PERFORMANCE OF CHILLI VARIETIES AGAINST *CHILLI LEAF CURL VIRUS* (ChLCV)

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PERFORMANCE OF CHILLI VARIETIES AGAINST *CHILLI LEAF CURL VIRUS* (ChLCV)

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Dedicated To

My Beloved Parents, Elder Sisters and Respected Supervisor

DEPARTMENT OF PLANT PATHOLOGY

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CERTIFICATE

This is to certify that the thesis entitled "**PERFORMANCE OF CHILLI VARIETIES AGAINST *CHILLI LEAF CURL VIRUS* (ChLCV)"**submitted to the Faculty of Agriculture**,** Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE (MS)** in **PLANT PATHOLOGY,** embodies the results of a piece of bona fide research work carried out by **SAMSUN NAHER**, Registration no.**13-05579** under my supervision and guidance. No part of this 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, 2020

Dhaka, Bangladesh

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PERFORMANCE OF CHILLI VARIETIES AGAINST *CHILLI LEAF CURL VIRUS* (ChLCV)

ABSTRACT

Chilli (*Capsicum frutescens)* is the second most important and widely grown vegetable crop in the world belongs to the family *Solanaceae*. A field experiment was conducted at the central research field of Sher-e-Bangla Agricultural University, Dhaka, Bangladesh during October 2018 to March 2019. The study was aimed to evaluate varietal performance of chilli against (ChLCV) and to assess the disease incidence (%) and PDI of *Chilli leaf curl virus* (ChLCV) among different varieties. In this study, in total 8 varieties were considered *viz*. BARI-1, BARI-2, BARI-3, Kalomorich, Bograjhal, Bindumashi, Dhanua and Sufia. The field experiment was carried out in randomized complete block design (RCBD) with three replications. All the varieties showed significant influence on different assayed parameters in the test crop chilli under field condition against ChLCV. Among the varieties, three varieties (Bogra jhal, Bindumashi) were found Moderately Resistant, three varieties (BARI-2, BARI-1, Sufia) were showed Moderately Susceptible, two varieties (Kalomorich, Dhanua) were Susceptible. BARI-3 variety was found Highly Susceptible against ChLCV compared to other varieties. Due to chilli leaf curl disease evident morphological changes appeared in leaves, twigs, flowers and fruits. Yield of different chilli varieties was found negatively correlated with the disease incidence (%) of ChLCV. Whereas yield loss of chilli varieties positively correlated with disease incidence (%) of ChLCV. Considering the disease incidence, PDI, growth and yield contributing characters among the chilli varieties it was evident that no resistant variety was found. Whereas, two local variety Bogra jhal and Bindu mashi showed appreciable performance against ChLCV.

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LIST OF ACRONYMS

Acronyms	Full form
AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
et al.	And others
TSP	Triple Super Phosphate
MOP	Muriate of Potash
DAS	Days after sowing
g	Gram
Kg	Kilogram
Cm	Centimeter
No.	Number
%	Per cent
wt.	Weight
CV%	Percentage of coefficient of variance
LSD	Least Significant Difference
V	Variety
^0C	Degree Celsius
NS	Non-Significant
SAU	Sher-e-Bangla Agricultural University
SRDI	Soil Resources and Development Institute
FAO	Food and Agricultural Organization
M.S.	Master of Science
m^2	Meter squares

CHAPTER I

INTRUDUCTION

Chilli (*Capsicum frutescens*) is an important commercial spice as well as vegetable crop used worldwide. It is a bushy plant belongs to the family *Solanaceae*. It is one of the most popular and nutritious spice all over the world including Bangladesh. Chilli was originated in the American tropics and it has been propagated throughout the world including the tropics, subtropics, and also temperate regions (Pickersgill, 1997). Chilli contains approximately 20-27 species, 5 of which are domesticated namely *C. annuum, C. baccatum, C. chinense, C. frutescens, and C. pubescens*, and are cultivated in different parts of the world. Among the five species of cultivated, *C. annuum* is one of the most common cultivated crops worldwide (Tong and Bosland, 1999) followed by *C. frutescens* (Bosland and Votava, 2003). It can be cultivated in both summer and winter seasons in Bangladesh. As a winter crop, however, it is grown mostly in Cumilla, Noakhali, Faridpur, Barisal, Patuakhali, and Bogura.

Chilli is famous for its pleasant aromatic flavour pungency and high coloring substance having a medicinal value. The pungency in Chilli is due to the alkaloid capsaicin contained in the pericarp and placenta of fruits. Green chillies are rich source of vitamins especially vitamin A, C, B1, B2 (Saimbhi *et al*., 1977; Sayed and Bhagvandas, 1980) and is also rich in vitamin P (rutin), which is of immense pharmaceutical importance. Vitamin C is present in more quantities in fresh green chilies than citrus fruits and Vitamin A is high in red chilli than carrots (Osuna Garcia *et al*., 1998 and Martin *et al.,* 2004). Chilli contains 1.29 mg protein, 11 mg calcium, 870 I.U. vitamin A, 17.5 mg ascorbic acid, 0.06 mg thiamin, 0.03 mg riboflavin and 0.55 mg niacin per 100 g edible green fruit (Joshi and Singh, 1975). Chilli is found to be comprised of many plant derived chemical compounds that promote health. The strong spicy taste comes due to the presence of active alkaloid compounds capsaicin, capsanthin and capsorubin. Chilli contains steam volatile oils, carotenoids, fatty oils, vitamins, mineral elements etc., (Bosland and Votava, 2003). Chilli reduces

platelet aggregation; they also act as vasodilators stimulating blood circulation. Chilli helps in reducing calories by increasing thermo genesis. Chilli reduces risk of cancer by preventing carcinogens from binding to DNA. They contain pain alleviating salicyclate compounds. In addition, consumption of chilli itself releases endorphins in the body which help in reducing pain.

In 2017, world production of fresh green chillies and peppers was 33.2 million tonnes and Bangladesh contributes 5% of the global total (FAOSTAT, 2017). The top 10 chilli producing countries, India, China, Ethiopia, Myanmar, Mexico, Vietnam, Peru, Pakistan, Ghana and Bangladesh. Accounted for more than 85% of the world production in 2009. Chilli is raised over an area of 1832 thousand hectares in the World, with a World Area and Production production of 2959 thousand tons.). India is the largest producer of chillies in the world. Its annual production level covers around 1.1 million tons. India also has the maximum area dedicated to the production of chilli and largest producer with 36% share in global production (Sahitya *et al.,* 2014). In Madhya Panradesh chilli is grown under an area of 54.41thousand ha with production of 93.57 thousand MT and productivity 0.98 ton per ha (Anon., 2013). In Bangladesh, the crop is grown in an area of about 66,235 hectare and its annual production is about 52,215 metric tons which is very low as compared to that of other chili growing countries in the World and the average yield of green chilli is1.3ton/ha (BBS, 2017). The low yield of chili in Bangladesh may be attributed to a number of reasons such as unavailability of quality seeds of high yielding varieties, fertilizer management, disease and insect infestation and improper cultivation facilities.

In Bangladesh, the occurrence of diseases caused by fungi, bacteria and viruses greatly hampers the production of chilli. Chilli is known to suffer from as many as 83 different diseases (Anonymous, 1960 and 1966). This crop suffers from about more than 40 fungal diseases (Rangaswami, 1979). Among these fungi, bacteria and viruses which are the major limiting factors in successful crop production, such as, damping off (*Pythium*

aphanidermatum),(Choanephora capsici and *Colletotrichum capsici*), leaf blight *(Alternaria alternata* and *Cercospora capsici*), Powdery mildew (*Leveillula taurica*), bacterial leaf blight (*Xanthomonas compestris pv. vesicatoria*).

Among the diseases, viruses are known to cause different symptoms like mosaic, ring spot, curling, yellowing etc., on chilli and these symptoms result in heavy losses. Agents like thrips, mites and whiteflies have been reported to produce viral disease and losses. Chilli is known to be affected by forty two viruses. Twenty two of them reported to occur naturally and twenty viruses can infect on artificial inoculation. Among the twenty four viruses reported to occur naturally on chilli, eleven viruses have been reported from India, *viz., Cucumber mosaic virus* (Anjaneyulu and Appa Rao, 1967*), Tobacco leaf curl virus* (Hussan, 1932;`and Vasudeva, 1954), *Indian chilli mosaic virus* (McRae, 1924 and Jha and Rayachaudhuri, 1956) *Potato virus Y* (Jeyarajan and Ramakrishnan, 1961 and 1969; Joshi and Bhargava 1962) and *Potato virus X* (Ramakrishnan, 1959; and Rao *et al.*, 1970). Prasada Rao (1976) reported *Tobacco ring spot virus*, *Pepper veinal mottle virus* and *Pepper vein banding virus*, *Chilli leaf curl virus* (Senanayake *et al.*, 2006) and *Tomato leaf curl New Delhi virus* (Khan *et al.*, 2006 and Ilyas,1996). Among them. the Chilli leaf curl disease (ChLCD) which is occurred by *(Chilli leaf curl virus*) is a major limiting factor for chilli production in the Indian subcontinent and is invariably caused by begomoviruses (Briddon *et al.*, 2003; Senanayake *et al*., 2006; Shih *et al*., 2003).

The *chilli leaf curl virus* (ChiLCV) disease on chilli was first reported in Pakistan by Shih *et al.* (2003) and in India by Senanayake *et al.*, (2006). Leaf crinkle or leaf curl complex was observed on chillies by Hussain (1932.Leaf curl due to thrips results upward curling of leaves and interveina buckling. Irregular scraping of epidermis could also be seen (Johnpulie, 1939). The largest and most economically significant groups of plant viruses transmitted by *Bemisia tabaci* are the Gemini viruses. It can be transmitted by

mechanically, by vector, by seed. Transmission of number of strains of TMV by mechanical sap inoculation chilli was reported by several workers (Palm, 1923; Holmes, 1937; Nakata and Takimoto, 1940; Doolittle and Beecher, 1942; Kovachevsky, 1940, McKinney, 1952; Newton, 1954; Miller and Thornberr, y, 1958; Murakshi, 1960: Greenleaf *et al.*, 1964; Adsuar *et al.*, 1971; Ragozzino *et al.*, 1972; Bidari, 1982). Doolittle and Walker (1923), Doolittle and Zaumey`er (1953) reported CMV was mechanically sap transmitted. Hussan (1932) reported that the leaf curl or leaf crinkle occurring on chillies was caused by *Bemisia tabaci* (*Bemisia gossypiperda*). Mishra *et al.* (1963), Muniyappa and Veeresh (1984) reported the transmission of chilli leaf curl by means of whitefly (*Bemisia tabaci*). Inoculated chilli plants showed typical leaf curl symptoms after 2-6 weeks. The whitefly serves as the potential vector for the spread of *Chilli Leaf Curl Virus* causing severe damage to chilli crop. It causes damage by sucking cell sap, secreting the honey dews and transmits a number of viral diseases (Khan and Ahmed, 2005). Hence, whitefly infestation can cause severe and also transmitted *Chilli Yellow Leaf Curl Virus* performed transmission by it, and crop damage can be reached up to 100%.

The role of chilli leaf curl within the disease complex is not clearly understood, therefore, a study has been undertaken with the following objectives. With all consideration, the aim of the proposed study is -

- To evaluate varietal performance of different chilli varieties against *Chilli leaf curl virus* (ChLCV)

-To assess the disease incidence and severity of *Chilli leaf curl virus* (ChLCV) among different varieties and

-To indicate the existence of significant variation for all traits (growth & yield) among different varieties

CHAPTER II

REVIEW OF LITERATURE

Chilli is a bushy plant belong the family *Solanaceae*, widely used as spice, native of Mexico. Chilli is famous for its pleasant aromatic flavour pungency and high coloring substance having a medicinal value but suffer from as many as 83 different diseases. *Chilli leaf curl virus* is considered one of the major constrain for the lower yield of chilli in our country.Hence in this chapter an attempt was made to compile the relevant reviews for the present investigation.

2.1. Origin and distribution

Chilli (*Capsicum frutescens*) is a bushy plant belong the family Solanaceae, widely used as spice, native of Mexico. . Chilli was originated in the American tropics and It has been propagated throughout the world including the tropics, subtropics, and also temperate regions (Pickersgill, 1997).

In 2017, world producti on of fresh green chillies and peppers was 33.2 million tonnes and Bangladesh contributes 5% of the global total (FAOSTAT, 2017).

It can be cultivated in both the summer and winter seasons in Bangladesh and average yield of green chilli is 1.3 ton/ha (BBS, 2017).

2.2. Nutritional value of chilli

Chilli is famous for its pleasant aromatic flavour pungency and high coloring substance having a medicinal value. Green chillies are rich source of vitamins especially vitamin A, C, B1, B2 (Saimbhi *et al*., 1977; Sayed *and* Bhagvandas, 1980) Joshi and Singh, (1975) stated that Chilli contains 1.29 mg protein, 11 mg calcium, 870 I.U. vitamin A, 17.5 mg ascorbic acid, 0.06 mg thiamin, 0.03 mg riboflavin and 0.55 mg niacin per 100 g edible green fruit.

Vitamin C is present in more quantities in fresh green chilies than citrus fruits and Vitamin A is high in red chilli than carrots (Osuna Garcia *et al*., 1998 and Martin *et al.*, 2004).

