VARIETAL SCREENING OF OKRA AGAINST *YELLOW VEIN CLEARING MOSAIC VIRUS (YVCMV)*

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This is to certify that thesis entitled, "VARIETAL SCREENING OF OKRA AGAINST YELLOW VEIN CLEARING MOSAIC VIRUS (YVCMV)" 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 IN PLANT PATHOLOGY, embodies the result of a piece of bona fide research work carried out by, Registration No. 13-05760 under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma in any institute.

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

Dated: 18 August, 2015
Place: Dhaka, Bangladesh

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ABSTRACT

The research work was conducted in the experimental site of department of Plant Pathology, Sher-e-Bangla Agricultural University, Dhaka-1207, to screen out the resistant cultivars of okra against *Yellow Vein Clearing Mosaic Virus (YVCMV)* transmitted by the white fly (*Bemesia tabaci*) during the period from March to July, 2014. Nine okra cultivars viz. BARI dherosh-1, Green finger, Anguli, Tower seed, Raja, Yuvraj, Shyamol bangla, Parvani kranti and Orka onamika were used as treatments. The screening of the selected cultivars was done based on different parameters like morphological features, yield and yield contributing characters and physiological features. In case of % disease incidence, the lowest disease incidence was found in cv Parvani kranti (9.74%) and the highest disease incidence was found in cv Yuvraj (81.14%) followed by Orka onamika (80.81%), while the other cultivars like Shyamol bangla, Raja, Anguli, Green finger and Tower seed showed high to moderate incidence respectively. In case of yield contributing characters like number of flowers per plant, number of fruits per plant comprising the yield, the highest yield per plant was recorded in Parvani kranti (616.0 gm) followed by BARI dherosh-1 (542.3 gm). The lowest yield per plant was recorded in cv Yuvraj (270.0 gm) preceded by cv Shyamol bangla (280.0 gm). The others gave moderate yield per plant. In case of physiological features, highest net chlorophyll content per plant was recorded in cv Parvani kranti (65.10 µ mol m^{-2} s^{-1}) while the lowest in cv Anguli (38.17 µ mol m^{-2} s^{-1}). In case of net assimilation rate, intercellular CO_2 concentration, respiration rate and stomatal conductivity, the performance of the cultivar Parvani kranti was much better than the other cultivars against *Yellow vein clearing mosaic virus (YVCMV)*. Parvani kranti showed better resistancy against *YVCMV* over others.

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CHAPTER I

INTRODUCTION

Okra (*Abelmoschus esculentus* L. Moench) is the member of Malvaceae and known as Lady's finger. It is locally known as "dherosh" or "bhindi". It is an annual vegetable crop grown from seed in tropical and sub-tropical parts of the world. Okra is probably originated in tropical Africa or possibly in tropical Asia, and is now widely grown throughout the tropics. The crop is well distributed throughout the Indian subcontinent and East Asia (Rashid, 1999). Its tender green fruits are popular as vegetables among all classes of people in Bangladesh and elsewhere. Though it is popular, its production is mainly concentrated during the summer.

Okra is a multipurpose crop. Its tender pods are cooked as vegetables, stewed with meat, cooked to make soup and also canned and dried. Okra seeds are roasted, grounded and used as substitute of coffee in Turkey. Okra is a nutritious and delicious vegetable, fairly rich in vitamins and minerals (Kushak *et al.,* 2003). The edible portion of pod (100 gm) has moderate levels of vitamin A (0.01 mg) and vitamin C (18 gm), calcium (90 mg), phosphorus and potassium. The content of thiamine (0.07 mg), riboflavin (0.08 mg) and niacin (0.08 mg) per 100 gm edible portion of pod is higher than that of many vegetables (Rashid, 1999). It is also the good sources of gum, starch, spice etc. Okra is said to be very useful against genito-urinary disorders, spermatorrhoea and chronic dysentery. Its medicinal value has also been reported in curing ulcers and relief from hemorrhoids (Adams, 1975).

The essential and nonessential amino acids that okra contains are comparable to that of soybean. Okra contains special fiber which takes sugar levels in blood under control, providing sugar quantity, acceptable for the bowels. Mucilage found in okra, is responsible for washing away toxic substances and bad cholesterol, which loads the liver. Okra ensures recovery from psychological and mental conditions, like, depression and general weakness. Okra is additionally applied for pulmonary inflammations, bowel

irritations, and sore throat. According to Indian researches, okra is a complex replacement for human blood plasma. In order to keep the valuable substances safe, it's necessary to cook okra as shortly as possible, processing it either with steam, or on low heat (Purseglove *et al.*, 1999).

