Tomato-16 variety.

- Growth and growth contributing characters (number of leaves, branch flower and plant height) as well as yield and yield contributing characters (number of fruits, fruit weight/plant, fruit yield (kg/plot), fruit yield (kg/ha) and fruit yield (ton/ha)) were highest in 3^{rd} planting and BARI Tomato-16 variety.

- Average whitefly population was minimum in 3^{rd} planting and BARI Tomato-16 variety.

- Disease incidence (%) & disease severity (%) of *TYLCV* were found positive relation with temperature.

- Disease incidence (%) & disease severity (%) of *TYLCV* were found positive and significantly correlated with the average whitefly population build up in the field.

- Average whitefly population and yield (ton/ha) of tomato were negatively and significantly correlated with each other.

- The yield (ton/ha) was found negatively and significantly correlated with disease incidence (%) and disease severity (%) of *TYLCV*.

- Considering the percentage of *TYLCV* disease incidence & severity, growth and yield contributing characters as well as the yield of two tomato varieties in three different planting time; 3rd planting (1st December planting) and BARI Tomato-16 variety gave the highest yield and promising level of tolerance against *TYLCV*.

CHAPTER VII
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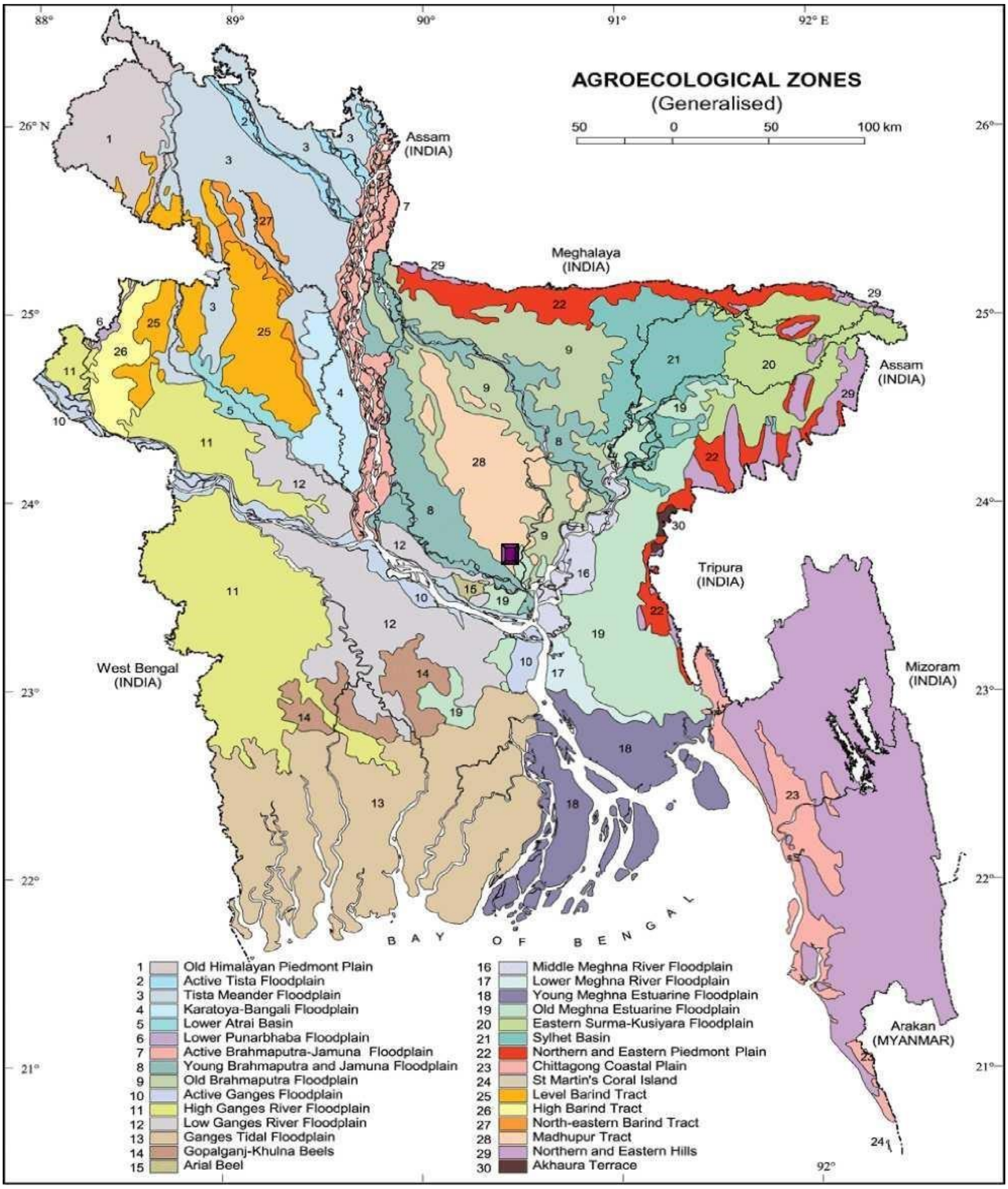
CHAPTER VIII

APPENDICES

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



Appendix II: The mechanical 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	0-15 cm 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, 2017	32	15	76
March, 2017	32	17	83
April, 2017	36	20	72
May, 2017	36	21	71

Source: Timeanddate.com/weather/bangladesh/dhaka