2.3. Diseases of chilli

Chilli is known to suffer from as many as 83 different diseases (Anonymous, 1960 & 1966).

Among these fungi, bacteria and viruses which are the major limiting factors unsuccessful crop production, Chilli is known to be affected by forty two viruses. Twenty two of them reported to occur naturally and twenty viruses can infect on artificial inoculation, chilli leaf curl virus (ChiLCV), chilli leaf curl India virus (ChiLCINV), chilli leaf curl Vellanad virus (ChiLCVV), tomato leaf curl Joydebpur virus and tomato leaf curl New Delhi virus (ToLCNDV) are known to be associated with chilli leaf curl disease (Khan *et al*., 2006; Kumar *et al*., 2011; 2012; Senanayake *et al*., 2007; Shih *et al*., 2007).

Recently, studies of Kumar *et al*., (2015) revealed the association of five distinct *Begomovirus* species with six different groups of betasatellites [ChiLCV, Pepper leaf curl bangaladesh virus (PepLCBV),*Tomato leaf curl virus* (ToLCV), ToLCNDV, *Papaya leaf curl virus* (PaLCuV) and beta satellites like ToLCBDB,, ChiLCB, ToLRnB, ToLCJoB, CroYVMB, RaLC].

Transmission of number of strains of TMV by mechanical sap inoculation chilli was reported by several workers (Palm, 1923; Holmes, 1937; Nakata and Takimoto, 1940; Doolittle and Beecher, 1942; Kovachevsky, 1940, McKinney, 1952; Newton, 1954; Miller and Thornberry, 1958; Murakshi.1960: Greenleaf *et al.*, 1964; Adsuar *et al.*, 1971; Ragozzino *et al.*, 1972; Bidari, 1982,)

Doolittle and Walker (1923); Doolittle and Zaumeyer (1953) reported that CMV was mechanically sap transmitted.

Brown *et al*., (2015) described that Whiteflies (*Bemisia tabaci* L) are mainly associated with transmission of *Begomovirus*.

2.4. Chilli leaf curl disease

Chilli leaf curl is a most destructive disease of chilli in India.Tropical and sub-tropical regions of the world where pepper is being cultivated face heavy losses

due to leaf curl disease (Mishra *et al*., 1963; Dhanraj and Seth, 1968; Chattopadhyay *et al*., 2008).

Maruthi *et al*., (2007) reported that leaf curl disease of chilli is currently a serious problem in all the major chilli growing area of India which accounts for second largest share of world chilli production. Leaf curl disease in chilli is caused by *Begomoviruses* which are the most devastating viruses of chilli plant.

The chilli leaf curl disease (ChLCD) which is occered by *(Chilli leaf curl virus*) is a major limiting factor for chilli production in the Indian subcontinent and is invariably caused by begomoviruses (Briddon *et al.,* 2003; Senanayake *et al*., 2006; Shih *et al*., 2003).

2.5. Historical Perspective

The C*hilli leaf curl virus* (ChLCV) disease on chilli was first reported in Pakistan by Shih *et al.* (2003) and in India by Senanayake *et al.* (2006).

Leaf curl or yellowing symptoms, typical of those caused by *Begomovirus* infection, *cotton leaf curl Multan virus* (CLCuMV) by (Hussain *et al.*,2004) and *Pepper yellow leaf curl Indonesia virus* (PepYLCIV) (Tsai *et al.*, 2006) have been associated with *chilli leaf curl virus* in Pakistan and Indonesia respectively.

In India, *Tomato leaf curl New Delhi virus* (ToLCNDV) was recently shown to be associated with chilli leaf curl disease occurring in Lucknow (Khan *et al*., 2006). The whitefly (*Bemisia tabaci*) is one of the most economically important pests of chilli in many tropical and sub-tropical regions (Block, 1982).

Shivanathan *et al.,* (1983) stated that in Sri Lanka in the wet and dry season on the epidemiology of chilli leaf curl disease infecting chilli (*Capsicum frutescens* and *C. annuum*), mungbean yellow mosaic disease infecting on mung bean (*Vigna radiata*) and okra yellow vein mosaic disease infecting okra, allwere transmitted by *Bemisia tabaci* (Gennadius).

According to Venette and Davis (2004) reported that among the potential economically important hosts of Chilli thrips pest in Western Hemisphere listed are banana, bean, cashew, castor, citrus, cocoa, corn, cotton, eggplant, grapes, litchi, longan, mango, melon, peanut, pepper, poplar, rose, strawberry, sweet potato, tea, tobacco, tomato and wild yams (*Dioscorea* spp.).

Tomato leaf curl Joydebpur virus symptoms on chilli were as mild yellowing, severe leaf curling, leaf distortion, stunting and blistering observed in the fields of Ludhiana, Punjab State, India (Shih *et al.*, 2006).

Leaf curl disease of chilli was emerged as a serious problem in Jodhpur district, the major chilli growing area of Rajsthan state. During December, very high disease incidence up to 100% observed in farmer's fields in Narwa and Tinwari villages. The characteristic field symptoms were upward curling, puckering and reduced size of leaves. Severely affected plants were stunted and produced no fruit. The virus from Narwa village was transmitted by whitefly (*Bemisia tabaci*) of test plants, which produced vein clearing, curling and stunting symptoms (Senanayake *et al.*, 2006).

According to Varma *et al*,(2011). *Begomoviruses* are a serious constraint in the cultivation of several crops in the Indian subcontinent. Chilli is an extensively cultivated crop which is an almost indispensable ingredient in the cuisines of India and many other countries.

2.6. Symptomology

Leaf crinkle or leaf curl complex was observed on chillies by Hussain (1932).

Leaf curl due to thrips results upward curling of leaves and interveinal buckling. Irregular scraping of epidermis could also be seen (Johnpulie, 1939).

Peiris (1953) showed that leaf curl caused by mites shows downward curling of leaves, partial suppression of lamina near the petiolar end and a shiny bronze colour on the lower surface of the leaves. Emerging young leaves in infected plants become brittle narrow and thicker.

Curling of leaf margin, reduction in leaf size, vein clearing were observed in India, Sri Lanka and USA (Puttarudraih, 1959).

Fernando and Peiris (1975) observed that *Chilli leaf curl virus* (ChLCV) causes vein clearing on young leaves at the early stages of infection upward or downward curling of young and old leaves and stunting in most cases. Curling of fruits could be seen in mature plants. Virus is transmitted by white fly, *Bemisia tabaci* they further reported that ChLCV does not persist throughout the life span of the vector.

Abaxial curling of the leaves accompanied by puckering, thickening and swelling of the veins were observed by Mishra *et al.* (1963) and Muniyappa and Veeresh (1984).

Appearance of most prominent symptoms such as vein clearing followed by veinal distortion, swelling of veins and veinlets on dorsal side were reported by Muniyappa (1980) and Ravi (1991).

Dhooria and Bindra (1997) found that mite density had to be at least 10-15 individual /leaf in order to produce leaf curl and necrosis, and symptoms were more pronounced on plants receiving 30-50 mites/leaf. Infected plants never recover after treatments with an insecticide if it is a viral infection, contrary to the plants infested by mites and thrips.

Ukey *et al.* (1999) studied that in chilli, the economic threshold level has been determined as 1 mite /leaf.

A severe infestation of chilli thrips makes the tender leaves and buds brittle, resulting in complete defoliation and total crop loss. Infested fruits develop corky tissues (Seal *et al*., 2006).

2.7. Identification and Diagnosis of *chilli leaf curl virus*

The *chilli leaf curl virus* (ChLCV) disease on chilli was first reported in Pakistan by Shih *et al.* (2003) and in India by Senanayake *et al.* (2006).

Sanap and Nawale (1987) reported that adult and nymphs of *Scirtothrips dorsalis* suck the cell sap of leaves, causing rolling of the leaf upward and leaf

size reduction. A heavy infestation of *Scirtothrips dorsalis* in pepper plants changes the appearance of the plant to what is called "chilli leaf curl." Appearance of discolored or disfigured plant parts suggests the presence of *Scirtothrips dorsalis*.

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

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.

The viruses of the genus Begomovirus consists of genome made up of either two genomic components, bipartite (known as DNA-A and DNA-B) or a single component, monopartite, showing homology to DNA-component of bipartite viruses (Rojas et al., 2005; Stanley *et al*., 2005).

During the past few years, monopartite begomoviruses and betasatellites associated with chilli leaf curl disease have spread to major chilli growing regions of the Indian subcontinent. To date, in India, *Chilli leaf curl virus* (ChiLCV), *Chilli leaf curl India virus* (ChiLCINV), *Chilli leaf curl Vellanad virus* (ChiLCVV), *Tomato leaf curl Joydebpur virus* and *Tomato leaf curl New Delhi virus* (ToLCNDV) are known to be associated with chilli leaf curl disease (Khan, *et al*., 2006; Kumar, *et al.*, 2011,2012; Senanayake, *et al*., 2007; Shih, *et al*., 2007).

Recently, studies of Kumar *et al*., (2015) revealed the association of five distinct begomovirus species with six different groups of betasatellites [ChiLCV, *Pepper leaf curl bangaladesh virus* (PepLCBV), *Tomato leaf curl*

virus (ToLCV), ToLCNDV, *Papaya leaf curl virus* (PaLCuV) and beta satellites like ToLCBDB,, ChiLCB, ToLRnB, ToLCJoB,CroYVMB, RaLC].).

Further synergistic interaction among different begomoviruses infecting chilli results in breakdown of natural resistance in otherwise resistant chilli plants to one begomovirus (Singh, *et al*., 2016).

2.8. Chilli leaf curl (ChLC) disease incidence (%) and disease severity (%)

A leaf curl disease incidence to the extent of 40–55% on chilli varieties, viz, IC 3471, IC 3432, IC 2345, IC 3412 and NP was observed (Mishra *et al*. 1963).

Assessment of losses due to (ChLCD) incidence was done on the basis of total weight of the fruit obtained from 5 plants selected for different stages of infection each time and expressed in terms of percentage (Sastry and Singh, 1973).

A survey was to assess incidence of chilli leaf curl viral complex on chilli in some districts of northern Karnataka. Some perennial types with small pungent fruits in Tarai region of Uttar Pradesh were shown to be immune to viruses. Selection from crosses between the perennial local types and NP -46 A was released under the name Pant C -1, and Pant -2, which were known to be resistant to leaf curl virus (Mathai *et al.*, 1977).

Natural occurrence of several viruses have been reported on chilli by various workers and among them *Chilli leaf curl virus* (ChLCV), *Cucumber mosaic virus* (CMV) and *Chilli vein mottle viru* (CVMV) have been reported as most destructive viruses affecting chilli cultivation in terms of incidence and yield loss (Green, S. K. 1992)

Roving surveys method was adopted to know the Chilli leaf curl disease incidence in different parts of Dharwad, Belguam, Haveri, Gadag, Bagalkot, Bijapur, Gulburga, Raichur and Bellary districts during the cropping period both *kharif* and *rabi*/summer 2002, 2003, 2004 and 2005.

A very high disease incidence (up to 100% of plants during December 2004) in farmer's fields in Narwa and Tinwari villages at Jodhpur District Rajasthan was also observed (Senanayake et al. 2007).

2.9. Transmission of Chilli leaf curl virus

The largest and most economically significant groups of plant viruses transmitted by *Bemisia tabaci* are the Gemini viruses. The ability of biotype of *B. tabaci* to transmit Gemini viruses has impact on chilli production (Jeffrey *et al.*, 1994). It can transmitted by mechanically, vector or seed.

2.9.1. Mechanical transmission of *chilli leaf curl virus*

Plants respond differently to different viruses depending on their level of resistance to a given virus. Susceptible plants react to viruses by either producing local lesions, where the virus infection is confined to the initial infected tissues or by producing systemic symptoms where the symptoms appear in tissues.

Local lesion has got greater significance for ascending plant viruses. When Holmes (1937) found that a relationship occurred between concentration of TMV and that number of local lesion produced on test plant.

Transmission of number of strains of TMV by mechanical sap inoculation chilli was reported by several researchers (Palm, 1923; Holmes, 1937; Nakata and Takimoto, 1940; Doolittle and Beecher, 1942; Kovachevsky, 1940, McKinney, 1952; Newton, 1954; Miller and Thornberry, 1958; Murakshi, 1960: Greenleaf *et al.*, 1964; Adsuar *et al.*, 1971; Ragozzino *et al.*, 1972; Bidari, 1982,).

Doolittle and Walker (1923) and Doolillte and Zaumeyer (1953) reported CMV was mechanically sap transmitted.

The virus TEV was easily sap transmissible reported by Laird and Dickson (1963).

Bidari and Reddy (1986) reported that TSWV is readily sap transmissible with only 10-20 per cent plants infected.

2.9.2. Vector transmission of *chilli leaf curl virus*

Hussan (1932) reported that the leaf curl or leaf crinkle occurring on chillies was caused by *Bemisia tabaci* (*Bemisia gossypiperda*).

Costa and Alves (1950) reported that PVY on chilli was transmitted by *M. persicae Sulz, Macrosiphum solanifolii* Ashm and other unidentified aphids.

Park and Fernando (1938), Mishra *et al*. (1963) and Dhanraj and Seth (1968) studied the transmission of virus and found that the virus is transmitted by wedge grafting and white fly (*Bemisia tabaci*).

