EVALUATION OF TOMATO GENOTYPES AGAINST *TOMATO YELLOW LEAF CURL VIRUS (TYLCV)*

By

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CERTIFICATE

This is to certify that the thesis entitled, "EVALUATION OF TOMATO GENOTYPES AGAINST TOMATO YELLOW LEAF CURL VIRUS (TYLCV)" submitted to the Department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment 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 SYED MD. SYDUJJAMAN, Registration no. 09-03437 under my direct supervision and guidance. No part of this thesis has been submitted for any other degree in any other institutions.

I further certify that any help or sources of information received during the course of this investigation have been duly acknowledged.

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Dedicated To

My

Beloved Parents

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26th May, 2016
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ABSTRACT

Present studies had been conducted to evaluate different varieties and lines of tomato against *Tomato yellow leaf curl virus (TYLCV)* during the period from October 2014 to March 2015. Five varieties namely BARI Tomato-3, BARI Tomato-7, BARI Tomato-9, Local jessore-2, Local jessore-3 and five lines namely BD-7276, BD-7281, BD-7290, BD-7754, BD-7762 were evaluated against *Tomato yellow leaf curl virus (TYLCV)*. The effect of diseases on yield and yield contributing characters were also observed. The tomato varieties and lines differed significantly among themselves in respect of disease incidence. The highest disease incidence was found in Local Jessore-3 (100%), Bd-7281 (100%), BD-7754 (100%) and BD-7762 (100%). The lowest disease incidence was found in the variety BARI Tomato-9 (00%). Considering the performance of selected tomato varieties and lines, it was observed that line BD-7276 was graded as tolerant against *Tomato yellow leaf curl virus (TYLCV)*. The cultivars BARI Tomato-3, BARI Tomato-7, Local Jessore-2 and line BD-7290 showed moderate resistance, while the lines BD-7762, BD-7754, BD-7281 and Local jessore-3 were highly affected by *Tomato Yellow Leaf Curl Virus (TYLCV)* among different treatments used in the experiment. In case of number of leaves, branch and flowers per plant, the maximum number of leaves, branch and flowers was recorded in the variety BARI Tomato-9 (72.00, 10.67 and 68.33 respectively). The minimum number of leaves, branch and flowers was obtained in the variety Local Jessore-3 (47.67, 6.00 and 51.67 respectively). On the basis of yield and yield contributing characters, the yield performance also differed significantly. The highest yield per plant was recorded in the variety BARI Tomato-9 (2.70 kg) and the lowest in Local Jessore-3 (1.09 kg). In case of the physiological features, we also founded a significant difference among the different varieties and lines. In case of net chlorophyll content, net assimilation rate, intercellular carbon-di-oxide concentration and respiration rate per plant, in all cases the highest value was recorded in the variety BARI Tomato-9 (65.17, 1.03, 37.33 and 1.25 respectively) and the lowest was in Local Jessore-3 (40.20, 0.33, 16.67 and 0.33 respectively).

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

Chapter 1

INTRODUCTION

INTRODUCTION

Tomato (*Lycopersicon esculentum*) is one of the most important and popular vegetables in the world because of its wider adaptability, high yielding potentiality and suitability for variety of uses in fresh as well as processed food industries (Meena and Bahadur, 2015). The tomato belongs to the family solanaceae 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 *Lycopersicon esculentum* and is native to Central, South and Southern North America. In Bangladesh, tomato is cultivated all over the country due to its adaptability to wide range of soil and climate (Ahamed, 1995). The tomato is composed mainly of water (approximately 90%), soluble and insoluble solids (5-7%), citric and other organic acids, and vitamins and minerals (Pedro and Ferreira, 2007). The best growing areas of tomato in Bangladesh are Chittagong, Comilla and Rajshahi and it ranks fourth in respect of production and third in respect of area (BBS, 2012-2013). It is high nutritious and consumed as in fresh or processed form like as cookies and salads. Tomatoes are an excellent source of minerals and vitamins (Sainju *et al.,* 2003; Naika *et al.,* 2005; Akinfasoye *et al.,* 2011). Its vitamin C content is particularly high (Kanyomeka and Shivute, 2005) and is an excellent source of lycopene, a powerful antioxidant and reduces the risk of prostate cancer Hossain *et al.,* (2004). It is even present when tomatoes are cooked. Tomato has an excellent nutritional profile owing largely to its balanced mixture of minerals (potassium, calcium, phosphorus, iron and zinc), vitamins (A, B1, B2, B6, biotine, folic acid, nicotinic acid, pantothenic acid, C, E and K), antioxidants such as carotenoids and polyphenolic compounds and carbohydrates. No doubt, because of its exceptional nutritive value, tomato is the world's major vegetable crop. Fresh ripe tomatoes are prevalently consumed raw in salad as well as curried in combination with variety of vegetables. Tomato can also be processed and canned into a wide range of value added products like soups, juices, pastes, sauces, ketchups and purees. Tomato is also having medicinal value. The pulp and juice are digestible and blood purifier Frasher *et al.,* (1991).

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Tomato (*Lycopersicon esculentum*) is one of the most important and popular vegetables in the world because of its wider adaptability, high yielding potentiality and suitability for variety of uses in fresh as well as processed food industries (Meena and Bahadur, 2015). The tomato belongs to the family solanaceae 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 *Lycopersicon esculentum* and is native to Central, South and Southern North America. In Bangladesh, tomato is cultivated all over the country due to its adaptability to wide range of soil and climate (Ahmed, 1995). The tomato is composed mainly of water (approximately 90%), soluble and insoluble solids (5-7%), citric and other organic acids, and vitamins and minerals (Pedro and Ferreira, 2007). The best growing areas of tomato in Bangladesh are Chittagong, Comilla and Rajshahi and it ranks fourth in respect of production and third in respect of area (BBS, 2012-2013). It is high nutritious and consumed as in fresh or processed form like as cookies and salads. Tomatoes are an excellent source of minerals and vitamins (Sainju *et al.*, 2003; Naika *et al.*, 2005; Akintasoye *et al.*, 2011). Its vitamin C content is particularly high (Kanyomeka and Shivute, 2005) and is an excellent source of lycopene, a powerful antioxidant and reduces the risk of prostate cancer Hossain *et al.*, (2004). It is even present when tomatoes are cooked. Tomato has an excellent nutritional profile owing largely to its balanced mixture of minerals (potassium, calcium, phosphorus, iron and zinc), vitamins (A, B1, B2, B6, biotine, folic acid, nicotinic acid, pantothenic acid, C, E and K), antioxidants such as carotenoids and polyphenolic compounds and carbohydrates. No doubt, because of its exceptional nutritive value, tomato is the world's major vegetable crop. Fresh ripe tomatoes are prevalently consumed raw in salad as well as curried in combination with variety of vegetables. Tomato can also be processed and canned into a wide range of value added products like soups, juices, pastes, sauces, ketchups and purees. Tomato is also having medicinal value. The pulp and juice are digestible and blood purifier Frasher *et al.*, (1991).

The cultivated tomato is the second most commonly consumed vegetable after potato in the world. It is being produced in most of the countries of the world with an estimated global production of over 162 million metric tons from an area of 4.83 million hectares Dagade *et al.,* (2015). It is one of the most important vegetable crops of both tropics and subtropics of the world. As a cash crop, it has great demand in the International market (Hannan *et al.,* 2007; Solieman *et al.,* 2013). The area under tomato cultivation in the world during last five years (2001-2005) was increased from 5837 to 6508 thousand hectares with a production ranging from 106171 to 126671 thousand metric tons, respectively (Anon. 2007). In Bangladesh during this period it was 14 to 17 thousand hectares with a production ranged from 100 to 122 thousand metric tons, respectively (Anon. 2007). In Bangladesh during 2011-2012 period the tomato production was 63000 acres was 255 metric ton (Year book of agricultural statistics-2012). The increasing trend of area under tomato cultivation and production indicate its importance as a crop. The average yield of tomato in Bangladesh is very low as compared to world average or many other tomato growing countries. Average yield of tomato in the world is 27t/ha whereas in Bangladesh it is around 7t/ha. Among the factors responsible for low yield of tomato, diseases are considered to be the most serious ones. Globally tomato is susceptible to more than 200 diseases, out of which 40 are caused by viruses (Martelli and Quacquarelli, 1982; Lukyanenko, 1991). However, the incidence and economic impact of virus infections in tomato varies greatly depending upon the country, the year, method of cropping (under cover or outdoors) and the virus itself (Martelli and Quacquarelli, 1982).

Tomato yellow leaf curl virus (*TYLCV*) causes a potentially destructive disease of tomatoes. *TYLCV* belongs to Geminivirus group (Czosnek and Laterrot, 1997). This disease is generally introduced in the fields on infected transplants, but is then spread from plant to plant by the insect vectors whitefly *(Bemisia tabaci)* in a semipersistant manner (Green and Kalloo 1994). *TYLCV* threatens both commercial tomato production in the fields and home garden was first reported in Israel in 1939-40 which seemed to be associated with the outbreak *of Bemisia tabaci.* The causal agent was described in 1964 and named as *Tomato yellow leaf curl virus* (*TYLCV*) by Cohen and Harpaz, (1964). Since then *TYLCV* has been reported from all over the tropics, subtropics, the Mediterranean, the Caribbean's and the Americas (Czosnek and Laterrot, 1997, and Nakhla *et al.,* 1994). The virus can cause up to 100% yield loss in tropics and subtropics depending upon severity and stage of infection (Green and Kalloo, 1994).