In Bangladesh, vegetable production is not uniform round the year. Most of the vegetables are produced in the winter, but very low in the summer; around 30% of the total vegetables are produced in the kharif season, while 70% produced in the Rabi season (Anon, 1993). Among them okra is very important one. The yearly okra production is 43.21 thousand metric tons from 10.35 thousand hectors of land in Bangladesh (BBS, 2011). The production is quite lower in comparison to our neighbor country like, in India it produces 7896.3 thousand metric tons from 1148.0 thousand hectors of lands (FAO, 2010). The yield is very low compared to that of other developing countries where the yield as high as 7-12 t/ha (Schippers, 2000). In Bangladesh the yield of okra is very low due to lack of management and disease incidence.

The yield and quality of okra depend on several factors like disease, insects, soils and climatic conditions. Among the factors responsible for limiting the yield and quality of okra, *Yellow vein clearing mosaic virus (YVCMV)* is the most important one as reported by Sastry and Singh (1974). The virus may cause more than 90% yield loss (Akanda, 1991). Kulkarni first reported the virus in 1942 as a destructive disease of okra prevalent in Bombay area of India. Later on, the virus was systematically studied and characterized by different Indian scientists (Cooper and Verma, 1950; Kumar and Moorthy, 2000 and Verma, 1955). They concluded that *Yellow vein clearing mosaic virus* is a member of Geminivirus group which is semi-persistently transmitted by whitefly (*Bemesia tabaci*). The virus is also transmitted through grafting, but not mechanically or through seeds. *Yellow vein clearing mosaic virus* has been considered as the most important factor of yield reduction in india and some other okra growing regions of the sub-continent (Farnendo and Udurawana, 1942; Harender *et al.*, 1993, Nath *et al.*, 1993, Sastry and Singh, 1975 and Singh and Chakrabarti, 1978). The virus seems to attack okra plants in

any stage of plant growth, spreads quickly in the field and adversely affects the growth and yield contributing characters due to remarkable alternation in cellular components of the infected plants (Hossain *et al.,* 1998; Sarma *et al.,* 1995).

Yellow vein clearing mosaic virus proved to be a severe problem in Bangladesh which can alone makes the okra cultivation non-profitable as reported by Akand (1991) and Ali (1999). The systematic works on *Yellow vein clearing mosaic virus* have not yet been done in Bangladesh. Some sporadic works have been reported to find resistant variety or control measures (Ali, 1999 and Ali *et al.,* 2000). Most of the research so far conducted in Bangladesh was disease survey type which listed the name of the disease observing the field symptoms, screening the varieties against the disease under natural conditions (Akanda, 1991 and Akanda *et al.,* 1991). Okra crop is suffered by many biotic and abiotic stresses. Among the different biotic stresses, *Yellow vein clearing mosaic virus (YVCMV)* is the number one devastating disease of okra. *YVCMV* is a semi persistent virus which transmitted by white fly *(Bemesia tabaci).*

The growth and development of a plant depends on its normal physiological and morphological processes. The pathogen may change the physiological and morphological processes to the infected plant. There are some reports on biochemical changes of several crops other than okra due to virus infection (Leal and Lastra, 1984; Haider and Hossain, 1994). Information regarding virus infection causing tremendous yield losses of okra is available (Hossain and Meah, 1989). But study on pigment content and physiological changes in virus infected okra is scanty.

Considering the facts the research program was designed with the following objectives-

- To evaluate the incidence level of okra *Yellow vein clearing mosaic virus (YVCMV)* against the popular cultivars.
- To screen the resistance okra cultivars against the *YVCMV* under pot condition.
- To investigate the morphological and physiological changes of the infected plant in compared to the healthy plants of okra.