Mishra *et al.* (1963), Muniyappa and Veeresh (1984) reported the transmission of *chilli leaf curl virus* by means of whitefly (*Bemisia tabaci*). Inoculated chilli plants showed typical leaf curl symptoms after 2-6 weeks.

Laird and Dickson (1963) reported the transmission of virus by *M. persicae, A. gossypii, M. solanifolii, M. pisi* and *A. spiraecola, A. craccivora* transmitted the virus in a Persistent manner (Kassanis, 1944; Herold, 1970).

Prasada Rao (1976) found that *M, persicae* and *A. gossypii* were able to transmit PVMV. Gowda and reddy (1989) observed that PVMV was transmitted by *M. persicae, A. gossypii* and *A. craccivora* resulting in 90, 100 and 30 per cent infection, respectively.

Pandurange Gowda (1979) and Bidari (1982) reported typical strain of potyvirus mechanically transmitted and nonpersistantly transmitted by aphids, *M. persicae, A. fabae* and *A. gossypii*.

Bidari and Reddy (1986) reported that TSWV none of the aphids transmitted the disease. Only nymphs of *T. tabaci* isolated and maintained on onion plants transmitted the virus to *C. annuum* cv. California Wonder and Byadgikaddi and not by *Scirtothrips dorsalis* as reported in groundnut.

Gowda and Reddy (1989) reported transmission percentage of various viruses. Potato virus Y was transmitted by *M. persicae*, A. *gossypii* and *A. craccivora* at 60, 80 and 20 per cent espectively and not transmissible by *T. citricidus and R. maidis*. El- Sanusi *et al.* Premchand.

Rao (1990) reported a number of plant species showing natural infection. They further reported that the disease is transmitted by whitefly, *Bemisia tabaci*, while it subsists on a wide range of its wild or perennial host plants.

Fereres *et al,* (1993) reported transmission of potato virus Y (PVY) by several aphids, indicated that *M. persicae* was the most efficient vector followed by *A. gossypii* and *Acyethosiphon pisum, A. fabae* was also capable of transmitting PVY but less efficiently.

Rao *et al*. (2003) found that chilli thrip sacted as vectors of tobacco streak virus (TSV) in groundnut crops in India. Recently, in Thailand its role as a vector of three tospoviruses (i.e., Melon yellow spot virus (MYSV), Watermelon silver mottle virus (WsMoV), and Capsicum chlorosis virus (CaCV)) in field crops was confirmed (Chiemsombat *et al.*, 2008).

2.9.3. Seed transmission of *chilli leaf curl virus*

Sakimura (1940) reported TSWV on bell pepper which was transmitted by *Thrips tabaci* Lind. It produced concentric zonations on leaves of bell pepper and mosaic mottling on terminal young leaves with dense coalescence of small rings, spots and concentric rings. It was not to be seed-borne.

McKinney (1952) reported a seed borne strain of TMV on pepper variety S.C. 40252.

However, Bidari (1982) reported that TMV is not transmitted through seeds and any aphid species tested. Jemmali (1987) reported seed contamination by TMV was mainly superficial.

Virus transmission from the seed to the plant was high. Cochran (1946) showed transmission of TMV through dodder.

Pandurange Gowda (1979) and Bidari (1982) reported that PVY is not transmitted through seeds.

Bidari (1982) reported that however was unable to transmit TRSV through aphids and seeds but easily transmitted by sap inoculation.

Bidari (1982) reported that the virus PVMV is not seed transmitted but readily sap transmissible and also by aphid vectors, *M. persicae, A.gossypii, A. craccivora, H. seteriae* and not by *R. maidis.*

Bidari and Reddy (1986) observed that the virus TEV was successfully sap inoculated and transmitted by aphids, *M. persicae* and *A. craccivora* to *C. annuum* cvs. California Wonder and Bydgi kaddi. It was not seed borne.

Singh and Shukla (1990) also found that the virus CMV was transmitted mechanically in seeds and by two aphids.

Various workers showed effective transmission of PVBV through sap and aphids *viz., M. persicae, A.gossypi, A. craccivora* but not through seeds and other aphids *viz., R. maidis,H. citricidus, H. setariae* (Simons, 1956*;* Prasad Rao, 1976*;* Pandurange Gowda, 1979*;* Bidari,1982*;* Gowda and Reddy, 1989*;* Reddy and Reddy, 1991).

2.10. Effect on growth and yield contributing characters by ChLCV

Buds are aborted and flowers distorted, shoots grow twisted and fruit may be mishappen and russeted. These similar symptoms were observed by Vasudeva and Samraj (1948), Sastry and Singh (1973), Muniyappa (1980), Sakia and Muniyappa (1989).

Chilli leaf curl complex means abaxial and adaxial curling of leaves accompanied by puckering and blistering of interveinal areas and thickening and swelling of veins (Senanayake *et al.*, 2006).

Sastry and Singh (1973) reported that TLCV infected plants produced very few fruits. When infected within 20 days after planting and resulting upto 92.3 (%) yield loss.

2.11. Yield loss due to ChLCV

The emerging threat of the viruses belonging to the genus *Geminivirus* has been extensively addressed earlier. The extent of yield loss caused by some geminiviruses has been estimated as high as100% and in some areas infection with viruses has rendered the growing peppers uneconomical, causing whole fields to be abandoned prior to harvest. Up to 96% loss in yield has been reported by *Bhendi Yellow vein mosaic virus.*

Sastry and Singh (1973) reported that TLCV infected plants produced very few fruits when infected within 20 days after planting and resulting upto 92.3(%) yield loss. Plants infected 35 and 50 days after transplanting resulted in 74 (%) and 22.9 (%) yield loss, respectively.

Reddy and Puttaswamy (1983) studied that chillies are prone to a wide range of pests, of which losses caused due to white mite (*Polyphagotarsonemous latus* Linn.) is economically important.

Ahamad *et al.* (1987) reported that in India, found that arthopod pest mainly *P.latus, Scirtothrips dorsalis* and *Spodoptera litura* caused an overall reduction in chilli yield upto the extent of 76.68%. Combined infestations of *P. latus* and *S. dorsalis* caused losses of 34.14 (%).

Bagale (1988) found that the losses due to Chilli thrips (*Scirtothrips dorsalis* Hood.) reported to range from 50 to 90%.

Narayana and Muniyappa (1995) reported that maize streak virus affected the plant growth and grain yield of maize when inoculated through the viruliferous plant hoppers. The premature death of seedlings was observed when infection was at 2nd and 4th leaf stages, while a considerable reduction in plant height (70.9 cm) and internodal length (5.7 cm) was observed to that of healthy plants

(127.0 cm and 12.2 cm). The yield reduction at 5th leaf stage was 94.9 per cent, while it was 65.8 (%) at 10-11th leaf stage infection.

According to Salane *et al.*, 2006 now due to this disease more than 90 per cent of chilli growers have switched over to some other profitable crop. Because of its damage potential to chili pepper, this dreadful pest (*Scirtothrips dorsalis*) is commonly referred as chilli thrips. Holtz, (2006) observed that if this insect becomes widely distributed in the United States it could cause annual crop losses in excess of $3 billion.

According to a survey by the Asian Vegetable Research and Development Committee, *S. dorsalis*is one of the most important limiting factors for the chilli production in the country along with aphid species, *Myzus persicae* Sulzer, *Aphis gossypii* Glover and mite *Polyphagotarsonemus latus* Banks (Hosmani, 2007).

Patel *et al.* (2009) found that yield loss solely dedicated to *S. dorsalis* damage can range between 61 to 74%.

According to Sarkar *et al.* (2013) they cause a havoc economic loss every year especially in the southern districts of West Bengal, India, and has become a threat to chilli growers.

In legumes, The yield loss have been estimated approximately 300 Million USD per year taking black gram ,mungbean, soybean together .Economic losses due to Geminivirus infections in cassava are estimated to be USD 1300-2300 Million in Africa.

CHAPTER III

MATERIALS AND METHODS

The present study regarding Varietal Performance against *Chili leaf curl virus* under field condition had been conducted during October 2018 to June 2019 at the experimental fields of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka. Required materials and methodology are described below under the following headings and subheadings.

3.1. Geographical location

The experiment was carried at the central farm of Sher-e-Bangla Agricultural University, Dhaka. The site is 22°46′N and 90°22′ E Latitude and at Altitude of 9 m from the sea level.

3.2. Agro-Ecological Region

The experimental field belongs to the Agro-ecological zone of "The Modhupur Tract'", AEZ-28 (Anon, 1988a). 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., 1989b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.3. Characteristics of soil

The soil of the experimental site belongs to the general soil type, Shallow Red Brown Terrace Soils under Tejgaon Series. Top soils were clay loam in texture, olive-gray with common fine to medium distinct dark yellowish brown mottles. Soil pH ranged from 6.1-6.3 and had organic matter 1.29%. The study area was flat having available irrigation and drainage system and above flood level. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done by Soil Resource and Development Institute (SRDI), Dhaka. The physicochemical properties of the soil are presented in Appendix II.

3.4. Weather conditions during the experiment

The weather condition of the experimental site was under the sub-tropical monsoon climate, which is characterized by heavy rainfall during Kharif season (April to September) and in the Rabi season (October to March) low rainfall associated with moderately low temperature, low humidity and short day. There was no rain fall during the month of December, January and February, little rain in March. Rabi is the more favorable for vegetable production. Details of the meteorological data in respect of temperature, rainfall and relative humidity during the study period were collected from Bangladesh Meteorological Department, Agargoan, Dhaka- 1207, Dhaka and have been presented in Appendix III.

3.5. Collecting material

Different eight types of variety used in this experiment. Three chilli varieties namely “BARI-1,BARI-2,BARI-3” was used in this study which was an open pollinated high yielding indeterminate type variety developed by the Vegetable Division of Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI), Gazipur. The rest of five varieties are collected from local market of Puran Dhaka. The name of varieties are Kalomorich, Bogra jhal, Bindu mashi, Sufia, Dhanuan are collected from Asad gate nursery. Planting material and collective source is given below in the table 1.

Table1. Collecting materials and their sources

Variety	Source
BARI-1	Division of Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI), Gazipur
BARI-2	Division of Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI), Gazipur
BARI-3	Division of Horticulture Research Center, Bangladesh Agricultural Research Institute (BARI), Gazipur
Bogra jhal	Sidduqe bazar,Puran Dhaka local market
Bindumashi	Sidduqe bazar,Puran Dhaka local market
Dhanua	Asad gate nursery
Kalomorich	Sidduqe bazar,Puran Dhaka local market
Sufia	Asad gate nursery

3.6. Raising of seedlings

Chilli seedlings were raised which situated on a relatively high seedbed. The size of each seed bed was 2.6 m × 2.5 m. The area was well prepared with spade and made into loose, friable and dried mass to obtain fine tilth. All weeds and stubbles were removed and the soil was mixed with well decomposed cow dung. Sevin 85 SP was applied around each seedbed as precautionary measure against ants and cutworms.10 grams of seeds were sown in each seedbed. After sowing, the seeds were covered with light soil to a depth of about 0.6 cm. Complete germination of the seeds took place within 4-6 days of' sowing. Necessary shading by bamboo mat was provided over the seedbed to protect the young seedlings from the scorching sunshine or heavy rain. Dithane M-45 was sprayed on the seedbeds at the rate of 2 g/l to protect the seedlings from damping-off and other diseases. Weeding, mulching, and irrigation were done from time to time as and when needed. No chemical fertilizer was used in the seedbed.

3.7. Layout and design

The experimental plot size was 250m^2 which have 25m length size and 10m breadth size. The experiment comprised 8 varieties of single factor and laid out in Randomized Complete Block Design (RCBD) with three replications. The whole field was divided `into three blocks and each block consisted of 8 plots. Altogether there were 24 unit plots. Each plot was (2.6 m × 2.5 m) in size. The distance between plots to plots was 1.0 m and distance between plant to plant was 45 cm and row to row was 90 cm (Appendix IV).

3.8. Preparation of the main field

The selected field for conducting the experiment was opened in the first week of December 2018 with a power tiller and was exposed to the sun light for a week. After one week the land was harrowed, ploughed and cross-ploughed several times followed by laddering to ensure a good tilth for well growth and development of chili seedlings. Weeds and stubbles were removed and finally obtained a desirable tilth of soil. The experimental field was partitioned into the unit plots in accordance with layout and design.

3.9. Fertilizer and manure application

Fertilizer was applied following the recommendations (Krishi projukti hatboi) of Bangladesh Agricultural Research Institute (BARI, 2019) during final land preparation. Before transplanting seedlings to main field from seedbed, Well decomposed cow dung (10 t/ha) was applied at the time of final land preparation. The sources of fertilizers used for N, P, K, S and Zn were urea (410 kg/ha), TSP (300 kg/ha), MP (200 kg/ha), and Zinc sulphate (15 kg/ha), respectively. The entire amounts of TSP, MP were applied during final land preparation. Only urea was applied in three equal installments at 30, 45 and 60 Days after transplanting (DAT). Application of potassium as K2SO4 will increase quality of chill .The doses of manure and fertilizer were used which is given below in the table form.