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TYLCV is an ssDNA plant virus, which belongs to the family Geminiviridae of the genus Begomovirus. The virus is mechanically non- transmitted, but transmitted by grafting and white fly *(Bemisia tabaci),* which could be able to infect plants at any stage of plant growth (Gupta, 2000; and Akanda, 2003). The impact of *TYLCV* on tomato production is estimated as severe. If plants are infected at an early stage, they do not bear fruit and their growth becomes severely stunted. The characteristic symptoms of *TYLCV* infected plant includes chlorotic margin, upward leaf cupping, leaf mottling, reduced leaf size, stunted growth and flower drop (Ganif, 2003; Green and Kalloo, 1994). Identification based only on symptomatology is possible, but needs high skill and care as because similar symptoms may be caused by other viruses or various growing conditions.

In Bangladesh *TYLCV* incidence was first reported by Akanda, (1991). Since then efforts have been made to characterize the virus systematically to 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). 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 manage 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 *et al.*, (2006).

Objectives

The research program was designed with the following objectives

- To evaluate the resistance tomato genotypes against ***Tomato Yellow Leaf Curl Virus (TYLCV)*** under pot condition.

- To evaluate the incidence level of ***Tomato Yellow Leaf Curl Virus (TYLCV).***

Chapter 2

REVIEW OF LITERATURE

REVIEW OF LITERATURE

Tomato suffers from many diseases of which yellow leaf curl is considered as the most important one. Reports on various aspects of this disease along it's with it associated findings have been reviewed and noted below.

2.1. Importance of tomato fruit morphology

Tomato fruits are important in marketing and processing industries in a variety of ways. Not only the host physiology change in tomato plants is crucial in tomato production, but also tomato fruit morphology is important. The guarantee of both characteristics will lead to a better tomato fruit production. Although tomato fruit quality has been studied in several aspects, the morphology of tomato fruits was relatively limited in knowledge. Great concerns about shape arise due to marketing since shape sorting of tomatoes is of great import to assess the sustainability for merchandized processing in terms of shape and size reported by Shi *et al.,* (2000).

Breeding fresh market tomato cultivars that maintain a symmetrical and uniform shape with smooth blossom scars is of critical importance to the industry Vavilav, (1951). Based on fruit morphology, consumers purchase tomato for specific purposes such as eating fresh and salads (grape, cherry tomato, tomatoes on the vine), for slicing to put onto hamburgers (beefsteak) or to use in sauces and stews (Roma tomatoes). In processing industry, elongated tomato fruit shape is desired due to the stability on the conveyer belt; better fit in cans than round tomatoes. As a result, the study of tomato fruit shape stability is important for the processing and fresh market industries, and even critical for tomato harvesting-related machine applications reported by Li *et al.,* (2011).

2.2. Historical background and characterization of *TYLCV*

TYLCV was first reported in Israel in 1939-40 associated with outbreak of whitefly *(Bemisia tabaci).* The causal agent was described in 1964 and named *Tomato yellow leaf curl virus* (*TYLCV*) by 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, Composites, 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 reported by 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 non-availability of tomato cultivars makes the situation more vulnerable in respect to the management of *TYLCV* reported by (Martalli and Quacquarelli, 1982).

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 *Solarium 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.*

A search for alternative hosts that may serve as disease reservoirs was conducted by testing 210 samples of 95 weed species. The following species were found to be infected: *Conyza sumatrensis, Chenopodium murale, Datura stramonium, Dittrichia viscose [Inula viscosa], Malva parvflora, Solanum nigrum, Convolvulus sp., Cuscuta sp.,* this was the first reference of *Conyza sumatransis, Chenopodium murale, Convolvulus sp.* and *Cuscuta sp.* As natural hosts of *TYLCV* stated by Jorda *et al.,* (2000).

Ingram *et al.,* (2001) mild symptoms consistent with *Tomato yellow leaf curl* *virus* (*TYLCV*), i.e. chlorosis, stunting and cupping of leaves, were observed in a greenhouse- grown tomato production operation in east-central Mississippi, USA. Symptom severity slightly increased over time. Results of PCR assay indicated the presence of *TYLCV* in symptomatic tissues. The strain of the virus was not determined. This is claimed to be the first report of *TYLCV* in Mississippi.

Jorda *et al.,* (2001) reported that two viral species of *Tomato yellow leaf curl virus* are present in Spain, *TYLCV-Sar* and *TYLCV-Is*. DNA was extracted from over 1320 tomato plant samples from Spain and was analyzed by polymerase chain reaction and constraint fragment length polymorphism analysis. *TYLCV-Sar* (43.4%) and *TYLCV-Is* (56.6%) coexisted in tomato crops and dislocation of *TYLCV-Sar* for *TYLCV*-was observed. A search for alternative hosts, which may serve as disease reservoirs, was conducted by testing 210 samples of 95 weed species. The following species were found to be infected: *Conyza sumatrensis, Chenopodium murale, Datura stramonium, Dittrichia viscosa [Inula viscosa], Malva parviflora, Solatium nigrum, Convolvulus* sp. and *Cuscuta* sp. This is the first reference of *Conyza sumatrensis, Chenopodium murale, Convolvulus* sp. and *Cuscuta* sp. as natural hosts of *TYLCV*. These plants were symptom less.

2.3. Disease symptoms

Pilowsky and Cohen, (1990) demonstrated that in Israel *TYLCV* causes 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. Fruit sets were greatly reduced and infected young plants produced almost no marketable yield.

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

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 part of Italy. The vector was found on nine wild and six cultivated plant species beside tomato.

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

Green and Kalloo, (1994) in their review described many aspects of *TYLCV*. Infected tomato plants are stunted, branches and petioles tend to assume erect position, leaflet are smaller than those of healthy plants, puckered and often show upward curling, margins with or without yellowing.

Sinisterra *et al.,* (2000) described the symptoms of *TYLCV* on tomato. These include stunting, curling, marginal chlorosis of leaves, reduced leaf size and marked reduction in fruit number.

Avgelis *et al.,* (2001) first reported that *TYLCV* in Greece. They described the disease symptom as leaf curling, reduced leaf size, yellowing, shortened internodes and a bushy appearance. Mechanical inoculation was unproductive while transmission was obtained by grafting on to healthy tomato plants.

Ganif, (2003) reported that leaf symptoms include chlorotic margins, small leaves that are cupped, thick rubbery. The majority (90%) of flowers abscises after infection and therefore few fruits are formed. *TYLCV* is considered as a phloem limited virus. But one study Michelson *et al.,* (1997) suggested that it is not phloem limited in all tissue types.

2.4. Diagnosis and identification of virus

Czosnek *et al.,* (1988) purified the *TYLCV* particles from infected tomato and dutura plants and detected typical twined particles, characteristic of member of geminivirus group. They confirmed that viruses containing fractions of purified preparations were infective in membrane transmission test with the whitefly vector.

Navot and Czosnek, (1989) developed a method for rapid detection of *TYLCV* in squashes of infected plants and insect vector. The DNA of *TYLCV* could be detected in squashbiots of tomato leaves, roots, flowers and fruits. Viral sequences were also detected *Tobacco mosaic virus, potato virus* Y and two others RNA viruses in infected tobacco plants using the method. The squash blot method was applied for *TYLCV* infections in the field in Israel and for diagnosing *TYLCV* in Turkey.

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

In Bangladesh Akanda, (1991) collected 23 tomato samples on the basis of symptoms from different parts of Bangladesh and noted six different types of symptom 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* (*AMV*) were identified on the basis of symptoms, electron microscopic study, inoculation test and serological test Akanda *et al.,* (1991a and 1991b). However, the author commented that the two major symptoms (*yellow mosaic and purple vein*) in respect to prevalence and crop damage could not be identified. The authors named the two viruses as *Tomato yellow leaf curl virus* (*TYLCV*) causing *yellow mosaic* symptom and *Tomato purple vein virus* (*TPVV*) causing purple vein symptom for the first time from Bangladesh.

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

Sinisterra *et al.,* (2000) reported that symptoms of stunting, curling, marginal chlorosis of leaves, reduced leaf size and marked reductions in fruit number were observed on tomato plants on the island of North Andros, Bahamas. Similar symptoms were observed on tomato plants in 1997 on Eleuthera. The causal organism was identified as *Tomato yellow leaf curl virus-Is* [Israel] (*TYLCV*-Is). This is the first report of *TYLCV-Is* in the Bahamas.

Sialer *et al.*, (2001) reported that symptoms of stunting, curling and yellowing of leaf margins, and marked reductions in the number of fruits were observed in some greenhouse-grown tomato cv. Naxos plants in the province of Bari in Apulia, Italy, were observed in the being an isolate of *TYLCV-Sar*. The nucleotide sequence of the 580 bp amplicon shared 99.5% homology with a clone from a Sicilian isolate and 97.5% with a clone from a Sardinian isolate of *TYLCV-Sar*. This is the first report of *TYLCV* in Apulia, Italy.