CHAPTER II
REVIEW OF LITERATURE

Yellow vein clearing mosaic virus (YVCMV) is the most destructive virus of okra in all okra growing countries. Kulkarni (1942) first reported the occurrence of a virus which was responsible for huge yield reduction of okra in Bombay, India. Uppal *et al.*, (1940) investigated the virus infecting okra and named it as *Yellow vein clearing mosaic virus.* The same disease was described as Yellow vein banding disease although the disease was characterized by vein clearing symptom and there was no evidence that the veins remained green or were banded by strips of yellow tissue in Ceylon by Fernando and Udurawana (1942). Bhendi yellow vein mosaic disease was first reported from Bombay (presently Mumbai) in India (Kulkarni, 1942). The causative virus, *Bhendi yellow vein mosaic virus (BYVMV),* was shown to be a begomovirus based on its morphological and serological relationship with other begomoviruses, such as *African cassava mosaic virus* (Harrison *et al.*, 1991).

Capoor and Verma (1950) worked on *yellow vein clearing mosaic virus* of okra and concluded that the disease is a serious problem for okra cultivation in India. The virus-vector relationship of okra yellow vein mosaic virus was also studied in India by Verma (1952). It was then established that the virus spraed by an insect vector (*Bemesia tabaci*) and through bud grafting (Capoor and Verma, 1950; Verma 1952).

Sastry and Singh (1974) demonstrated that in the Indian subcontinent, the virus is however distributed in the sub-tropical regions in the rainy season crop and in the tropical regions in the spring-summer crop. Late on, Handa (1993) conducted electron microscopy of virus while he was working in Indian Agricultural Research Institute (IARI) for his PhD degree and concluded that okra *yellow vein clearing mosaic virus* is a member of graminivirus group. It, therefore seem that

yellow vein clearing mosaic virus of okra was studied in India extensively and introduced by the scientists mainly to plant virus literature. However, there are controversies or differences in the nomenclature and abbreviation of the virus name infecting okra. In most, Indian literatures, the virus was named as *Yellow vein clearing mosaic virus (YVCMV)* of bhindi, Bhindi/Bhendi *yellow vein mosaic virus (BYVMV), Hibiscus yellow vein mosaic virus (HYVMV), Okra yellow vein mosaic virus (OYVMV),* etc. (Ali *et al.,* 2000; Bhagat, 2000; Borah and Nath, 1995; Handa and Gupta, 1993; Sharma *et al.,* 1987). In Bangladesh, a similar disease has been investigated as *Lady's finger yellow vein clearing mosaic virus, Okra mosaic virus* (Anonymous, 1993; Akanda, 1991; Miah, 1988). In the recent study, the name of the virus is used as *Okra yellow vein clearing mosaic virus (OYVCMV)* or simply *Yellow vein clearing mosaic virus (YVCMV)* to accommodate all these synonyms and also to differentiate the other viruses infecting okra.

The works on 0kra *yellow vein clearing mosaic virus* conclusively proved that the disease manifests itself with the vein clearing symptoms, which gradually transformers to vein mosaic, chlorosis, etc. as typical symptoms. The virus seemed to be non-transmissible mechanically and through seeds. The virus is also found to be non-persistently by an insect vector (*Bemesia tabaci*) and also through grafting. It was also established that the virus is a member of geminivirus group (Handa and Gupta, 1993; Handa, 1993; Harrison *et al.,* 1991; Capoor and Verma, 1950).

The other viruses so far infect okra have been reported by Chakraborty *et al.,* (1997) and Givord *et al.,* (1972). The virus reported by Givord *et al.,* (1972) was found to be mechanically transmitted and the other one reported by Chakraborty *et al.,* (1997) was identified as *Okra enation leaf curl virus*, which differed distinctly with *OYVCMV* in respect to symptom, severity and yield damage as reported by Capoor and Verma (1950), *Harender at el.,* (1993), Nariani and seth (1958), Nath and Saikia (1993) and Sastry and Singh (1975).

Characteristics of *YVCMV*

Symptoms

The common symptoms of okra *yellow vein clearing mosaic virus (YVCMV)* are vein clearing, vein chlorosis and yellowing having mosaic noted by the researches worked on the virus at the beginning (Handa 1991, Cooper and Verma 1950, Uppal *et al.*, 1940 and Kulkarni 1942). They also included dwarfing of the infected plants those produced distorted small sized fruits as the peculiarity of the symptoms of *YVCMV.*

Fernando and Udurawana (1942) observed the development of vein banding along with vein clearing, chlorosis and stunting due to a virus disease of okra at Srilanka and they named the virus as *Okra yellow vein banding virus.* The severe stunting of *OYVMV* infected plants was reported by Sastry and Singh (1975). The infected plants produced few leaves and fruits as they described.