Table 2. Doses of fertilizer application

Name of fertilizer and manure	Does/ha
Cow dung	10 ton
Urea	410 kg
TSP	300kg
MP	200kg
Zn	15kg

3.10. Selected for variety against ChLCV

In total eight (8) varieties were considered in this experiment. These were as follows as BARI-1, BARI-2, BARI-3, Bogra Jhal, Bindu Mashi, Dhanua, Kalomorich and Sufia.

3.11. Transplanting of seedlings

Healthy and uniform sized 35 days old seedlings were uprooted separately from the seedbeds. The seedbeds were watered before uprooting the seedlings so as to minimize the root injury. The seedlings were transplanted in the pits of the experimental plots in the afternoon on10 November, 2018 maintaining a spacing of 45 cm and 90 cm between the rows and plants, respectively. Light irrigation was given immediately after transplanting by using a watering cane. In order to gap filling and to check the border effect, some extra seedlings were also transplanted around the border area of the experimental field.

3.12. Intercultural operations

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

3.12.1. Gap filling

Gap filling was done in place of dead or injured wilted seedlings in the field using healthy seedlings of the same stock previously planted in the border area. The transplanted seedlings in the experimental plot were kept under careful observation. Those seedlings were transplanted with a big mass of soil with roots to minimize transplanting stock. Replacement was done with healthy

seedling having a boll of earth. The transplants were given shading and watering for 7 days for their proper establishment.

3.12.2. Weeding and mulching

Weeding and mulching were conducted as and whenever necessary to keep the crop free from weeds, for better soil aeration and to break the soil crust. It also helps in conservation of soil moisture. Four subsequence weeding were done manually at 15, 30, 45 and 55 DAS to keep the plots free from weeds. The selected plots under the treatment of T3 were BARI-3.

3.12.3. Stalking

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

3.12.4. Drainage

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

3.12.5. Irrigation

Adequate Irrigations were given throughout the growing season as and when necessary. Immediately after transplanting, the experimental plot was semi-flooded by irrigation. The crop was irrigated when needed depending on the moisture status of the soil and requirement of plants.

3.13. Data collection

Three plants from each plot were randomly selected for data collection. The collected parameters were shown during field experiment.

- Number of infected plants/plot
- Number of healthy leaves/plant
- Number of infected leaves/plant
- Leaf length (cm)
- Leaf diameter (cm)
- Number of branches/plant
- Plant height (cm)

- ❖ Number of flowers/plant
- ❖ Length of fruits/plant
- ❖ Single fruit weight (g)
- ❖ Yield (kg/ha)
- ❖ Yield (t/ha)

3.14. Identification of ChLCV by visual observation

Identification of the virus disease was done mainly through visual observation of typical symptoms of ChLCV infection like upward curling, cupping, interveinal buckling, crinkle with or without marginal chlorosis, smaller leaflets and stunting of the plant (Green and Kalloo, 1994 and Sinistera *et al*., 2000). The incidence of ChLCV was calculated by counting the infected plants at 60 and 75 DAT on the basis of the appearance of symptoms. The plants were inspected every day morning to note the appearance of the symptoms starting from the following day of transplantation.

A **B**

Plate 1. Symptoms of ChLCV by visual observation
(A) Healthy plant of chilli, **(B)** Infected plant of chili

3.15. Disease incidence (%)

Chilli leaf curl disease incidence was recorded by direct counting method. Infected plants were counted at regular intervals and the final percentage was worked out. The following formulas were used to calculate the percentage of disease incidence and severity-

Disease incidence (%) was computed by formula developed by (Mayee and Datar, 1986).

$$\text{Disease incidence (\%)} = \frac{\text{No. of plants infected}}{\text{Total number of plants}} \times 100$$

3.16. Percent disease index

Percent disease index was calculated by the formula given by Wheeler (1969)

$$\text{Percent disease index} = \frac{\text{Total disease rating}}{\text{Total no of observation X Maximum scale}} \times 100$$

Scale	Description	Disease Reaction
0	No symptoms on plants	Immune (I)
1	1% or less leaves exhibiting symptoms	Resistant (R)
3	1 to 10% leaves exhibiting symptoms	Moderately Resistant (MR)
5	11 to 20% leaves exhibiting symptoms	Moderately Susceptible (MS)
7	21 to 50% leaves exhibiting symptoms	Susceptible (S)
9	51% or more leaves exhibiting symptoms	Highly Susceptible (HS)

3.17. Harvest and post-harvest operations

The crop harvest was completed at 75 DAT. The crop was harvested plot wise. The harvested fruits were sorted into individual bags for each plot separated by healthy and infected. They were taken to the khamar shed after sorting the fruits on the floor, weighed separately.

3.18. Yield reduction (%)

Percent yield reduction in terms of fruit weight was calculated as follows (Mousanejad *et al*., 2010).

$$\text{Yield reduction (\%)} = \frac{\text{Yield of healthy plant} - \text{Yield of infected plants}}{\text{Yield of healthy plant}} \times 100$$

3.19. Statistical analysis

The collected data were compiled and analyzed statistically using the analysis of variance (ANOVA) technique with the help of a computer package program Statistis-10 and the mean differences were adjusted by Least Significance Difference (LSD) test at 5% level of probability (Gomez and Gomez, 1984). The means of growth and yield data were compared by LSD Bar diagram and graphs were also used to interpret the data as and when necessary.

CHAPTER IV

RESULTS AND DISCUSSION

The present experiment was conducted to study varietal performance of chilli against *Chilli Leaf Curl Virus* (ChLCV) under field condition. The data on disease incidence (%), percent disease index, growth characters and yield and yield attributing characters are studied. To fulfill the objectives to the results of the research were described under the following headings and sub headings.

4.1. Effect on chilli leaf curl disease incidence (%) among different varieties of chilli at 60 and 75 DAT

The disease incidence (%) of ChLCV among different varieties was varied significantly. The disease incidence of ChLCV was ranged 3.70 (%) to 51.85 (%) and 9.40 (%) to 61.05 (%) at 60 DAT and 75 DAT, respectively. The results of chili leaf curl disease incidence (%) are shown in table 3.

At 60 DAT, the lowest disease incidence 3.70 (%) was found in BARI-1 and Bogra jhal. Bogra jhal and BARI-1 which are statistically similar with each other where it preceded by 7.41 (%) found in variety BARI-2. On the other hand, the highest ChLCV disease incidence 51.85 (%) was recorded in BARI-3 variety followed by Dhanua variety which disease incidence of Chilli leaf curl virus was 18.81 (%). Among the varirtal performance, the lowest disease incidence of Kalomorich and Bindumashi varieties were 14.81 (%) and 15.11 (%) which are statistically similar.

At 75 DAT, Statistically differences were found in disease incidence (%) of ChLCV. The disease incidence of ChLCV was ranged 9.40 (%) to 61.05 (%) at 75 DAT among different varieties. The lowest ChLCV disease incidence 9.40 (%) was found in Bograjhal variety preceded by 11.11 (%) found in variety Bindumashi. On the other hand, the highest ChLCV disease incidence 61.05 (%) was found in BARI-3 variety followed by Dhanua variety where disease incidence was 29.51 (%). Among the varietal performance we could be

concluded as BARI-3 variety was susceptible variety against ChLCV which showed lowest disease incidence (%) at 60 DAT and 75 DAT, respectively.

Table 3. Disease incidence (%) of ChLCV among different varieties at 60 DAT and 75 DAT

Variety	Disease incidence (%)	
	60 DAT	75 DAT
Kalomorich	14.81 c	27.31 c
BARI-3	51.85 a	61.05 a
Bogra jhal	3.70 f	9.40 h
Bindumashi	15.11 c	11.11 g
Dhanua	18`.81 b	29.51 b
BARI-2	7.41 e	21.81 e
BARI-1	3.70 f	24.31 d
Sufia	11.11 d	14.81 f
LSD $_{(.05)}$	0.85	0.70
CV (%)	6.61	6.47

DAT= Days after transplanting, CV= Coefficient of variation,

* LSD was calculated at (.05) level of significance, means followed by same lettering not significantly different.

BARI= Bangladesh Agricultural Research Institute

4.2. Effect of percent disease index among different varieties of chilli at 60 DAT and 75 DAT

The percent disease index of ChLCV among different varieties was varied significantly. It was found that the percent disease index of ChLCV was ranged 2.99 (%) to 41.99 (%), 7.61 (%) to 52.04 (%) at 60 DAT and 75 DAT respectively. The results of disease percent disease index are shown in table.3. At 60 DAT the lowest percent disease index of ChLCV was found 2.99 (%) in BARI-1 and Bogra jhal giving reaction Moderately Resistant (MR) where the disease incidence (%) of BARI-1 and Bogra jhal 2.99 (%) preceded by BARI-2 variety 6 (%).On the other hand, the highest percent disease index of ChLCV was recorded 41.9 (%) in BARI-3 variety giving reaction of Susceptible (S)

followed by Dhanua variety which % ChLCV disease incidence was 15.23 (%).

At 75 DAT, The percent disease index of ChLCV was ranged 7.61 (%) to 52.04 (%) at 75 DAT among different varieties. The lowest ChLCV percent disease index 7.6 (%) was again found in Bograjhal variety which showed Moderately Resistant (MR) reaction. preceded by 8.99 (%) found in variety Bindumashi. On the other hand, the highest ChLCV percent disease index 52.04 was found in BARI-3 variety had given Highly Susceptible (HS) reaction followed by Dhanua variety showed Percent disease index was 23.90 with susceptible reaction. Among the varietal performance we could be concluded as BARI-3 variety was susceptible variety against ChLCV which showed highest percent disease index at 60 DAT and highly susceptible 75 DAT, respectively.

Table 4. Effect of different varieties on percent disease index of ChLCV in chilli at 60 DAT and 75 DAT

Variety	Percent disease index 60 DAT		Percent disease index 75 DAT	
	PDI	Reaction	PDI	Reaction
Kalomorich	11.99	MS	21.71	S
BARI-3	41.99	S	52.04	HS
Bogra jhal	2.99	MR	7.61	MR
Bindu mashi	12.23	MS	8.99	MR
Dhanua	15.23	MS	23.90	S
BARI-2	6.00	MR	17.66	MS
BARI-1	2.99	MR	20.28	MS
Sufia	9.00	MR	11.99	MS

MR= Moderately Resistant MS= Moderately Susceptible S= Susceptible HS= Highly Susceptible

BARI= Bangladesh Agricultural Research Institute

4. 2.1. Grouping of chilli varieties into different categories for *Chilli leaf curl virus* resistance

Among the varieties, none of the varieties recorded zero per cent ChLCV disease incidence in field, two varieties (Bogra jhal and Bindumashi) recorded between 1-10 per cent infection grouped in MR (moderately resistant). BARI-2, BARI-1 and Sufia varieties recorded percent disease index between 11-20 percent with moderately susceptible reaction. Kalomorich and Bindumashi varieties showed between 21-50 (%) percent disease incdex under natural field conditions. Out of eight varieties, very low PDI was observed in two varieties *viz.,* Bogra jhal 7.61 (%) and Bindumashi 8.99 (%), whereas the highest PDI was observed in BARI-3 variety 52.04 (%). The result of reaction of different chilli varieties against ChLCV are showen in (table-5).

Table 5. Grouping of chilli varieties in to different categories for *Chilli leaf curl virus* resistance

Variety	Disease index	Reaction
Kalomorich	21-50	S
BARI-3	>51	HS
Bogra jhal	1-10	MR
Bindu mashi	1-10	MR
Dhanua	21-50	S
BARI-2	11-20	MS
BARI-1	11-20	MS
Sufia	11-20	MS

MR= Moderately Resistant MS= Moderately Susceptible S= Susceptible HS= Highly Susceptible

BARI= Bangladesh Agricultural Research Institute

4.3 Comparison between disease incidence (%) and percent disease index at 60 DAT

Among all tested varieties, the highest disease incidence was 51.85 (%) and percent disease index 41.99 of ChLCV was found in BARI-3 variety followed by Dhanua variety of disease incidence was 18.81 (%) and percent disease index 15.23. On the other hand, the lowest disease incidence was 3.7 (%) and percent disease index 2.99 of ChLCV was found in BARI-1 and Bogra jhal variety which preceded by BARI-2 variety disease incidence of 7.41(%) and percent disease index 6 at 60 DAT. Results are shown in figure 1.