Polston *et al.*, (2002) noted that tomato plants with symptoms of stunting, curling and marginal chlorosis of leaves, reduced leaf size, and marked reduction in fruit number, similar to those caused by *Tomato yellow leaf curl virus* (*TYLCV),* were observed in Henderson County, North Carolina, USA. In 2001, symptomatic plants appeared in a 40-A (18.2 ha) field in 12 foci of 12 plants each, at a total incidence of less than 1%.

2.5. Vector and transmission of virus

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

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

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

Charif 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.

Al Hitty and Sharif, (1987) reported that cucumber could be the best host of whitefly due to trapping of vector. *TYLCV* infection was reduced by 48% if planted as trap crop in tomato field.

Brown and Bird, (1992) noted that plant viruses transmitted by whiteflies causes over 40 diseases of vegetable, and fiber crops worldwide. Depending on the crops 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.* Assays using molecular hybridization with a specific *TYLCV* probe were carried out on 55 wild and cultivated species. It was found that black nightshade. Jimson weed and *Euphorbia* sp. were natural hosts of the virus.

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 (*ITmLCV*) and *Tomato yellow leaf curl* geminiviruses from Nigeria (*TYLCV*-nig) and Senegal (T*YLCV*-sen). The results demonstrated that the frequency of transmission from tomato to tomato depend both on the whitefly culture and the virus isolates.

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

2.6. Yield loss

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

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

According to Green and Kalloo, (1994) *TYLCV* was distributed all over the world; especially it was a risk of production in Mediterranean Basin, west east Africa. *TYLCV* caused 50-70% yield reduction usually, which may be as high as 100%.

Tomato yellow leaf curl virus (*TYLCV*) comprises of a group geminivirus species of the genus Begomovirus under the family Geminivirus that causes severe damage to tomato in tropical and subtropical region. In Spain it can cause even 100% yield loss. Common bean acts as a reservoir of *TYLCV* reported by Sanchez *et al.,* (1999).

Lapidot *et al.,* (2001) described *Tomato yellow leaf curl virus* (*TYLCV*) as one of the most devastating Begómoviruses of cultivated tomato in the tropical and subtropical region. In the Mediterranean region yield loss can be up to 100%.

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 the USA. In many cases yield loss can be up to 90% reported by Ganif, (2003).

Polston *et al.*, (2005) reported that *TYLCV* is causes 90% reduction of marketable yield if infected within 8 weeks after transplanting and 45% if infection occurs between 8-14 weeks after transplanting.

2.7. Management of *TYLCV*

Many reports, from cultural to transgenic have been published on the management of *TYLCV* of tomato in the world. Few works are reviewed under the following subheading.

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

Al Musa, (1982) studied the effect of some intercrops on *TYLCV* of tomato. In the field trial cucumber, eggplant and crop were planted in alternate rows of tomato 30 days before the tomato seedlings were transplanted. *TYLCV* was effectively delayed in cucumber interplant plots whereas; corn or eggplant was not found suitable.

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

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

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

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

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

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

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

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

Simone and Momol, (2001) reported that to identity 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.

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

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

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

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

2.8. Works conducted in Bangladesh

Seven viral diseases on tomato in Bangladesh. The viruses' are *Cucumber mosaic virus* (*CMV*), *Tomato yellow leaf virus* (*TYLCV*), *Tomato leaf curl virus* (*TLCV*), *Tobacco 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 widely distributed reported by Alam, (1995).

Shih *et al.,* (1998) studied the molecular characterization of two samples (BD1 and BD2) of yellow leaf curl on tomato from farmer's field near Gazipur, Bangladesh. Sequence comparisons were made with 10 distinct tomato infecting whitefly transmitted Gemini viruses. The overall sequence homology between BD1 and BD2 was 87.5%. Their coat protein (VI), precoat protein (V2), replicase (C1) and symptom expression (C4) ORFs showed nucleotide identities of 98, 97, 84 and 87% respectively. The extremely high cp gene but low rep gene sequence identity suggests that the two viruses are distinct viruses, one of which might have been derived by recombination with another distinct gemenivirus which exists in the same location. Bd1 also shared high nucleotide sequence identity (>90%) with *TYCV*-Ban3 from India, suggesting that it might be a strain of that virus. BD2 had less (>90%) sequence identity with Ban3, indicating that those two viruses are not related.

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 numbers of whitefly and spread of *TYLCV.*

Rashid *et al.,* (2001) reported that *Tomato yellow leaf curl virus* (*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.

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 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.

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

Chapter 3

MATERIALS AND METHODS

MATERIALS AND METHODS

This chapter described the materials and methods that were used in carrying out the experiment. It included a description of *Tomato Yellow Leaf Curl Virus (TYLCV)* of tomato varieties in the pot conditions. These comprised collection of popular tomato cultivars, identification of *"Tomato Yellow Leaf Curl Virus (TYLCV)"* from infected tomato plant, conduction of pot experiment and recording compilation and analysis of data.

3.1. Experimental site

The experiment was conducted at the farm of Horticulture, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh during the period from October 2014 to March 2015. The experimental area was situated at 23°46' N latitude and 90°22'E longitude at an altitude of 8.6 meter above the sea level (Anon. 1988). The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract", AEZ-28 (Anon. 1988). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as islands surrounded by floodplain (Anon., 1988). (Appendices-I).

3.2. Characteristics of soil

The soil of the experiment was carried out in a medium high land belonging to the Modhupur tract under the agro ecological zone (AEZ) 28. The soil texture was silt loam, non-calcareous, dark grey soil of Tejgaon soil series with a p^H 6.7. Soil samples of the experimental pots were collected from a depth of a 0 to 30 cm before conducting the experiment and analyzed in the Soil Resources Development Institute (SRDI), Farmgate, Dhaka. (Appendices- II).

3.3. Climate

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 35.10^0C and the average minimum temperature was 30.40^0C. 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. (Appendices-III).

3.4. Planting materials used for experiment

Ten genotypes of tomato were used for the present research work. Seeds of all the genotypes were collected from BARI (Bangladesh Agricultural Research Institute), Gazipur.

Table 1: Name and origin of 10 tomato genotypes used in the present study

Sl. No.	Genotypes No.	Name/Acc No. (BD)	Origin
1	G_1	Local Jessore-3	PGRC,BARI
2	G_2	BARI Tomato-3	HRC, BARI
3	G_3	BARI Tomato-7	HRC, BARI
4	G_4	BARI Tomato-9	HRC, BARI
5	G_5	Local Jessore-2	PGRC, BARI
6	G_6	BD-7276	PGRC, BARI
7	G_7	BD-7281	PGRC, BARI
8	G_8	BD-7290	PGRC, BARI
9	G_9	BD-7754	PGRC, BARI
10	G_{10}	BD-7762	PGRC, BARI

PGRC=Plant Genetic Research Centre, HRC= Horticulture Research Centre. BARI=Bangladesh Agricultural Research Institute

3.5. Treatments of the experiment

Treatment was considered as following-

T_1= Local Jessore-3

T_2= BARI Tomato-3

T_3= BARI Tomato-7

T_4= BARI Tomato-9

T_5= Local Jessore-2

T_6= BD-7276

T_7= BD-7281

T_8= BD-7290

T_9= BD-7754

T_{10}= BD-7762

3.6. Experimental design

The experiment was laid out in a complete randomized design (CRD) with six replications. There were 10 treatments combinations. The total numbers of unit pots were 60. Each treatment contains 6 pots.

3.7. Growing of tomato seedlings

Tomato seedlings were grown in a seedbed. Soils were mixed with the desired amount of compost and fertilizers followed by sterilized and poured in seedbed as per requirement. The seeds were sown in individual row on 6 October 2014 and care was taken so that germination and seedlings development could be proper.

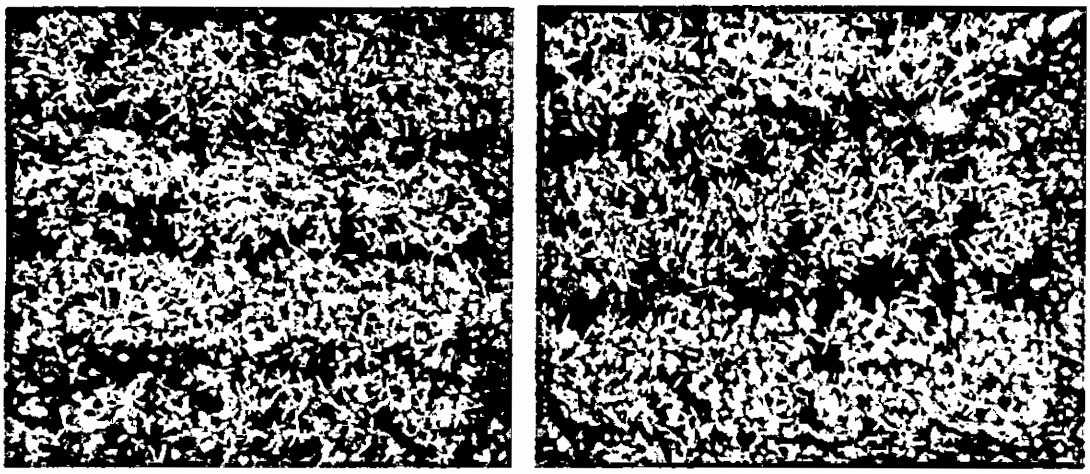

Figure 1: Seedlings on seedbed.