Capoor and Verma (1950) also studied symptomatology and host range and noted that the first visible symptom is small vein clearing due to *Yellow vein mosaic virus* infection which gradually extends to other veins and finally turns into vein chlorosis, vein banding and profuse vein-swelling on the under sides of leaves. The veins of the leaves of infected plants are thick, brittle, dark green and curl downward. The infected plants produce pale colored, hard and fibrous fruits. Mechanical inoculation test conducted by them was found to be non-responsive. Seed transmission test using seeds from infected plants also proved to be negative. Graft transmission using buds of infected plants was positive in their experiment. Insect transmission using jassids (*Empoasca devastans* Distant, *Empoasca* sp.), Aphid (*Aphis gossypii* Glover) and Whitefly (*B. tabaci* Genn) was conducted by the same authors and the result revealed that among the species tested, only *B. tabaci* could be able to transmit the virus using dodder (*Cuscuts reflexa* Roxb). Capoor and Verma (1950) also reported that the host range of *Yellow vein mosaic virus* of okra is restricted to malvaceous plants although they could be able to

transmit virus in six different plant species out of 34 different plant species tested through vector inoculation.

Handa and Gupta (1993) characterized the *Yellow vein mosaic virus* of bhindi (*Abelmoschus esculentus* L.) as a geminivirus having 18 × 30 nm in size. They performed ELISA test using polyclonal antiserum of *Indian cassava mosaic bigeminivirus (ICMV)* and found close relationship of *Yellow vein mosaic virus* of okra with *ICMV*. The result also demonstrated that *Bhindi Yellow vein mosaic virus* was more closely related to *ICMV* than that of *African cassava mosaic bigeminivirus (ACMV).*

Virus-vector relationship of YVCMV and their transmission

Bhagabati and Goswami (1992) studied on the incidence of *Yellow vein clearing mosaic virus* of okra in relation to whitefly population and different sowing dates. They counted the highest whitefly population in the crop sown in May to June, while the incidence of *Yellow vein mosaic virus* of okra was the highest (100%) in crop sown in late October. They observed a high positive correlation between the virus disease incidence and population of whitefly.

Varma (1952) studied the relationship of *YVMV* and its vector whitefly. Though a single insect was able to transmit the virus, the minimum number of flies required to produce 100 percent infection was about 10. The first visual symptom is the clearing of small veins, which usually starts at various points near the leaf margins in about 15 – 20 days after inoculation of plants. Affected plants early come to flower and chemical control of the disease is difficult. Destruction of alternative hosts, control of white fly and other sucking insects and uprooting and burying of infected plants are some of the measures to reduce the vector population and also the diseased. Wild okra species such as *A. pungens, A. crinitus, H. vitifolius, H. panduracformis* are immune to this virus. During the last two decades several resistant varieties have been developed which are giving sustainable high yields in virus prone areas.

The results on the virus-vector relationship of *Okra yellow vein mosaic virus* conducted by Capoor and Verma (1950) and Verma (1952) in India demonstrated that the virus is transmitted by whitefly (*Bemesia tabaci*). They also established the transmission of the virus through bud grafting.

Sastry and Singh (1975) investigated the effect of *Yellow vein mosaic virus* on growth and yield of okra based on the infection of plants at different growth stages. The results revealed that the infected plants severely stunted and produced very few leaves and fruits when the infection occurred within 35 days after germination. The yield reduction was estimated on an average as high as 93.80% when the plants were infected within 35 days following germination. The yield reduction was estimated as 83.63% and 49.63% in the plants infected within 50 and 60 days following germination, respectively. They concluded that the time of infection by the virus determines the extent of yield loss of okra.

Sharma *et al.,* (1987) assessed the effect of temperature on the incidence of *Hibiscus yellow vein mosaic virus (HYVMV)* on six varieties of okra over a period of six years. The incidence of *HYVMV* was found to increase with the decreased temperature in September compared with August. A significant negative correlation co-efficient between temperature and virus incidence was detected. It was also evident that the varieties those were free of virus in August developed virus symptoms in September. They observed that the temperature had influence on the resistance on *HYVMV* and could therefore, be under the control of a polygenic system.

Jeyarajan *et al*., (1988) reported that there was no outbreak of *Bemesia tabaci* in farmer's fields in the Coimbatore district of Tamil Nadu, India in March 1986, which transmitted *Tomato leaf curl virus, Tapioca mosaic virus, Urd bean yellow*

mosaic virus and Bhendi yellow vein mosaic viruses at the rate of 80.0, 5.3, 67.4 and 84.0% respectively and all the viruses are the members of geminivirus group.