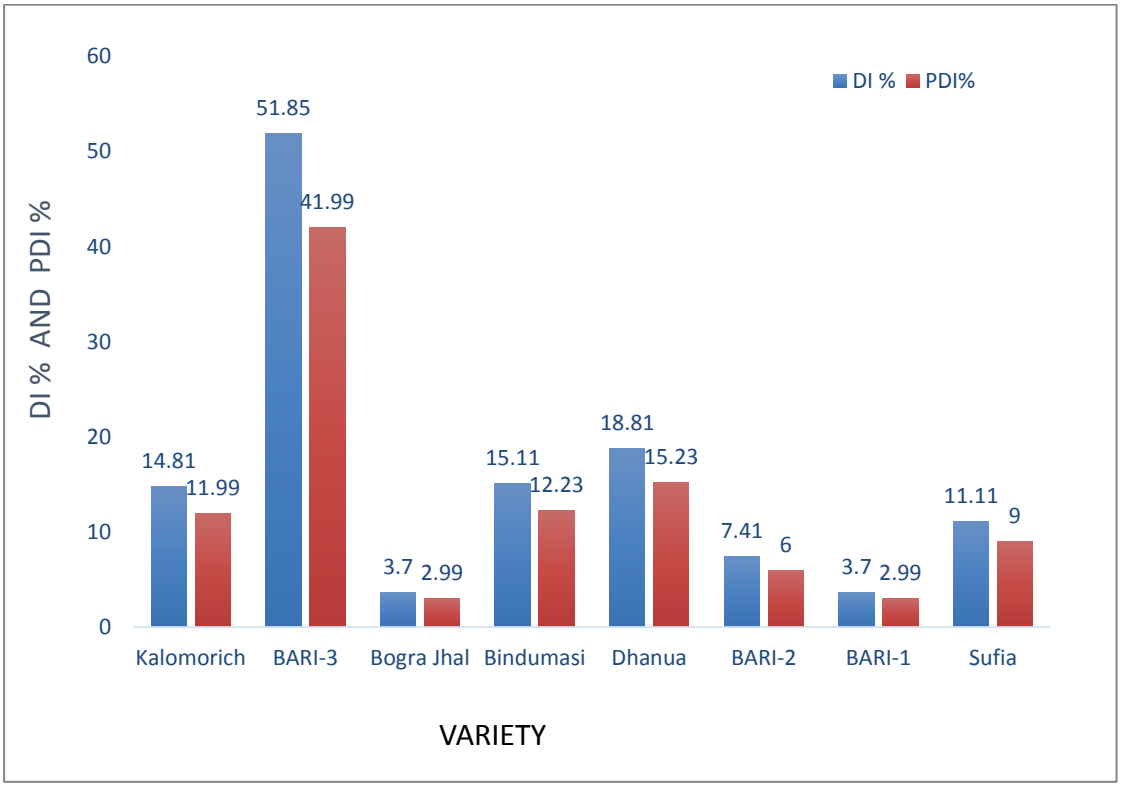


Figure 1. Comparison between disease incidence (%) and percent disease index at 60 DAT

4.4. Comparison between disease incidence (%) and percent disease index at 75 DAT

Among all tested varieties, the highest disease incidence was 61.05 (%) and percent disease index 52.04 of ChLCV was found in BARI-3 variety followed by Dhanua variety which was disease incidence was 29.51(%) and percent disease index 23.09. On the other hand, the lowest disease incidence was 9.4 (%) and percent disease index 7.61 of ChLCV was found in Bograjhal variety preceded by Bindumashi which was disease incidence 11.11(%) and percent disease index 8.99 at 75 DAT. Results are shown in figure 2.

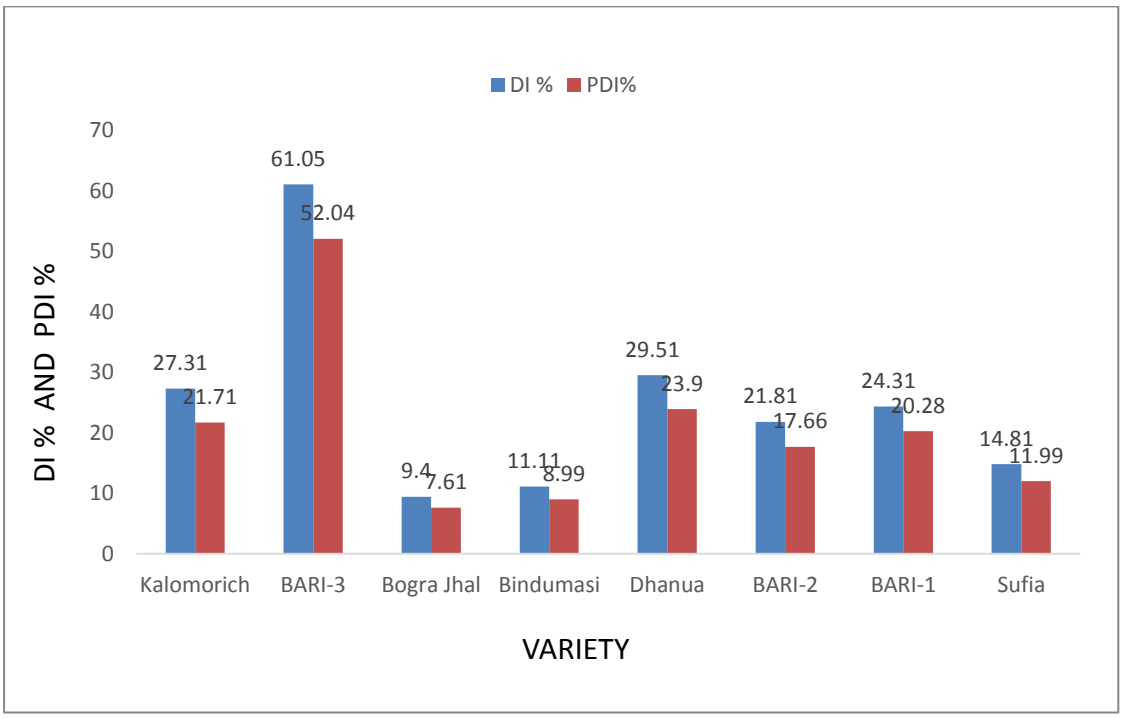


Figure 2. Comparison between disease incidence (%) and percent disease index at 75DAT

4.5. Morphological Changes of shape and size of leaves, twig, flower and fruits due to ChLCV diseases/Symptomology

Infection with Chilli leaf curl virus among different varieties exposed their morphological changes in leaves, twig, flower and fruits which are shown in plate 2.

4.5.1. Changes in leaves

Plants have smooth medium sized, elliptical and slender leaves. Color of leaves turned from light greenish to dark greenish. Infection with *Chilli leaf curl virus* (ChLCV) causes at the early stages of infection upward or downward curling of young and old leaves and stunting in most cases. Curling of leaf margin, reduction in leaf size. The typical symptoms consisting of leaf curling, rolling, puckering, blistering of interveinal areas and thickening and swelling of the veins, shortening of internodes and petioles, crowding of leaves and stunting of whole plants, older leaves may become leathery and brittle.

4.5.2. Changes in twig

Plant with twig shows slender type banches with elliptical leaves shapes. Infected twig almost shows upward or downward of curling leaves with aborted flower and misshapen fruit.

4.5.3. Changes in flower

Flowers with a greenish white to greenish yellow color .Infection with *Chilli leaf curl virus* (ChLCV), Flower shows aborted, shorten, distorted and twisted flower compared to healthy flower.

4.5.4. Changes in fruit

Fruit typically grows a pale yellow and mature to a bright red color. Berry type fruit typically grows at apex with pointed, blunt, sunken shape from left to right. Infection with *Chilli leaf curl virus* shows curling of fruits could be seen in mature plants. Buds are aborted and flowers distorted, shoots grow twisted and fruit may be mishappen.

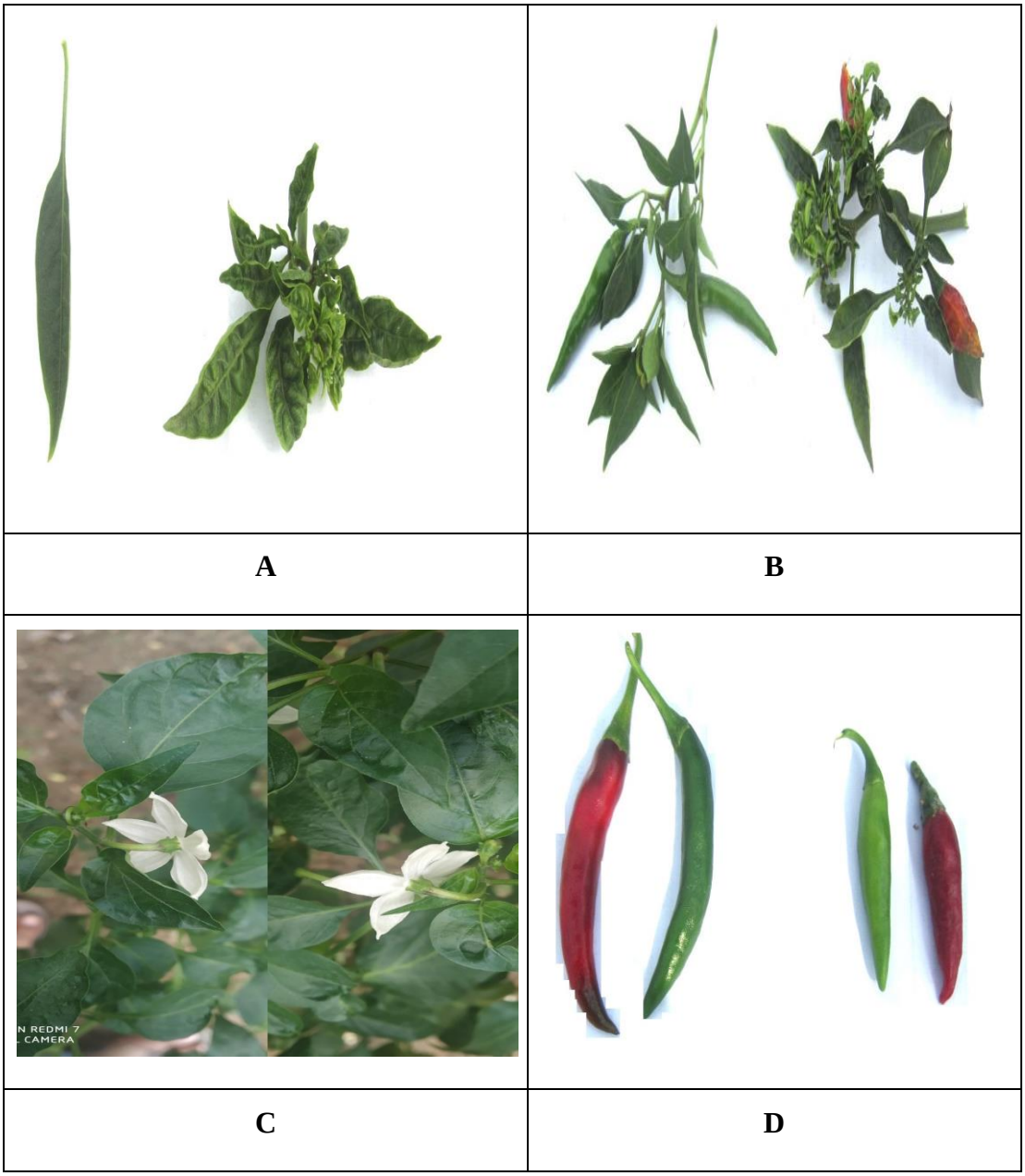


Plate 2. Morphological Changes of shape and size of leaves, twig, flower and fruits due to ChLCV disease

(A) Healthy and infected leaf, **(B)** Healthy and infected twig

(C) Healthy and infected flower, **(D)** Healthy and infected fruits

4.6. Effect of *Chilli Leaf Curl Virus* on morphological features of growth promoting characters among varieties of chilli

Appreciable variation were found in number of healthy and infected leaves, leaf length, leaf breadth, plant height among different varieties of chilli against *Chilli leaf curl virus*. These results are presented in table 6.

4.6.1 Number of healthy leaves and infected leaves per plant against ChLCD at 75 DAT

Number of healthy leaves/plant affected by ChLCD differed significantly among different varieties. Results revealed that the variety of Dhanua produced the highest number of healthy leaves/plant (1011.62) at 75 DAT. BARI-3 variety produced the lowest number of healthy leaves / plant (525.23) at 75 DAT which are statistically similar to BARI-2 (626) and Bograjhal (630.20) variety respectively.

Number of infected leaves/plant affected by ChLCV differed significantly among different varieties. Results revealed that BARI-3 variety showed the highest number of infected leaves/plant (23.93) at 75 DAT. Bindumashi showed the lowest number of infected leaves/plant (9.05) at 75 DAT which is statistically similar with Dhanua (9.45). Among the varietal performance, kalomorich appeared that the moderately lower number of infected leaves/plant (15.24) at 75 DAT which was statistically same with Bograjhal (17.33) and Sufia (17.33) at 75 DAT, respectively.

Table 6. Number of healthy leaves/plant and number of infected leaves/plant at 75 DAT

Variety	No. of healthy leaves 75 DAT	No. of infected leaves75 DAT
Kalomorich	852.21 c	15.24 b
BARI-3	525.23 f	23.93 a
Bogra jhal	630.20 f	17.33 b
Bindu mashi	935.19 b	9.05 c
Dhanua	1008.62 a	9.45 c
BARI-2	626.71 f	20.87 ab
BARI-1	738.92 d	13.10 bc
Sufia	690.25 e	17.33 b
LSD $_{(.05)}$	38.67	3.426
C.V (%)	6.80	6.95

DAT= Days after transplanting, CV= Coefficient of variation,

* LSD was calculated at (.05) level of significance, means followed by same lettering not significantly different.

BARI= Bangladesh Agricultural Research Institute

4.6.2. Number of branches/plant

Variation was found for number of branches/plant at different days after transplanting affected by *ChLCV* considering the performance of different varieties. It was found that the variety of BARI-3 showed the lowest number of branches/plant (4.03) at 75 DAT which is statistically same with the variety of Kalomorich (5.77) and BARI-1, (6.39) at 75 DAT. The highest number of branches/plant was the variety Sufia (8.59). Among the varietal performance, the lowest number of branches/plant was achieved from Bogra jhal (4.44) which was statistically similar with Dhanua (4.55).