3.8. Pot preparation and transplanting of seedlings

The pots were filled up with the soil with in ratio 1:1:1 (Sand: Silt: Clay) collected from the SAU Farm. Before making the soil ready for the pots, a natural sterilization was given to the soil. The soil was exposed for proper sun drying for 7 days to make them pathogen free. After pot preparation, only one healthy seedling was transplanted in each pot. The pot to pot distance was maintained.

Figure 2: Transplanted seedlings on pot.

3.9. Manure and fertilizer management

The entire quantity of cow dung (20 kg) was applied to the soil after being sterilized. Urea, triple super phosphate (TSP), murate of potash (MoP), zinc sulphate and boron were given at the rate of 5kg, 2kg, 1.5kg, 0.75kg and 0.60 kg, respectively. TSP, Zinc sulphate, boron were given as basal during final pot preparation.

3.10. Intercultural operations

3.10.1. Gap filling

After one week of transplanting, a minor gap filling was done where it is necessary using the seedlings from the same source.

3.10.2. Weeding

During plant growth period three hand weeding were done, first weeding was done at 20 DAT followed by second and third weeding at 40 and 60 DAT respectively.

3.10.3. Application of irrigation water and drainage

Irrigation water was added to each pot according to the critical stage. The experimental pots were irrigated through watering cans. Stagnant water was effectively drained out at the time of heavy rains.

3.11. Identification of *Tomato yellow leaf curl virus (TYLCV)*

Identification of the virus was done through visual observation on the basis of typical symptoms of *TYLCV* infection like upward curling, cupping, with or without marginal chlorosis, smaller leaflets and stunting of plant Sinistera *et al.,* (2000). The incidence of *TYLCV* was calculated by counting the plants inspected everyday on the basis of the appearance of symptoms typical to the virus starting from the transplanting date. The plants were inspected every day morning to note the appearance and development of the symptoms. It was continued up to harvesting.

3.12. Parameters assessed

60 plants were selected and harvested carefully from the total experimental site and mean data on the following parameters were recorded-

- Number of leaves per plant
- Number of branch per plant
- Number of flowers per plant
- Number of fruits per plant
- Fruit diameter
- Single fruits weight
- Yield
- Plant height
- Chlorophyll content in leaves
- Root length
- Root width
- Root weight
- % Disease incidence
- Net assimilation rate
- Inter cellular CO_2 concentration
- Respiration rate per plant

3.13. Collection of data

For data collection on different physiological and morphological parameters from the selected plants, different measures were taken. Data over the parameters were taken in the following ways-

3.13.1. Number of leaves per plant

Number of leaves of plants from each pot at 20, 40 and 60 days after transplanting (DAT) was recorded. Only the smallest young leaves at the growing point of the plant were excluded from counting.

3.13.2. Number of branch per plant

Number of branch of plants from each pot at 20, 40 and 60 days after transplanting (DAT) was recorded. As there were no young branch left at the maturity point of the plant, those were excluded from counting. Calculating the total number of branches, the total number was recorded.

3.13.3. Number of flowers per plant

Only the healthy flowers from the plants were counted at 20, 40 and 60 DAT. The average number of flowers from each plant was recorded.

3.13.4. Number of fruits per plant

Mean number of tomato fruits of plants from each pot as per treatment was recorded.

3.13.5. Fruit diameters

Mean diameter of collected tomatoes from each pot as per treatment were measured in centimeter (cm) with the help of a slide calipers.

3.13.6. Single fruits weight

Single fruits weight of plants from each pot was measured in gram (g) with the help of digital balance.

3.13.7. Yield

The average yield of per plant was measured in kg.

3.13.8. Plant height

Average plant height of plants from each pot was recorded at 20, 40 and 60 days after transplanting (DAT). It was measured with the help of a meter scale from the ground level to the tip of the longest stem in centimeter (cm).

3.13.9. Chlorophyll content in leaves

The average chlorophyll content in the leaves of the plants was recorded with the help of "S-pad", which is an advanced technology to directly measure the chlorophyll content in plant leaf at 20, 40 and 60 days after transplanting (DAT).

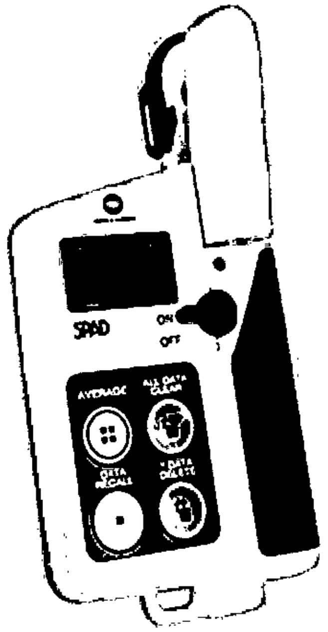

Figure 3: S-pad machine to collect chlorophyll content in leaves.

3.13.10. Root length

Root lengths of collected roots after harvesting from each pot were measured in centimeter (cm) with the help of a slide calipers.

3.13.11. Root width

Root widths of collected roots after harvesting from each pot were measured in centimeter (cm) with the help of a slide calipers.

3.13.12. Root weight

Root weight of collected roots after harvesting from each pot was measured in gram (g) with the help of digital balance.

3.13.13. Disease incidence

The disease incidence was expressed in percentage on the basis of stage as well as total i.e., average of three stages.

The percent disease incidence was calculated using the following formula:

$$\% \text{ Disease incidence} = \frac{X_1}{X} \times 100$$

Where,

X= Total number of plants

X_1= Number of plants infected

The disease incidence reaction was assessed by using the following disease rating scale-

Table 2: Disease rating scale of *TYLCV*

Rating Scale		Incidence Range (%)
0	Immune	0 %
1	Highly resistant	1-10 %
2	Moderate resistant	11-25 %
3	Tolerant	26-50 %
4	Moderate susceptibility	51-60 %
5	Susceptibility	61-70 %
6	High susceptibility	71-100

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

3.13.14. Net assimilation rate per plant

The average net assimilation rate was recorded from the plants by using "LC-Pro+" machine at 20, 40 and 60 days after transplanting (DAT).

3.13.15. Intercellular CO_2 concentration per plant

The average intercellular CO_2 concentration was recorded from the plants by using "LC-Pro+" machine at 20, 40 and 60 days after transplanting (DAT).

3.13.16. Respiration rate per plant

The average respiration rate was recorded from the plants by using "LC-Pro+" machine at 20, 40 and 60 days after transplanting (DAT).

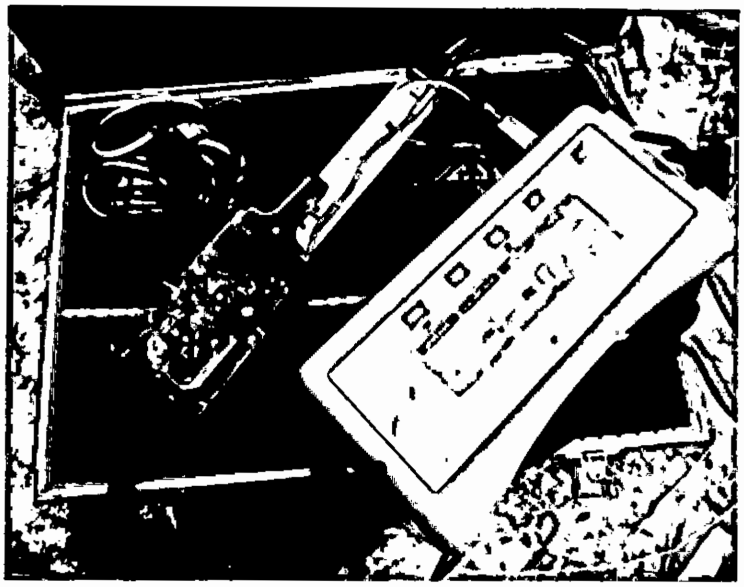

Figure 4: LC-pro+ machine to collect physiological data.

3.14. Statistical analysis of data

The data were analyzed statistically by using the analysis of variance (ANOVA) and MSTAT-C software for proper interpretation. The mean value was compared according to Duncan's Multiple Range Test (DMRT) at 5% level of significance. Tables, bar diagram, linear graphs and photographs were used to present the data as and when required.

Chapter 4

RESULTS

RESULTS

This chapter includes the experimental results. The evaluation of tomato genotypes against *Tomato yellow leaf curl virus (TYLCV)* of some selected tomato varieties viz. BARI tomato-3, BARI tomato-7, BARI tomato-9, Local jessore-2, Local jessore-3 and lines viz. BD-7276, BD-7281, BD-7290, BD-7754, BD-7762 under pot condition. Results were compiled based on morphological and physiological parameters and on % of disease incidence.