Tsering and patel (1990) conducted an experiment on the vector transmission of geminivirus using *Bemesia tabaci* and noted that *Bemesia tabaci* exposed to tobacco infected by *Tobacco leaf curl virus (TLCV)* and then to okra infected by *Okra yellow vein mosaic geminivirus (OYVMV)* in glass house trials, 8 of 15 tobacco plants become infected with *TLCV* and 5 of 15 okra plants with *OYVMV*. The reversed initial exposure of the vectors gave similar results. The results concluded that the both viruses were transmitted simultaneously and with equal efficiency by *Bemesia tabaci.*

About 100% infection of okra *yellow vein clearing mosaic virus (YVCMV)* in the okra in Bangladesh causing as high as 90% yield loss as reported by Akanda (1991). He performed ultra structural studies of infected tissues and serology using antisera of 20 different viruses including *Mungbean yellow mosaic virus* and concluded that might be a member of geminivirus group.

Kandian and Naresh (1991) conducted an experiment on the influence of weather factors on whitefly population and disease incidence of *Okra yellow vein mosaic virus (OYVMV).* The results of their study revealed that the weather factors especially temperature and relative humidity have pronounced effect on the population build up of *Bemesia tabaci* in okra field. The spread of yellow vein mosaic disease of okra is depended upon the number of whitefly present in okra. The results of their study suggested that the temperature between 25 to 30^0C and relative humidity more than 40% were formed to be most congenial for *B. tabaci.*

Significantly positive association between disease incidence and whitefly population, temperature, relative humidity and rainfall was recorded by Nath *et al.,* (1993). They also observed the negative correlation of fruit yield with disease incidence.

Goswami and Bhagbati (1992) conducted a field trial in Jorhat, Assam India during 1991 to find out the natural incidence *of Yellow vein mosaic virus* of bhindi (*Abelmoschus esculentus* L.) in relation to different dates of sowing. The lowest viral disease incidence (16.7%) was recorded on okra sown at the beginning of October and the highest (100%) on the crop sown in May and June. The disease incidence was 36.5% and 54.2% in February and March sown crop, respectively.

A field experiment was conducted by Board *et al.,* (1993) to find out the relationship of *Bemesia tabaci* population dencity and the prevalence of *Yellow vein mosaic virus* of okra in 1988 and 1989 cropping seasons. In both the years the population of the vector reached a maximum size during first week of October. Symptoms of *YVMV* found to be appeared one week after infestation with *Bemesia tabaci*. The disease percentage was recorded to progressively increase with the corresponding increase of vector population. Adults of *Bemesia tabaci* and *YVMV* symptoms were found at 16 and 20 days after seed sowing. The virus incidence was recorded as 41% and 90% in the crops of the 26 February and 8 April sowing respectively.

Handa *et al.* (1993) screened 14 cultivars in the field under natural infection by *Yellow vein mosaic virus* of okra. The results suggested that Parbhani Kranti was promising and tolerant against the virus and a selection from Ghana was found highly resistant. It was also observed that agronomic practices improved the yield to 65-67 q/ha in spring and 55-60 q/ha in the kharif season when plants were planted maintaining 60 × 30 cm space.

Mohapatra *et al*. (1995) recorded the weekly incidence of *Yellow vein mosaic virus* of okra and compared the severity index. A minimum variation on the severity index was observed among the varieties. Pusa Sawani was the most susceptible variety and recorded 100% infection, while varieties like HRB-9-2, DOV-91-4 and Pashupati was tolerant against the virus at least under field condition.

Sarma *et al.* (1995) observed that *Yellow vein mosaic virus* of okra infection reduced chemical constituents of okra leaves, such as chlorophyll, reducing sugar, phosphorus and potassium content, whereas total phenol, total sugar, non reducing sugar, nitrogen and protein contents increased. The extent of increase or decrease of these constituents was found to be varied with the time of infection of okra by the virus i.e. on the stages of plants get infected by the virus. Total sugar, reducing sugar, nitrogen, protein, phosphorus and potassium contents of the green fruits were decreased by virus infection.