4.6.3. Plant height (cm)

The results on the effect of ChLCV infection on plant height of chilli among different varieties are summarized. No significant variation was found on plant height among the varieties. Irrespective of varieties healthy plants produced higher plant height in comparison to ChLCV infected plants. The variety of BARI-3 produced the lowest plant height 55.373 cm. Among varieties, the highest plant height was achieved from Kalomorich 70.630 cm.

4.6.4. Leaf length (cm)

Significant variation was not found for the leaf length at different days after transplanting affected by ChLCV considering the performance of different varieties. It was found that the variety of BARI-3 showed the lowest size of leaf length (4.16 at 75 DAT) which was statistically same with the variety of Bindumashi (5.43cm), Dhanua (5.33cm), BARI-1 (6.03cm) and Sufia (5.06cm), respectively.

4.6.5. Leaf breadth (cm)

The results on the effect of ChLCV infection on leaf breadth of chilli among different varieties are summarized in. Significant variation was found on plant height among the varieties. The variety of BARI-3 produced the lowest size of leaf bredth (1.41cm) which was statistically same with Bindumashi (1.68 cm), Dhanua (1.4 cm) varieties. Kalomorich (2.64 cm) which was statistically same with BARI-2(2.86 cm) and Sufia (2.49 cm).Lower leaf breadth of Bogra jhal (2.14 cm) which was statistically same with BARI-1 (2.14 cm).

Table 7. Mean performance of growth attributing characters among different varieties of chilli against ChLCD at 75 DAT

Variety	Plant height (cm)	No. of branches/plant	leaf length (cm)	leaf breadth (cm)
Kalomorich	70.63a	5.77 b	8.07 a	2.64 a
BARI-3	55.37 a	4.03 b	4.16 c	1.41 b
Bogra jhal	64.90 a	5.55 bc	6.50 b	2.14 ab
Bindu mashi	67.24 a	4.44 cd	5.43 bc	1.68 b
Dhanua	62.29 a	6.51 ab	5.33 bc	1.41 b
BARI-2	61.11 a	4.55 cd	7.04 ab	2.86 a
BARI-1	60.04 a	6.39 b	6.03 bc	2.14 ab
Sufia	57.97 a	8.59 b	5.06 bc	2.49 a
$LSD_{(.05)}$	17.89	0.4132	0.3305	0.2105
C.V. (%)	16.48	19.68	19.16	20.29

CV= Coefficient of variation,

* LSD was calculated at (.05) level of significance, means followed by same lettering not significantly different.

BARI= Bangladesh Agricultural Research Institute

4.7. Effect of *Chilli Leaf Curl Virus* on yield contributing parameters of chili among different varieties

Due to infection of *Chilli Leaf Curl Virus* among the varieties they exposed their different yield contributing parameters, which are shown in table 8.

4.7.1. Number of flowers/plant

Number of flowers/plant was significantly affected by ChLCV under different varieties. Among the varietal performance, the variety of BARI-3 performed the lowest number of flowers/plant (1.89) which was significantly different from all other varieties. It was also found that the variety of Kalomorich showed highest number of flowers/plant (7.00) which are statistically similar with Dhanua (6.77). Among the other varieties, the lowest number of

flowers/plant was achieved from the varieties of Bindumashi (4.0333), Bograjhal (5.3133) which was statistically identical with the each other respectively.

4.7.2. Single fruit length/plant (cm)

Length of fruits/plant affected by ChLCV was significantly against different varieties applied to the crop. Results revealed that the variety, the lowest length of fruits/plant (6.80cm) was found from the variety of BARI-3 which was significantly similar with the varieties of Bograjhal (7.02cm) and Kalomorich (7.18cm), respectively. The highest length of fruits/plant (8.97cm) was produced from BARI-2 which was also significantly different from all other varieties. Among the other varieties, moderately lower length of fruits/plant was found from the variety of BARI-1(7.76cm) and Bindumashi (7.92cm) which was statistically similar with each other.

4.7.3. Single fruit (green) weight (gm)

The ChLCV transmitted by whitefly had significant influence on single fruit (green) weight of chilli against different varieties applied. The variety of BARI-3 produced lowest single fruit (green) weight (1.24 g) which was non-significant with all varieties and preceded by the variety of Bograjhal (1.86 g). The highest single fruit (green) weight (2.60 g) was produced from the variety of Kaloamorich which was followed by BARI-2 variety (2.32 gm). Among the other varieties, the moderately higher single fruit (green) weight (2.32 g) was found from BARI-2 which was statistically identical with the varieties of Bindumashi (2.25), Sufia (2.22), Dhanua (2.21) and BARI-1(2.12), respectively.

Table 8. Mean performance of yield contributing characters against ChLCD among different varieties of chilli at 75 DAT

Variety	No of flowers/plant	Single fruit length (cm)	Single fruit (green) weight (g)
Kalomorich	7.0 a	7.18 c	2.60 a
BARI-3	1.89 e	6.80 c	1.24 c
Bogra jhal	5.31 b	7.02 c	1.86 bc
Bindu mashi	4.03 b	7.92 abc	2.25 ab
Dhanua	6.77 a	8.47 b	2.21 ab
BARI-2	2.33 f	8.97 a	2.32 ab
BARI-1	2.85 de	7.763 abc	2.12 b
Sufia	3.55 cd	7.26 bc	2.22 ab
$LSD_{(.05)}$	0.8349	0.51	0.42
C.V. (%)	16.20	10.68	19.52

CV= Coefficient of variation,

* LSD was calculated at (.05) level of significance, means followed by same lettering not significantly different.

BARI= Bangladesh Agricultural Research Institute

4.8. Mean performance of *Chilli Leaf Curl Virus* on yield (ton/ha) among different chilli varieties

There were significant variation found among all the varieties, are shown in figure 3. Among all varieties, fruit yield (ton/ha) performed lowest in BARI-3 variety against ChLCV which gave 3.43 (t/ha) yield preceded by Bindumashi 3.54 (t/ha).Whereas, the highest fruit yield 7.36 (t/ha) was found in BARI-1 variety.

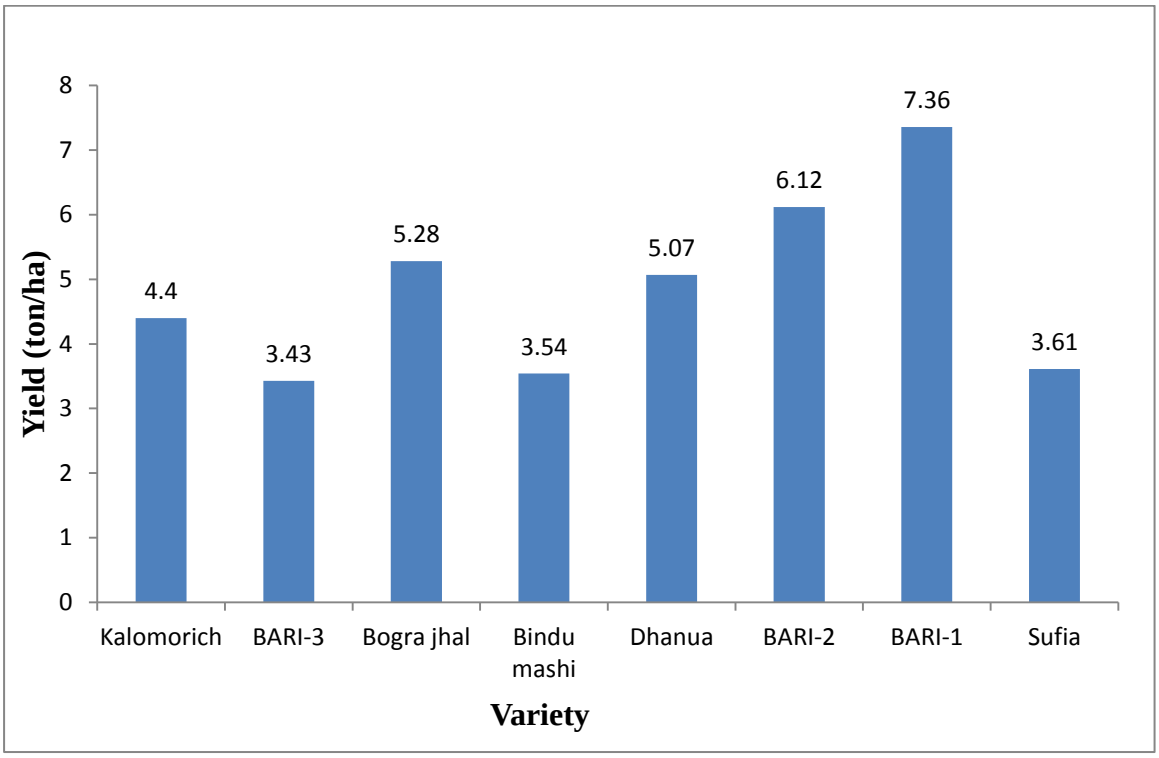


Figure 3. Mean performance of *Chilli Leaf Curl Virus* on yield (ton/ha) among different chilli varieties

4.9. Yield reduction (%) due to ChLCV among different varieties of chilli

Among varietal performance against ChLCV, The recommended yield of these varieties are Kalomorich 5.8 (t/ha), BARI-3 8 (t/ha), Bogra jhal 7.5 (t/ha), Bindumashi 5.5 (t/ha), Dhanua 7.5 (t/ha), BARI-2 10 (t/ha), BARI-1 11 (t/ha) and Sufia 5.5 (t/ha), respectively. Wherares it could be revealed that the highest yield reduction 57.12 (%) was achieved from BARI-3 variety where the substraction from the recommended yield was BARI-3 8 (t/ha) to the actual yield was 3.43 (t/ha) expressed in percentage of yield reduction.

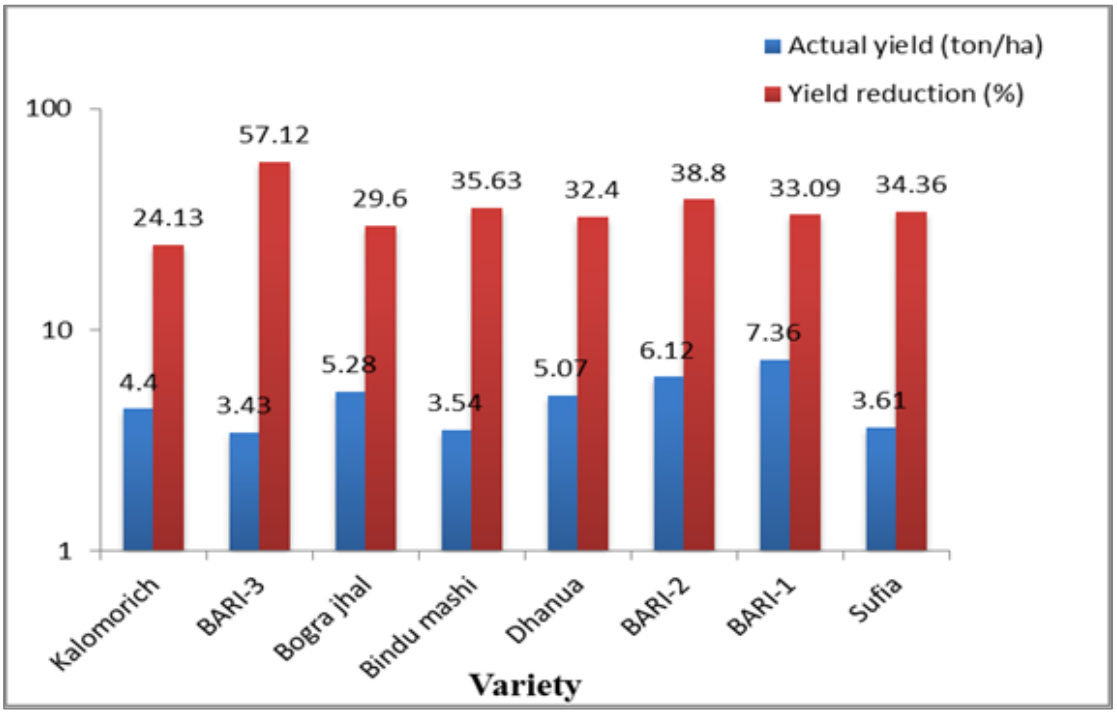
Table 9. Yield reduction (%) due to ChLCV among different varieties of chilli

Variety	Recommended Yield (t/ha)	Actual yield (t/ha)	Yield reduction (%)
Kalomorich	5.8	4.4	24.13
BARI-3	8	3.43	57.12
Bogra jhal	7	5.28	29.6
Bindu mashi	5.5	3.54	35.63
Dhanua	7.5	5.07	32.4
BARI-2	10	6.12	38.8
BARI-1	11	7.36	33.09
Sufia	5.5	3.61	34.36

BARI= Bangladesh Agricultural Research Institute

4.10. Comparison between actual yield (ton/ha) and % yield reduction among different varieties against ChLCV

Significant variations of total yield and % yield reduction were found different varieties of chilli during the experiment due to the effect of *Chilli leaf curl virus.* Yield reduction (%) compared with actual yield the highest yield reduction 57.12 (%) was achieved from BARI-3 variety where the lowest actual yield was 3.43 (t/ha) with worst performance.