4.1. The morphological features which are identical, in-relation to yield and yield contributing character in tomato against *Tomato yellow leaf curl virus (TYLCV)*

4.1.1. Number of leaves and branch per plant of selected tomato genotypes

The maximum number of leaves per plant was obtained in the variety BARI Tomato-9 (72.00) followed by variety Local Jessore-2 (69.00) and lines BD-7276 (68.67), BD-7281 (67.00), BD-7754 (65.00). The minimum number of leaves was obtained in variety Local Jessore-3 (47.67) preceded by BARI Tomato-7 (52.00), BD-7290 (62.00), BD-7762 (63.00) and BARI Tomato-3 (64.00). Among the varieties and lines BARI Tomato-9 (72.00) and Local Jessore-3 (47.67) are statistically different. There was no significant difference between the variety BARI Tomato-3 (64.00) and Local Jessore-2 (69.00) and among the lines BD-7276 (68.67), BD-7281 (67.00), BD-7290 (62.00), BD-7754 (65.00) and BD-7762 (63.00).

The maximum number of branch per plant was recorded in the variety BARI Tomato-9 (10.67) followed by BD-7276 (9.33), BD-7762 (9.00), Local Jessore-2 (9.00), BD-7281 (8.67). The minimum number of branch per plant was found in Local Jessore-3 (6.00) preceded by BARI Tomato-7 (6.33), BD-7290 (7.67), BD-7754 (7.67), BARI Tomato-3 (8.33). Among the varieties and lines it has been showed that variety BARI Tomato-9 (10.67), BARI Tomato-3 (8.33), Local Jessore-2 (9.00) and lines BD-7276 (9.33), BD-7762 (9.00) and BD-7281 (8.67) were statistically identical. BARI Tomato-9 (10.67) and Local Jessore-3 (6.00) were statistically different. The results are presented in Table-3.

Table 3: Number of leaves and branch per plant of selected tomato genotypes against *Tomato yellow leaf curl virus (TYLCV)*

Variety	Leaves/Plant	Branch/Plant
Local Jessore – 3	47.67 c	6.00 d
BARI Tomato – 3	64.00 abc	8.33 abcd
BARI Tomato – 7	52.00 bc	6.33 cd
BARI Tomato – 9	72.00 a	10.67 a
Local Jessore – 2	69.00 ab	9.00 ab
BD – 7276	68.67 ab	9.33 ab
BD – 7281	67.00 ab	8.67 abc
BD – 7290	62.00 abc	7.67 bcd
BD – 7754	65.00 abc	7.67 bcd
BD – 7762	63.00 abc	9.00 ab
CV (%)	14.79	15.46
LSD Value$_{(0.05)}$	15.88	2.17

4.1.2. Number of flowers and fruits per plant of selected tomato genotypes

The maximum number of flowers per plant was obtained in the variety BARI Tomato-9 (68.33) followed by BD-7754 (65.33), BD-7290 (63.00), Local Jessore-2 (62.67), BARI Tomato-3 (62.67). The minimum number of flowers per plant was found in the variety Local Jessore-3 (51.67) preceded by BARI Tomato-7 (53.67), BD-7762 (59.33), BD-7281 (60.33), BD-7276 (61.67). Among the varieties and lines it has been showed that variety BARI Tomato-9 (68.33) and Local Jessore-3 (51.67) are statistically different.

There was no significant difference in BD-7754 (65.33), BD-7290 (63.00), BD-7276 (61.67), BD-7281 (60.33), BD-7762 (59.33), Local Jessore-2 (62.67) and BARI Tomato-3 (62.67).

The maximum number of fruits per plant was obtained in the variety BD-7290 (41.33) and BD-7762 (41.33) followed by Local Jessore-3 (39.00), BD-7276 (38.67), Local Jessore-2 (37.67). The minimum number of fruits per plant was recorded in BARI Tomato-7 (29.33) preceded by BD-7754 (31.67), BARI Tomato-3 (32.00), BARI Tomato-9 (36.33), BD-7281 (36.33). Among the varieties and lines the value of line BD-7290 (41.33) and variety BARI Tomato-7 (29.33) were statistically significant. There was no significant difference between lines BD-7290 (41.33), BD-7762 (41.33), BD-7281 (36.33), BD-7276 (38.67) and varieties Local Jessore-3 (39.00), Local Jessore-2 (37.67), BARI Tomato-9 (36.33). The results are presented in figure 5.

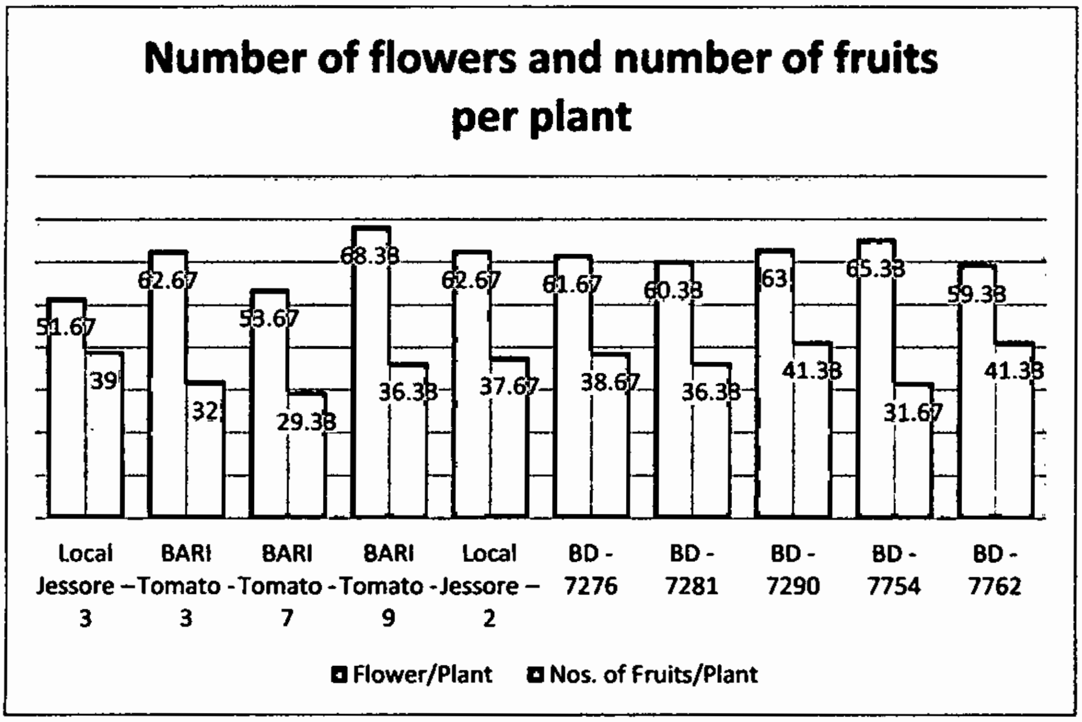

Figure 5: Graphical presentation on number of flowers and fruits per plant of selected varieties and lines against *Tomato yellow leaf curl virus (TYLCV)*.

4.1.3. Fruits diameter (cm), single fruits weight (g) and yield (kg) of different tomato genotypes

The maximum number of fruits diameter was obtained in the variety BARI Tomato-9 (5.03 cm) followed by BD-7754 (4.57 cm), Local Jessore-3 (4.30 cm), BARI Tomato-3 (4.13 cm), Local Jessore-2 (4.03 cm). The minimum number of fruits diameter was obtained in the BD-7276 (2.70 cm) preceded by BD-7762 (3.13 cm), BARI Tomato-7 (3.27 cm), BD-7290 (3.30 cm), BD-7281 (3.70 cm). Among the varieties and lines it has been showed that BARI Tomato-9 (5.03 cm), BARI Tomato-3 (4.13 cm) and BD-7281 (2.70 cm) are statistically different. There was no significant difference in BD-7281 (3.70 cm), BD-7290 (3.30 cm), BD-7762 (3.13 cm) and BARI Tomato-7 (3.27 cm). There was one line BD-7754 (4.57 cm) and two varieties Local Jessore-3 (4.30 cm), Local Jessore-2 (4.03 cm) were also statistically significant.

The maximum number of single fruits weight was recorded in the variety BARI Tomato-9 (69.33 g) followed by BARI Tomato-7 (63.33 g), BARI Tomato-3 (60.67 g), BD-7754 (55.33 g), BD-7281 (37.33 g). The minimum number of single fruits weight was recorded in the variety BD-7762 (26.33 g) preceded by BD-7290 (27.33 g), Local Jessore-3 (32.33 g), Local Jessore-2 (32.33 g), BD-7276 (33.00 g). Among the varieties and lines it had been showed that variety BARI Tomato-9 (69.33 g) and lines BD-7754 (55.33 g), BD-7281 (37.33 g), BD-7762 (26.33 g) were statistically different. There was no significant difference in BD-7290 (27.33 g), BD-7276 (33.00 g), Local Jessore-3 (32.33 g) and Local Jessore-2 (32.33 g).