Figue 4. Comparison between actual yield (t/ha) and % yield among different varieties against ChLCV

4.11 Relationship between disease incidence (%) and yield (t/ha)

The relationship between disease incidence (%) and yield performance of chilli plants was also studied. From the study it was revealed that there is inverse relation disease incidence (%) and yield**.** When disease incidence is increased, the yield of chilli is decreased. Relation between yield and disease incidence (%) of ChLCV in the field condition are shown in figure 5. This figure showed a negative correlation between disease incidence (%) of ChLCV infection with yield. A regression line was fitted between yield and disease incidence (%) of ChLCV. There was negative and significant relationship (R^2 = 0.513 and Y= -0.0602x+ 7.1756) between yield and disease incidence (%) (figure 5). The R^2 value indicates that the spread of ChLCV in the field might be attributed by yield and 51.30 (%) fruit yield will be affected.

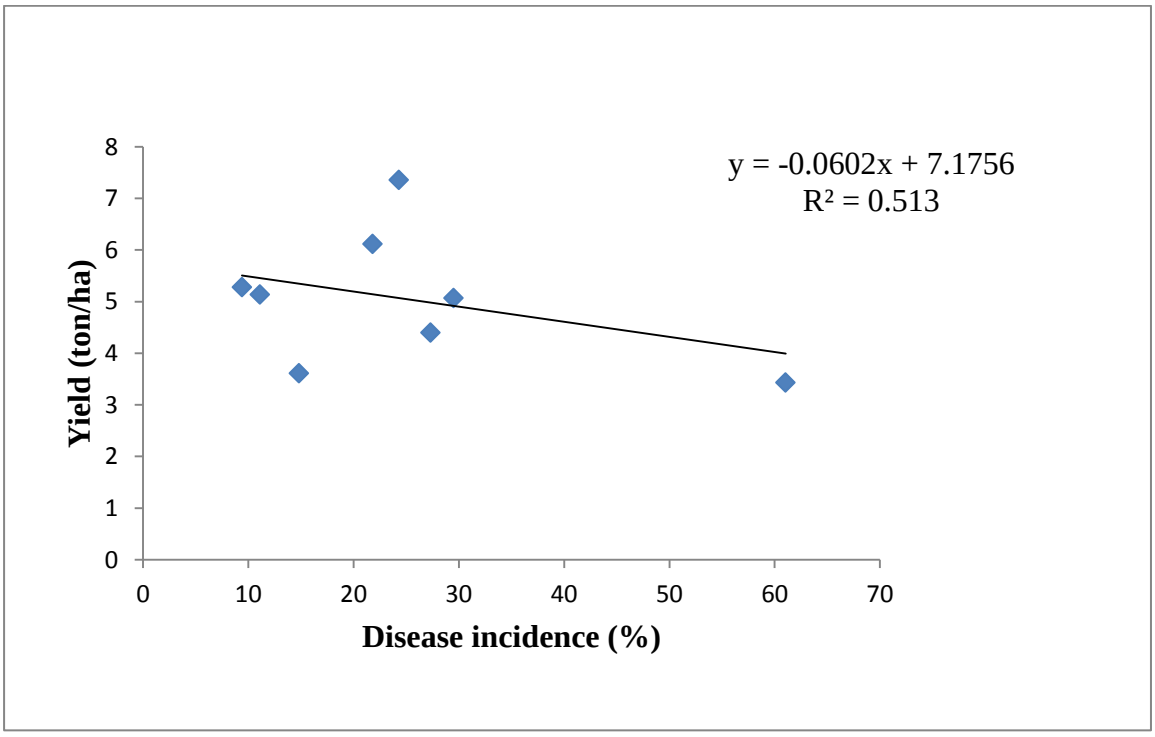


Figure 5. Relationship between disease incidence (%) and yield (t/ha)

4.12 Relationship between disease incidence (%) and yield loss (%)

Relation between yield loss and disease incidence (%) of ChLCV in the field condition are shown in (figure 6).This figure showed a strong positive correlation between disease incidence (%) of ChLCV infection and yield loss. With the increase of disease incidence (%), the yield loss is also increased. A regression line was fitted between yield loss (%) and disease incidence (%) of ChLCV. There was positive and significant relationship (R' = 0.6555 and Y= 44.196x- 47.379) between yield loss and disease incidence (%) (fig. 6). The R2 value indicates that the spread of ChLCV in the field might be attributed by yield loss. It was also found that ChLCV infected plants were maximum when the yield loss of BARI-3 variety was the highest.

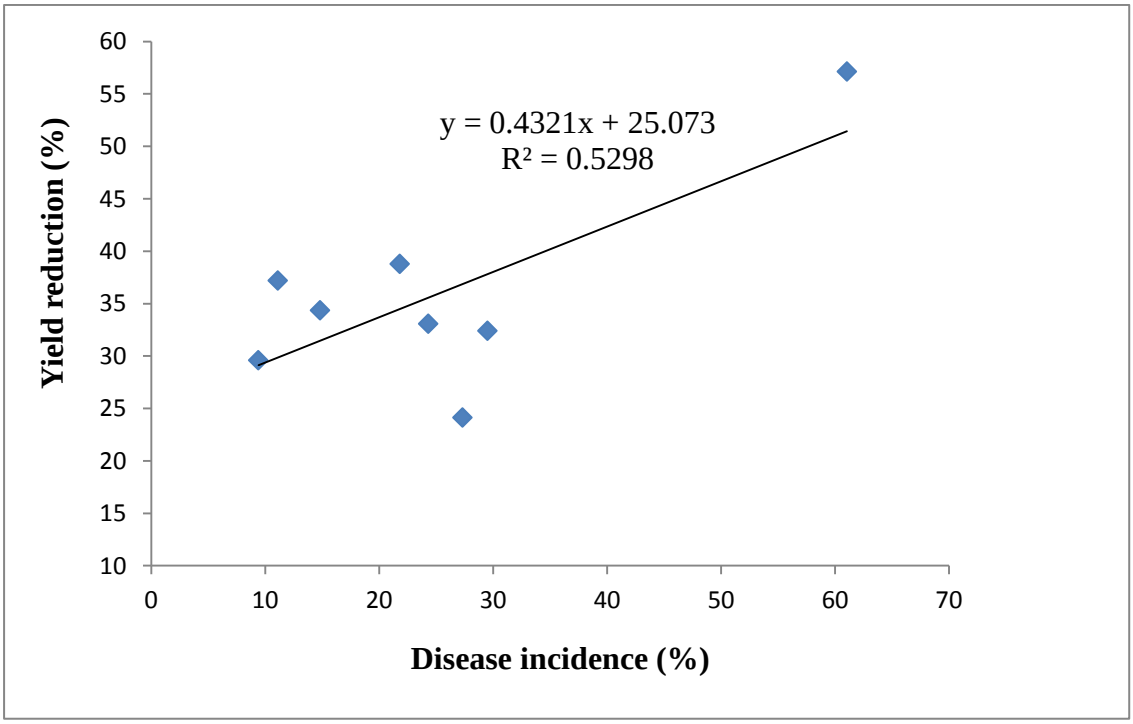


Figure.6. Relationship between disease incidence (%) and yield loss in the chilli field.

DISCUSSION

Chilli Leaf curl virus is an important disease of chilli in Bangladesh. It is existing in the country for several decades and is a threat to chilli cultivation. In Bangladesh, the crop is grown in an area of about 66,235 hectare and its annual production is about 52,215 metric tons which is very low as compared to that of other chili growing countries in the World and the average yield of green chilli is1.3ton/ha (BBS, 2017). *Chilli leaf curl virus* is considered one of the major constrain for the lower yield of chilli in our country.

The present experiment was undertaken to study the varietal performance of different varieties of chilli against *Chilli leaf curl virus* under field condition. The main objective of this study is to assess the disease incidence (%) and percent disease index of *Chilli leaf curl virus* among different varieties. Considerable varietal performance was observed against *Chilli leaf curl virus* using different varieties. Different varieties were used *viz.* Kalomorich, BARI-3, Bogra jhal, Bindumashi, Dhanua, BARI-2, BARI-1, Sufia for the evaluation of disease incidence (%) against ChLCV.

Disease incidence (%) and PDI

In present investigation, it was noticed that the disease incidence (%) due to *Chilli Leaf Curl Virus* was found in almost all the plots at 75 DAT. The highest disease incidence was recorded in the variety of BARI-3 51.85 (%) at 60 DAT. The lowest disease incidence was found in both Bogra jhal and BARI-1 variety 3.70 (%) at 60 DAT. At 75 DAT, the lowest ChLCV disease incidence 9.40 (%) was again found in Bograjhal variety. On the other hand, the highest disease incidence 61.05 (%) was found in BARI-3 variety. At 60 DAT, the lowest percent disease index of ChLCV was found 2.99 (%) in BARI-1 and Bogra jhal giving reaction Moderately Resistant (MR) and the highest percent disease index of ChLCV was recorded 41.99 (%) in BARI-3 variety giving reaction of Susceptible (S). At 75 DAT, the lowest percent disease index 7.61 (%) was again found in Bograjhal variety which had given Moderately Resistant (MR) reaction and the highest percent disease index 52.04 (%) was

found in BARI-3 variety had given Highly Susceptible (HS) reaction. The results regarding the percent disease index of ChLCV in chilli that observed in this study was almost similar as observed by Sastry and Singh (1973), Al-Musa (1982), Green and Kalloo (1994) and Ali *et al*. (2005). Azam *et al.* (1997) in chili.

Grouping of chilli varieties in to different categories for *Chilli leaf curl virus* resistance

In the following study, none of the varieties recorded zero percent ChLCV disease incidence in field. Among the varieties, the highest percent disease index 52.04 (%) under natural field conditions was achieved from BARI-3 variety with highly susceptible reaction and infection more than 51%. Out of eight varieties, very low percent disease index was observed in two varieties *viz.,* Bograjhal 7.61 (%) and Bindumashi 8.99 (%) with moderately resistant reaction. Disease index was 1-10% found by Mali *et al.* (2006); Kumar *et al.* (2006) in chili varieties due to ChLCV.

Comparison between disease incidence (%) and percent disease index

The experiment indicates, the highest disease incidence was (51.85%) and percent disease index 41.99 (%) of ChLCV was found in BARI-3 variety. On the other hand, the lowest disease incidence 3.7 (%) and percent disease index 2.99 (%) of ChLCV was found in BARI-1 and Bogra jhal variety at 60 DAT. At 75 DAT, the highest disease incidence was 61.05 (%) and percent disease index 52.04 (%) of ChLCV was found in BARI-3 variety and the lowest disease incidence was 9.4(%) and percent disease index 7.61 (%) of ChLCV was found in Bograjhal variety, similar findings investigated by Kumar *et al.* (2011) in different chili varieties because of ChLCV.

Symptomology

The symptoms observed are downward curling of leaves, light and, vein clearing, puckering of leaf lets, stunting and bushy appearance due to reduced internodal length with partial to complete sterility and Infected twig almost shows upward or downward of curling leaves with aborted flower and misshapen fruit. Similar symptoms were observed by Vasudeva and Samraj (1948); Sastry and Singh (1973); Muniyappa (1980); Sakia and Muniyappa (1989) *Chilli leaf curl virus* is most destructive and chilli leaf curl disease means abaxial and abaxial curling of leaves accompanied by puckering and blistering of interveinal areas and thickening and swelling of veins, reported by Kumar, R. V., Singh, A. K. and Chakraborty, S. (2012) in different chili varieties due to ChLCV.

Effect on morphological features of growth promoting characters among varieties of chilli due to ChLCV

The lowest number of leaves, flowers and fruits per plant were recorded in the variety of BARI-3. Significant variation was found for number of branches/plant at different days after transplanting affected by ChLCV considering the performance of different varieties. The variety of BARI-3 showed the lowest number of branches/plant. The highest number of branches/plant of the variety Sufia. Irrespective of varietes healthy plants produced higher plant height in comparison to ChLCV infected plants. The variety of BARI-3 produced the lowest plant height. Among the varieties, the highest plant height was achieved from Kalomorich. The lowest number of leaves, flowers and fruits per plant were recorded in the variety of BARI-3. On the other hand, it was found that the variety of BARI-3 showed the lowest size of leaf length (4.16cm) at 75 DAT and leaf bredth was (1.41cm). Similar results were found in the previous study that was conducted by Zeeshan and Kudada (2018) on chilli disease caused by ChLCV.

Effect of ChLCV on yield contributing parameters of chili among different varieties

The yield of individual variety depends on the number of flowers and fruits per plant. The variety of BARI-3 performed the lowest number of flowers/plant. The variety of Kalomorich showed highest number of flowers/plant which were statistically similar with Dhanua. It was observed that the disease intensity progressively increased and number of fruit weight progressively decreased with the later infection of the disease. The same results were found in the previous study that was conducted by Zeeshan and Kudada (2018) due to ChLCV infection on chili varieties.

Comparison Yield and Yield reduction (%)

The lowest yield was achieved from the variety of BARI-3 among all varieties. Whereas the highest yield per plant/plot was found in the BARI-1. Yield reduction was calculated over recommended yield and compared with actual yield. But considering the economic condition, the actual yield of BARI-3 variety was lowest from the recommended yield. That's why the yield reduction % was highest of BARI-3. The same results were found in the previous study that was conducted by Mousanejad *et al*. (2010), assessment of yield loss due to rice blast disease.

Relationship between disease incidence (%) and fruit yield

From the relationship it was revealed that there was inverse relation disease incidence (%) and yield**.** When disease incidence is increased, the yield of chilli is decreased. So, it considered that the condition of a negative relation between disease incidences (%) of ChLCV infection and yield supported by the findings of Gupta (2000), Senanayake *et al.* (2006) reported maximum disease incidence (100%) observed when chilli was infected by chilli leaf curl complex disease. Severely affected plants were noticed reduction of plant growth and no fruit production.

Relationship between disease incidence (%) and yield loss (%)

Relation between yield loss and disease incidence (%) of ChLCV in the field condition showed a strong positive correlation between disease incidence (%) and yield loss. It found that ChLCV infected plants were maximum when the yield loss of BARI-3 variety was the highest. The findings of Lenné and Sonoda (1982) which was conducted for anthracnose infection on yield of the tropical forage legume *Stylosanthes hamate* supported the findings.

CHAPTER V

SUMMARY AND CONCLUSION

Chilli (*Capsicum frutescens)* is the second most important and widely grown vegetable crop in the world belongs to the family *Solanaceae*. It is one of the most popular and nutritious spice all over the world including Bangladesh. Chilli was originated in the American tropics and it has been propagated throughout the world including the tropics, subtropics, and also temperate regions (Pickersgill, 1997). As a winter crop, it is grown mostly in Cumilla, Noakhali, Faridpur, Barisal, Patuakhali, and Bogura. In 2017, world production of fresh green chilli and peppers was 33.2 million ton and Bangladesh contributes 5% of the global total (FAOSTAT, 2017). In Bangladesh, the crop is grown in an area of about 66,235 hectare and its annual production is about 52,215 metric tons which is very low as compared to that of other chili growing countries in the World and the average yield of green chilli is1.3 t/ha (BBS, 2017). Chilli leaf curl is the most serious disease and limiting factor in chilli cultivation in many parts of the country. Hence, whitefly infestation can cause severe and also transmitted *Chilli Yellow Leaf Curl Virus* performed transmission by it, and crop damage can be reached up to 100%.

The study on chilli was carried out at the central Farm of Sher-e- Bangla Agricultural University, allowed for the Department of Plant Pathology Dhaka-1207, during October to march, 2018 with normal agronomic practices. The study was to evaluate the performance of selected varieties against *chili leaf curl virus* under field condition. In total 8 varieties were considered viz. BARI-1, BARI-2, BARI-3, Bogra jhal, Bindumashi, Dhanua, Kalomorich and Sufia. From the investigation, the performance of selected eight varieties against ChLCV in case of disease incidence (%), percent disease index (PDI), growth contributing characters like plant height (cm), number of branches, number of healthy and infected leaves, leaf length (cm) and leaf breadth (cm), yield contributing characters such as Number of flower/plant, Single fruit length, fruit weight (g), yield/plot, yield (t/ha) were discussed.

In case of disease incidence (%) of ChLCV, the highest disease incidence was recorded 51.8 (%) and 61.05 (%) at 60 DAT and 75 DAT respectively was recorded in the variety of BARI-3. The lowest disease incidence 3.70 (%) at 60 DAT both BARI-1 and Bograjhal variety and 9.40(%) was recorded in bograjhal at 75 DAT. In case of PDI, the highest PDI 41.99 (%) with susceptible and 52.04 (%) with highly susceptible reaction at 60 DAT and 75 DAT respectively was also recorded in BARI -3 variety. The lowest PDI was 2.99(%) found in variety of both Bograjhal and BARI-1 with the reaction of Moderately Resistant at 60 DAT. At 75 DAT the lowest PDI also 7.61(%) was recorded in Bograjhal variety with Moderately Resistant reaction. BARI-3 variety showed the highest disease incidence 51.85(%) and 61.05(%) and percent disease index 41.99(%) and 52.04(%) against ChLCV at 60 DAT and 75 DAT respectively.

The symptoms observed are downward curling of leaves, light and, vein clearing, puckering of leaf lets, Infected twig almost shows upward or downward of curling leaves with aborted flower and misshapen fruit.

In the following study, all growth and yield contributing characters including disease incidence (%) showed significant reduction of growth and yield among the varieties due to ChLCV. There were considerable yield reductions among the varieties due to ChLCV from each of their recommended yield. None of the varieties had impressive tolerance against the diseases. However, it needs further investigations before final recommendation.

There was negative correlation between disease incidence (%) of ChLCV and yield (t/ha). With the increased of disease incidence (%) among the chilli varieties due to ChLCV, yield of chilli varieties decreased.

Relation between yield loss and disease incidence (%) of ChLCV in the field condition showed a strong positive correlation between disease incidence and yield loss. It found that ChLCV infected plants were maximum when the yield loss of BARI-3 variety was the highest.

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

- In case of disease incidence of ChLCV, the highest disease incidence was recorded 51.85(%) and 61.05(%) at 60 DAT and 75 DAT respectively was recorded in the variety of BARI-3. The lowest disease incidence 3.70(%) at 60 DAT both BARI-1 and Bograjhal. At 75DAT the lowest disease incidence 9.40(%) was recorded in bograjhal.
- Among the varieties, two varieties (Kalomorich, Dhanua) showed susceptible reaction, three varieties (Bogra jhal, Bindumashi) showed moderately resistant reaction, and other three varieties (BARI-2, BARI-1, Sufia) showed moderately susceptible reaction. Only BARI-3 variety was highly susceptible against ChLCV for chilli cultivation compared to other considering variety.
- ChLCV disease produces leaf curl symptoms, causes vein clearing on young leaves at the early stages of infection upward curling of young and old leaves and stunting in most cases.
- Study on all growth and yield contributing characters including disease incidence showed significant reduction of growth and yield among the varieties due to ChLCV. There were considerable yield reductions among the varieties due to ChLCV from each of their recommended yield. None of the varieties had impressive tolerance against the diseases.
- A negative correlation was found between disease incidence (%) and yield (ton/ha) of ChLCV. Relation between yield loss and disease incidence (%) of ChLCV in the field condition showed a strong positive correlation between disease incidence and yield loss.
- Considering the disease incidence, PDI, growth and yield contributing characters among the chilli varieties it was evident that no resistant variety was found from this investigation. Whereas, two local variety Bogra jhal and Bindu mashi showed appreciable performance against ChLCV.

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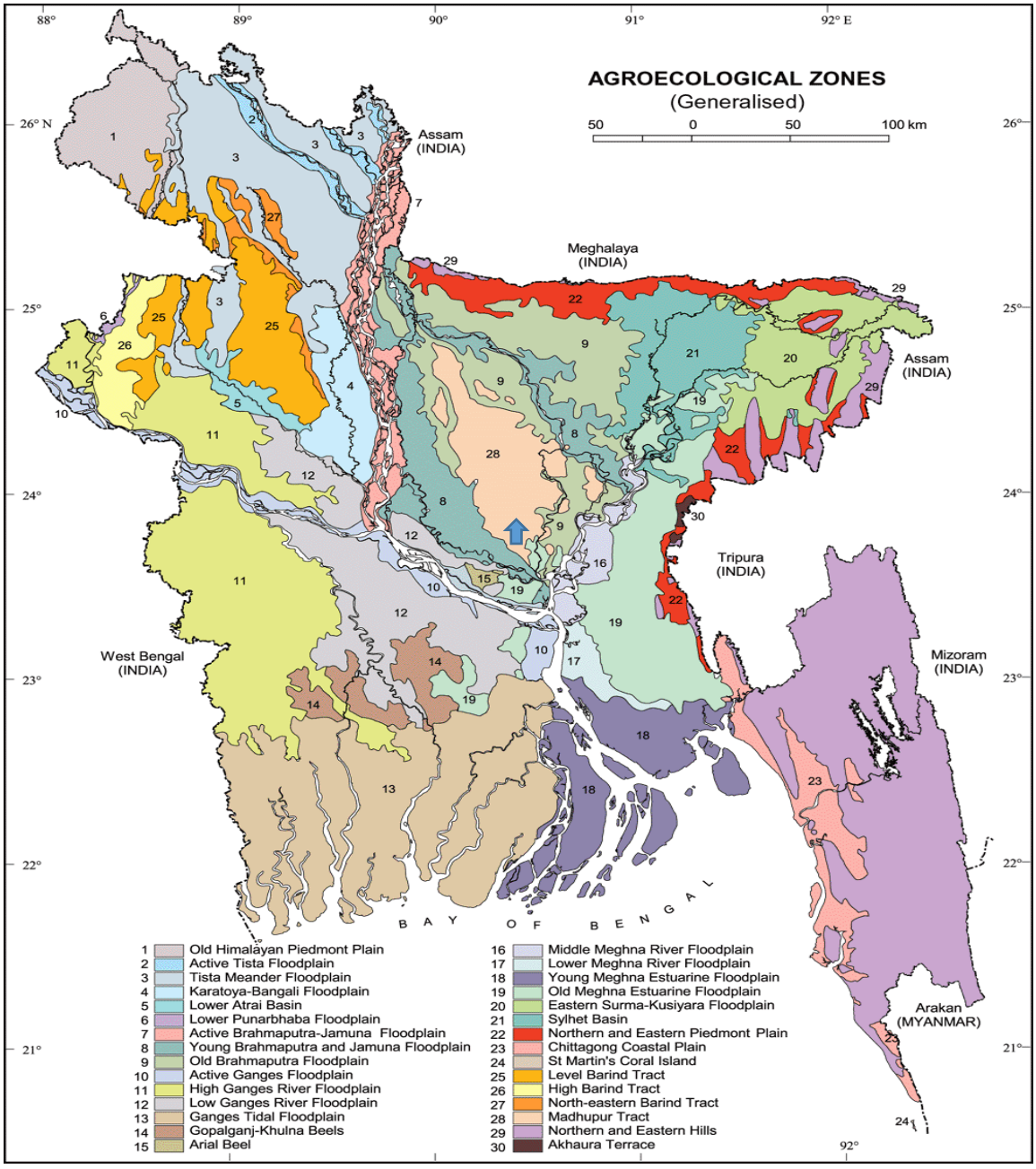
APPENDICES

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



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

Morphological characteristics

Morphological features	Characteristics
Location	Experimental Field, SAU, Dhaka
AEZ	Madhupur Tract (28)
General Soil Type	Shallow red brown terrace soil
Land type	Medium high land
Soil series	Tejgaon
Topography	Fairly leveled
Flood level	Above flood level
Drainage	Well drained
Texture	Loamy

Chemical composition

Constituents	0-15 cm depth
p^H	6.00-6.63
Total N (%)	0.07
Available P (μ g/g)	18.49
Exchangeable K (μ g/g)	0.07
Available S (μ g/g)	20.82
Available Fe (μ g/g)	229
Available Zn (μ g/g)	4.48
Available Mg (μ g/g)	0.825
Available Na (μ g/g)	0.32
Available B (μ g/g)	0.94
Organic matter (%)	0.83

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

Appendix III. Monthly meteorological information during the period from November, 2018 to April, 2019.

Year	Month	Temperature (^{0} C)		Relative humidity (%)	Total rainfall (mm)
		Maximum	Minimum		
2018	November	28.10	11.83	58.18	47
	December	25.00	9.46	69.53	00
2019	January	25.2	12.8	69	00
	February	27.3	16.9	66	39
	March	31.7	19.2	57	23
	April	33.50	25.90	64.50	119

Source: Metrological Centre, Agargaon, Dhaka (Climate Division)

Appendix IV. Photograph showing plants in chilli on the experimental field

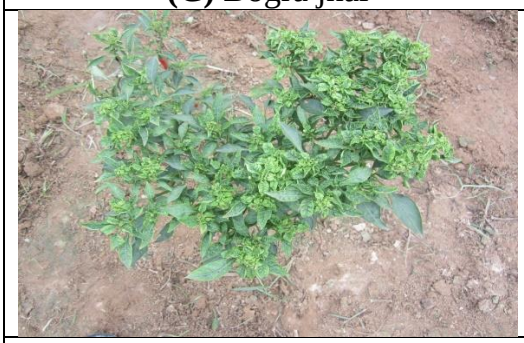
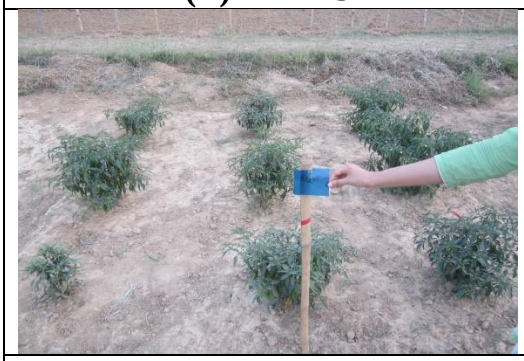
(A) Experiment plot

(B) Healthy plant

(C) Severely diseased plant

(D) Harvesting and data collection

Appendix V. Different Chilli varieties in the experiment field

	
(A) BARI-1	**(B)** Bindumashi
	
(C) Bogra jhal	**(D)** BARI-2
	
(E) BARI-3	**(F)** Sufia
	
(G) Dhanua	**(H)** Kalomorich