The highest yield per plant was recorded in the variety BARI Tomato-9 (2.70 kg) followed by BARI Tomato-3 (1.95 kg), BARI Tomato-7 (1.89 kg), BD-7754 (1.65 kg), BD-7276 (1.60 kg). The lowest yield was recorded in Local Jessore-3 (1.09 kg) preceded by BD-7762 (1.20 kg), Local Jessore-2 (1.33 kg), BD-7290 (1.42 kg), BD-7281 (1.52 kg). Among the lines and varieties, the value of varieties BARI Tomato-9 (2.70 kg), BARI Tomato-3 (1.95 kg), Local Jessore-3 (1.09 kg) and line BD-7281 (1.52 kg) were statistically different. There was no significant difference in BD-7754 (1.65 kg), BD-7276 (1.60 kg), BD-7290 (1.42 kg) and Local Jessore-2 (1.33 kg). The results are presented in Table-4.

Table 4: Fruits diameter (cm), single fruits weight (g) and yield (kg) per plant of different selected varieties and lines against *Tomato yellow leaf curl virus (TYLCV)*

Variety	Fruits diameter (cm)	Single fruit's weight (g)	Yield (kg)
Local Jessore – 3	4.30 abc	32.33 de	1.09 f
BARI Tomato – 3	4.13 bc	60.67 bc	1.95 b
BARI Tomato – 7	3.27 def	63.33 ab	1.89 bc
BARI Tomato – 9	5.03 a	69.33 a	2.70 a
Local Jessore – 2	4.03 bcd	32.33 de	1.33 def
BD – 7276	2.70 f	33.00 de	1.60 cd
BD – 7281	3.70 cde	37.33 d	1.52 d
BD – 7290	3.30 def	27.33 e	1.42 de
BD – 7754	4.57 ab	55.33 c	1.65 bcd
BD – 7762	3.13 ef	26.33 e	1.20 ef
CV (%)	10.93	9.48	10.50
LSD Value$_{(0.05)}$	0.71	7.06	0.29

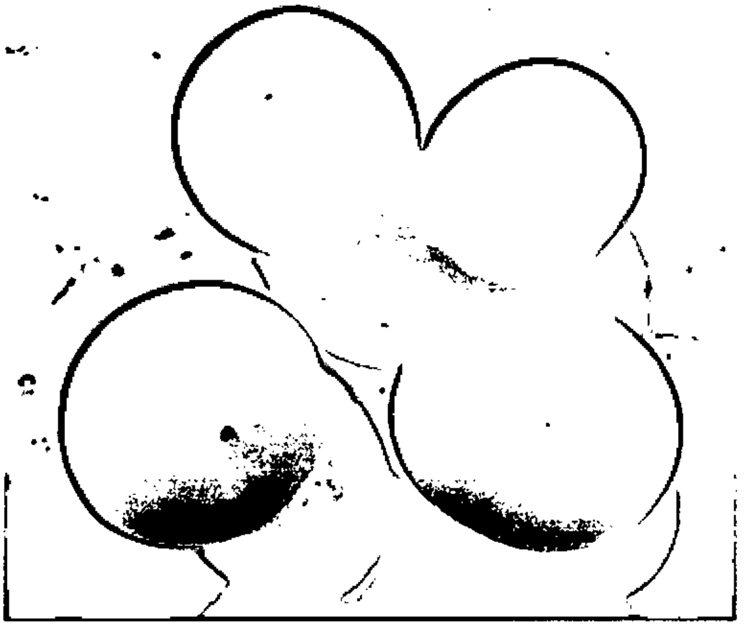

Figure 6: The best fruits among the varieties & lines, BARI Tomato-9.

Figure 7: The best fruits among the lines, BD-7754.

4.2. The features related to the growth and growth contributing character in tomato genotypes against *Tomato Yellow leaf curl virus (TYLCV)*

4.2.1. Plant height (cm) and net chlorophyll content per plant (µ mol m^{-2} s^{-1}) of tomato genotypes

The highest plant height was recorded in the variety BD-7290 (85.67 cm) followed by BD-7762 (84.67 cm), BD-7281 (83.67 cm), BD-7276 (82.33 cm), BD-7754 (80.33 cm). The lowest plant height was recorded in the variety BARI Tomato-9 (52.33 cm) preceded by Local Jessore-3 (67.33 cm), BARI Tomato-7 (72.67 cm), Local Jessore-2 (77.00 cm), BARI Tomato-3 (78.33 cm). Among the varieties and lines it has been showed that variety BARI Tomato-9 (52.33 cm) was significantly different from the other all varieties and lines. The all other lines and varieties were significantly identical.

The net chlorophyll content in the leaves of the plant was measured by the "S-Pad" machine. The highest net chlorophyll content per plant was recorded in the BARI Tomato-9 (65.17) followed by BD-7281 (54.83), BARI Tomato-3 (53.53), BD-7754 (53.10), Local Jessore-2 (52.50). The lowest net chlorophyll content per plant was recorded in Local Jessore-3 (40.20) preceded by BD-7276 (47.80), BD-7762 (50.50), BARI Tomato-7 (50.53), BD-7290 (52.43). Among the lines and varieties the value of variety BARI Tomato-9 (65.17), Local Jessore-3 (40.20) and lines BD-7281 (54.83), BD-7276 (47.80) were statistically different. There was no significant difference between BARI Tomato-3 (53.53), Local Jessore-2 (52.50), BARI Tomato-7 (50.53), BD-7754 (53.10), BD-7762 (50.50) and BD-7290 (52.43). The results are presented in the Table-5.

Table 5: Plant height (cm) and net chlorophyll content (μ mol m^{-2} s^{-1}) per plant of different selected varieties and lines against *Tomato yellow leaf curl virus (TYLCV)*

Variety	Plant height (cm)	Chlorophyll content ($\mu mol m^{-2} s^{-1}$)
Local Jessore – 3	67.33 ab	40.20 e
BARI Tomato – 3	78.33 a	53.53 bc
BARI Tomato – 7	72.67 a	50.53 cd
BARI Tomato – 9	52.33 b	65.17 a
Local Jessore – 2	77.00 a	52.50 bc
BD – 7276	82.33 a	47.80 d
BD – 7281	83.67 a	54.83 b
BD – 7290	85.67 a	52.43 bc
BD – 7754	80.33 a	53.10 bc
BD – 7762	84.67 a	50.50 cd
CV (%)	12.33	3.83
LSD $Value_{(0.05)}$	16.05	3.39

4.2.2. Root length (cm), root width (cm) and root weight (g) of selected tomato genotypes

The highest root length was observed in the variety BARI Tomato-9 (24.50 cm) followed by BARI Tomato-3 (19.33 cm), BARI Tomato-7 (17.50 cm), BD-7754 (17.50 cm), BD-7276 (16.67 cm). The lowest root length was observed in the variety BD-7290 (14.33 cm) preceded by Local Jessore-3 (15.33 cm), BD-7281 (16.00 cm), Local Jessore-2 (16.17 cm), BD-7762 (16.33 cm). Among the lines and varieties the value of variety BARI Tomato-9 (24.50 cm) was significantly different from all other varieties and lines. There was no significant difference between varieties BARI Tomato-3 (19.33 cm), BARI Tomato-7 (17.50 cm), Local Jessore-3 (15.33 cm), Local Jessore-2 (16.17 cm) and lines BD-7754 (17.50 cm), BD-7276 (16.67 cm), BD-7290 (14.33 cm), BD-7281 (16.00 cm) and BD-7762 (16.33 cm).

The highest root width was recorded in the variety BARI Tomato-9 (16.33 cm) followed by BD-7281 (15.83 cm), BARI Tomato-3 (15.33 cm), BD-7762 (15.17 cm), BD-7290 (15.00 cm). The lowest root width was recorded in the variety Local Jessore-3 (12.67 cm) preceded by BARI Tomato-7 (13.33 cm), BD-7276 (13.50 cm), BD-7754 (13.67 cm), Local Jessore-2 (14.33 cm). All the lines and varieties were statistically identical.

The highest root weight was observed in the variety BARI Tomato-9 (17.00 g) followed by BD-7762 (16.67 g), BARI Tomato-7 (13.67 g), BD-7290 (13.33 g), Local Jessore-2 (13.00 g). The lowest root weight was observed in the variety Local Jessore-3 (8.67 g) and BARI Tomato- 3 (8.67 g) preceded by BD-7281 (11.33 g), BD-7754 (12.33 g), BD-7276 (12.33 g). Among the lines and varieties the value of variety BARI Tomato-9 (17.00 g) and Local Jessore-3 (8.67 g) was statistically different. There was no significant difference between BD-7762 (16.67 g), BD-7281 (11.33 g), BD-7754 (12.33 g), BD-7276 (12.33 g), BD-7290 (13.33 g), BARI Tomato-7 (13.67 g) and Local Jessore-2 (13.00 g). The results are presented in the Table-6.

Table 6: Root length (cm), root width (cm) and root weight (g) per plant of different selected varieties and lines against *Tomato yellow leaf curl virus (TYLCV)*

Variety	Root length (cm)	Root width (cm)	Root weight (g)
Local Jessore -3	15.33 b	12.67 a	8.67 b
BARI Tomato - 3	19.33 b	15.33 a	8.67 b
BARI Tomato - 7	17.50 b	13.33 a	13.67 ab
BARI Tomato - 9	24.50 a	16.33 a	17.00 a
Local Jessore – 2	16.17 b	14.33 a	13.00 ab
BD – 7276	16.67 b	13.50 a	12.33 ab
BD – 7281	16.00 b	15.83 a	11.33 ab
BD – 7290	14.33 b	15.00 a	13.33 ab
BD – 7754	17.50 b	13.67 a	12.33 ab
BD - 7762	16.33 b	15.17 a	16.67 a
CV (%)	15.21	14.06	24.86
LSD Value$_{(0.05)}$	4.49	3.47	5.37

4.2.3. Correlation between chlorophyll content (μ mol m^{-2} s^{-1}) and yield (kg)

Correlation study was done to establish the relationship between the chlorophyll content (μ mol m^{-2} s^{-1}) and yield (kg) of infected tomato plants. From the study it was revealed that significant correlation was observed between the two parameters (Figure -8). It was evident from the Figure -8 that the equation $y = 0.0604x - 1.51$ gave a good fit to the data and the co-efficient of determination ($R^2 = 0.6443$) showed that, fitted regression line had a significant regression co-efficient. From these relations it can be concluded that the yield of tomato was strongly ($R^2 = 0.6443$) as well as positively (slope= 0.823) correlated with the chlorophyll content of tomato plants.

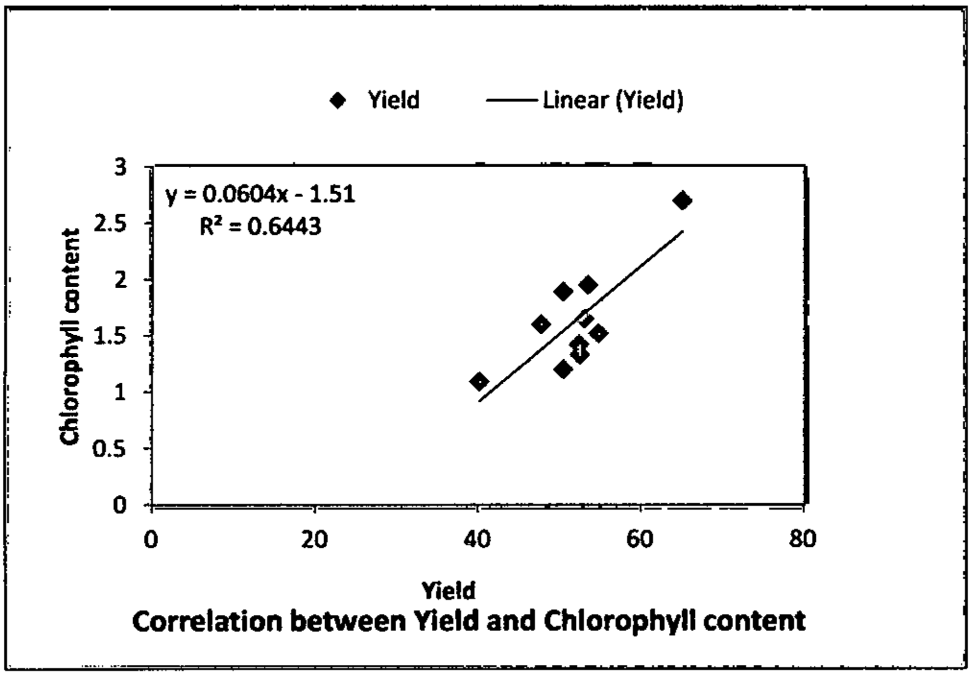

Figure 8: Relationship between Chlorophyll content and Yield.

4.3. Reaction of selected varieties and lines of tomato against *Tomato Yellow Leaf Curl Virus (TYLCV)*

The effect of different varieties and lines on incidence of tomato leaf curl disease was observed based on disease rating scale of *TYLCV* shown in Table 2 in materials and method section. In case of varieties and lines, the highly susceptible variety and lines was found in Local jessore-3, BD-7281, BD-7754 and BD-7762. On the other hand one variety showed immune BARI Tomato-9. Among the varieties and lines one tolerant line was found BD-7276. Four susceptible varieties were found these are BARI Tomato-3. BARI Tomato-7, Local jessore-2 and BD-7290. This result is presented in Table 7.

Table 7: Reaction of selected varieties and lines of tomato against *Tomato Yellow Leaf Curl Virus (TYLCV)*

Variety/Lines	Disease incidence	Level of resistance/ susceptibility
Local Jessore – 3	100%	Highly Susceptible
BARI Tomato – 3	66.67%	Susceptible
BARI Tomato – 7	66.67%	Susceptible
BARI Tomato – 9	00%	Immune
Local Jessore – 2	66.67%	Susceptible
BD – 7276	33.33%	Tolerant
BD – 7281	100%	Highly Susceptible
BD – 7290	66.67%	Susceptible
BD – 7754	100%	Highly Susceptible
BD – 7762	100%	Highly Susceptible

Figure 9: Highly resistant variety BARI Tomato-9.

Figure 10: Highly susceptible varieties.

4.4. The physiological features which are identical, in-relation to plant growth and development in tomato against *Tomato Yellow leaf curl virus (TYLCV)*

The physiological features like net assimilation rate, carbon-di-oxide concentration and respiration rate are very much important in-response to plant growth and development. The data over these parameters was taken by using the advanced "LC-Pro^{+}" machine.

4.4.1. Net assimilation rate (g $m^{-2} \cdot d^{-1}$), intercellular carbon-di-oxide concentration (ppm) and respiration rate (ppt/s) of selected tomato genotypes

The maximum net assimilation rate per plant was recorded in BARI Tomato-9 (1.03) followed by BD-7281 (0.90), BARI Tomato-3 (0.83), BARI Tomato-7 (0.68), BD-7276 (0.67). The minimum net assimilation rate per plant was recorded in Local Jessore-3 (0.33) preceded by Local Jessore-2 (0.47), BD-7754 (0.51), BD-7762 (0.56), BD-7290 (0.56). Among the varieties and lines it has been showed that variety BARI Tomato-9 (1.03) and Local Jessore-3 (0.33) was statistically different. There was no significant difference in BARI Tomato-3 (0.83), BARI Tomato-7 (0.68), Local Jessore-2 (0.47), BD-7754 (0.51), BD-7762 (0.56), BD-7290 (0.56), BD-7281 (0.90) and BD-7276 (0.67).

The maximum intercellular carbon-di-oxide concentration per plant was recorded in BARI Tomato-9 (37.33) followed by BD-7281 (32.00), BD-7754 (29.33), Local Jessore-2 (28.33), BARI Tomato-7 (27.33). The minimum intercellular carbon-di-oxide concentration per plant was recorded in Local Jessore-3 (16.67) preceded by BD-7762 (25.33), BARI Tomato-3 (26.33), BD-7276 (26.33), BD-7290 (26.67). Among the varieties and lines the value of variety BARI Tomato-9 (37.33) and Local Jessore-3 (16.67) were significantly different. There was no significant difference in BD-7281 (32.00), BD-7754 (29.33), BD-7762 (25.33), BD-7276 (26.33), BD-7290 (26.67), Local Jessore-2 (28.33), BARI Tomato-7 (27.33) and BARI Tomato-3 (26.33).

The highest respiration rate per plant was recorded in the BARI Tomato-9 (1.25) followed by BARI Tomato-7 (0.69), BD-7762 (0.62), Local Jessore-2 (0.62), BARI Tomato-3 (0.58). The lowest respiration rate per plant was recorded in the Local Jessore-3 (0.33) preceded by BD-7281 (0.43), BD-7276 (0.45), BD-7290 (0.51), BD-7754 (0.53). Among the lines and varieties the value of variety BARI Tomato-9 (1.25), BARI

Tomato-7 (0.69) and Local Jessore-3 (0.33) are statistically different. There was no significant difference in the variety Local Jessore-2 (0.62), BARI Tomato-3 (0.58) and line BD-7290 (0.51), BD-7762 (0.62), BD-7754 (0.53). The results are presented in Table-8.

Table 8: Net assimilation rate (g m^{-2} d^{-1}), intercellular carbon-di-oxide concentration (ppm) and respiration rate (ppt/s) per plant of different selected varieties and lines against *Tomato yellow leaf curl virus (TYLCV)*

Variety	Net assimilation rate (g m^{-2} d^{-1})	Intercellular CO_2 concentration (ppm)	Respiration rate (ppt/s)
Local Jessore – 3	0.33 c	16.67 c	0.33 f
BARI Tomato – 3	0.83 ab	26.33 b	0.58 bcd
BARI Tomato – 7	0.68 abc	27.33 b	0.69 b
BARI Tomato – 9	1.03 a	37.33 a	1.25 a
Local Jessore – 2	0.47 bc	28.33 ab	0.62 bc
BD – 7276	0.67 abc	26.33 b	0.45 def
BD – 7281	0.90 ab	32.00 ab	0.43 ef
BD – 7290	0.56 bc	26.67 b	0.51 cde
BD – 7754	0.51 bc	29.33 ab	0.53 cde
BD – 7762	0.56 bc	25.33 b	0.62 bc
CV (%)	35.19	17.70	13.26
LSD $Value_{(0.05)}$	0.39	8.31	0.13

Chapter 5

DISCUSSIONS

DISCUSSION

Tomato (*Solanum lycopersicum*) belonging to the family Solanaceae, is one of the important, popular and nutritious vegetables grown in Bangladesh and cultivated in all parts of the country Haque *et al.,* (1999). Tomato contains a number of nutritive elements almost double compared to fruit apple and shows superiority with regard to food values (Barman, 2007). Food value of tomato is greatly dependent on its chemical composition such as dry matter, terrible acidity, total sugar, total soluble solids and ascorbic acid etc. Studies in USA indicate that flavor and taste of tomato are related to free sugars, organic acids and sugar acid ratios Kader *et al.,* (1978). It is an important condiment in most diets and a very cheap source of vitamins. Tomatoes help wash out the toxins and other contaminants from the body and act as a gentle stimulant for kidneys. Tomato is also effective in curing morning sickness, excessive gas formation in the intestine, gastro-intestinal diseases, indigestion etc. Tomato is also helpful in preventing joint pain problems and the respiratory disorder as well (Friedman, 2013). The yield of tomato in our country is not satisfactory enough in comparison to requirement Aditya *et al.,* (1999). The yield of tomato depends on numerous factors including genotype or the variety. Plant breeders have produced hundreds of tomato varieties to suit every climate, garden site and taste. Various cultivars produce fruit that range in size from small marbles to giant grapefruits (Benton, 2008). Breeding over the past 50 years has substantially changed the tomato plant and its fruit characteristics. Varieties available today for use by both the commercial and home gardener have a wide range of plant characteristics. Some varieties may remain favorable for many years while others might be supplanted by newer cultivars after a few seasons (McAvoy and Ozores-Hampton, 2010). By this time BARI released a good number of varieties. *Tomato yellow leaf curl virus* (*TYLCV*) is supposed to be the major constrain for the lower yield of tomato in Bangladesh. This virus causes devastating effects on tomato production, because most of the plant gets infected in the field level when *TYLCV* attacks in the field. Akanda *et al.*, (1991) reported about 100% infection of *Tomato Yellow Leaf Curl Virus (TYLCV)* in the tomato field resulting yield loss as high as 90%. So far there are no varieties are reported in Bangladesh to resistant against *TYLCV*. The main objective of this study was to evaluate the resistance tomato genotypes against *Tomato Yellow Leaf Curl Virus (TYLCV)*. The experiment was conducted at the farm of Horticulture, Sher-e-Bangla Agricultural University (SAU), Dhaka-1207, Bangladesh during the period from October 2014 to March 2015. The varieties used in the experiment were BARI Tomato-3, BARI Tomato-7, BARI Tomato-9, Local Jessore-2 and Local Jessore-3. The lines used in the experiment were BD-7276, BD-7281, BD-7290, BD-7762 and BD-7754.

5.1. Morphological features

The infected tomato plant shows different morphological responses against different morphological features. The yield of individual cultivars depends on the number of leaves, branch, flowers and fruits per plant. The lowest number of leaves per plant was recorded in variety Local Jessore-3 preceded by BARI Tomato-7, BD-7290 and BD-7762, BARI Tomato-3. The maximum number of leaves per plant was obtained in the variety BARI Tomato-9 followed by variety Local Jessore-2 and lines BD-7276, BD-7281 and BD-7754.

The minimum number of branch per plant was found in Local Jessore-3 preceded by BARI Tomato-7, BD-7290, BD-7754 and BARI Tomato-3. The maximum number of branch per plant was recorded in the variety BARI Tomato-9 followed by BD-7276, BD-7762, Local Jessore-2, BD-7281.

The lowest number of flowers/plant was recorded in the variety Local Jessore-3 preceded by BARI Tomato-7, BD-7762, BD-7281 and BD-7276. Whereas the highest number of flowers/plant were founded in BARI Tomato-9 followed by BD-7754, BD-7290, Local Jessore-2 and BARI Tomato-3.

The lowest number of fruits/plant was recorded in the BARI Tomato-7 preceded by BD-7754, BARI Tomato-3, BARI Tomato-9 and BD-7281. Whereas the highest number of fruits/plant were founded in the variety BD-7290 and BD-7762 followed by Local Jessore-3, BD-7276 and Local Jessore-2.

The lowest yield/plant was recorded in Local Jessore-3 preceded by BD-7762, Local Jessore-2, BD-7290 and BD-7281. Whereas the highest yield/plant was founded in the

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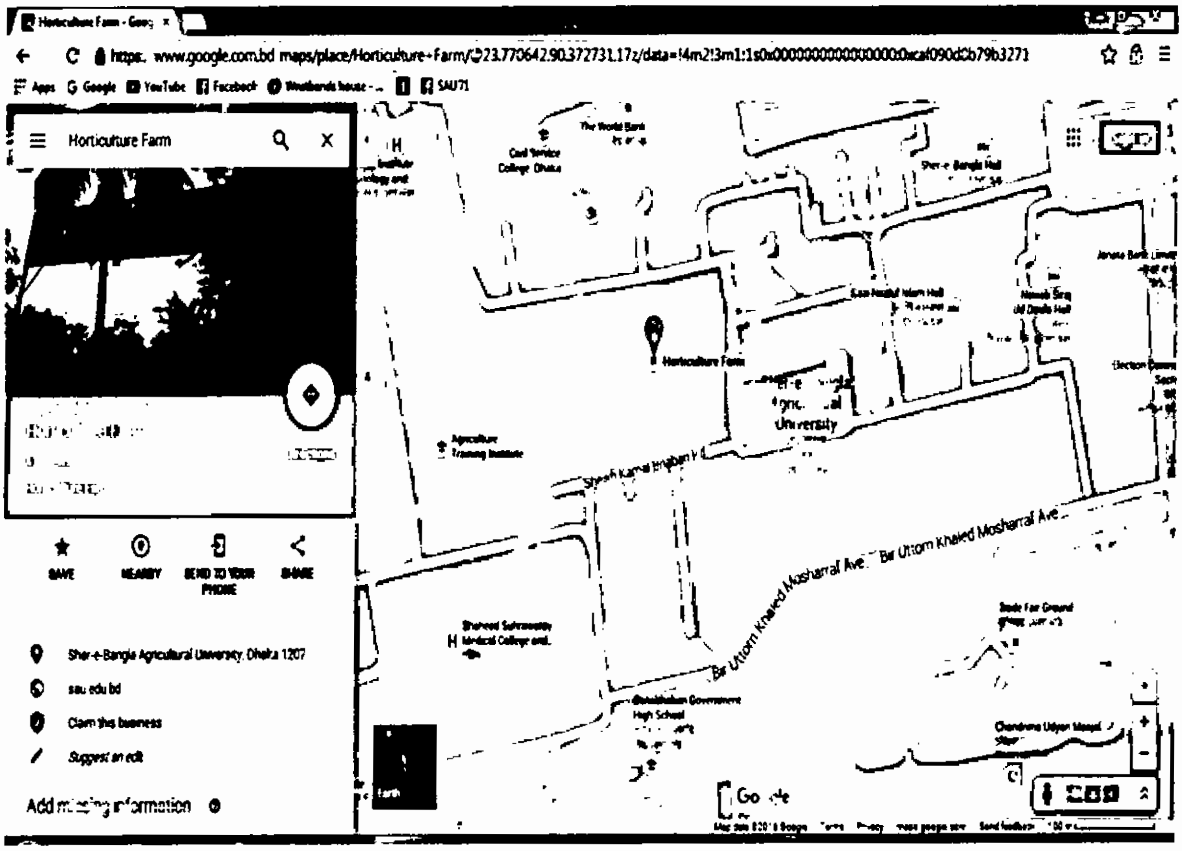
APPENDICES

APPENDICES

Appendix-I. Map showing the experimental site



Appendix-II. Physiochemical properties of soil, used in the experimental pots

Characteristics	Value
Particle size analysis	
% Sand	25.68
% Silt	53.85
% Clay	20.47
Textural class	Silty-loam
pH	5.8-7.1
Organic carbon (%)	0.31
Organic matter (%)	0.54
Total N (%)	0.027
Phosphorus(µg/g soil)	23.66
Exchangeable K (me/100 g soil)	0.60
Sulphur (µg/g soil)	28.43
Boron (µg/g soil)	0.05
Zinc (µg/g soil)	2.31

Source: Soil Resources Development Institute (SRDI), Dhaka-1207

Appendix-III. Monthly average relative humidity, maximum and minimum temperature, rainfall and sunshine hour of the experimental period (October 2014 to March 2015)

Month	Average RH (%)	Average Temperature (°C)		Total Rainfall (mm)	Average Sunshine hours
		Min.	Max.		
October	89	27.5	34.8	185.8	7.8
November	84	25.4	33.7	165.3	6.9
December	81	24.5	32.9	160.4	4.8
January	76	20.6	31.7	120.6	4.8
February	69	22.8	30.7	95.8	4.9
March	64	23.4	33.5	65.8	5.2

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207.