Bhagabati *et al.* (1992) explained the effect of *Yellow vein mosaic virus* of okra on some morphological parameters. They noted that infection by *YVMV* retarded the growth and development of susceptible varieties of okra plants in India. The leaf area, fruit length, fruit weight and volume were drastically reduced by virus infection. Moisture content of both diseased leaves and fruits was higher than that of the of healthy okra plants at all growth stage.

Hossain *et al*. (1998) investigated the reaction of okra variety to *yellow vein mosaic virus (YVMV)* and biochemical changes in its infected leaf constituents. Okra cultivars BARI-1, Comilla, Pusa Shawny and local were evaluated for their reaction to *YVMV* reaction, particularly biochemical changes in leaf constituents in response to *YVMV*. BARI-1 had the lowest percentage leaf infection among the cultivars, while the highest disease incidence was observed in Pusa Shawny.

The rate of infection of *Yellow vein clearingmosaic virus (YVCMV)* decreased as the age of the inoculated plants increased was recorded by Pun *et al.* (1999). It was observed that 100% infection of *Yellow vein mosaic virus (YVCMV)* occurred when 7-days old okra plants were inoculated whereas, the infection percentage dropped down to 31.70% when 49-days old plants were inoculated. They found that the incubation period of virus was increased with increased plant age.

Rashid *et al.* (1999) reported the development of okra variety resistant to *Yellow vein clearing mosaic virus (YVCMV)* at Bangladesh Agricultural Research Institute, Joydevpur, Gazipur and released the variety named as BARI dherosh-1.

Bhagat (2000) worked on the impact of *Yellow vein clearing mosaic virus (YVCMV)* on growth and yield of bhindi (*Abelmoschus esculentus* L.). Three okra varieties namely Parbhani Kranti, Vaishali Vadhu and Pusa Sawani were grown in the field to find out the effect of *YVCMV* infection on the growth and yield of okra. The plant height, number of leaves, fruits/plant, fruit length, fruit diameter, fruit weight/plant was found to be less affected due to virus infection in the resistant cultivar Parbhani Kranti in comparison to susceptible Vaishali Vadhu and Pusa Sawani.

Bhagat *et al.* (2001) conducted an experiment to find out the rate of dissemination of okra *Yellow vein clearing mosaic virus (YVCMV)* in okra cultivars Pusa Sawani (highly susceptible), Vaishali Vadhu (susceptible), Parbhani Kranti (resistant). The maximum rate of disease development was between 35-45 days after sowing (DAS).

The name of the virus infecting okra producing scientific type of symptoms is recognized as *Okra yellow vein clearing mosaic virus (OYVCMV)* to accommodate all synonyms used for the virus as reported by Begum (2002).

CHAPTER III

MATERIALS AND METHODS

This chapter described the materials and methods that were used in carrying out the experiment. It included a description of screening of okra varieties in the pot conditions with the protection through the net. These comprised collection of popular okra cultivars, growing of indicator plants for the vectors, identification of *"Yellow vein clearing mosaic virus"* from infected okra plant, conduction of pot experiment and recording compilation and analysis of data.

3.1 Experimental site

The experiment was conducted in the experimental site of Plant Pathology Department at Sher-e-Bangla Agricultural University (SAU), Dhaka during March to July, 2014 in kharif-2. The location of the experimental site was at $23^0 46^{'}$ N latitude and $90^0 24^{1}$ E longitude with elevation of 9 meters above the sea level and have been presented in Appendix 1.

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 silty 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 and have been presented in Appendix 3.

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 during the experimental period were collected from Bangladesh Meteorological Department, Agargaon, Dhaka and have been presented in Appendix 2.

3.4 Planting materials used for experiment

In total 9 popular okra cultivars were used in this study. The okra cultivar **"BARI dherosh-1"** was used as a resistant variety to *Yellow vein clearing mosaic virus (YVCMV)*. The other eight cultivars namely Green finger, Tower seed, Raja, Anguli, Parvani kranti, Yuvraj, Shyamol bangla and Orka onamika were collected from popular seed breeders and used as the test cultivars.

3.5 Treatments of the experiment

Treatment was considered as following-

T_1=BARI dherosh-1
T_2=Green finger
T_3=Tower seed
T_4=Raja
T_5=Anguli
T_6=Parvani kranti
T_7=Yuvraj
T_8=Shyamol bangla
T_9=Orka onamika

3.6 Experimental design

The experiment was laid out in a complete randomized design (CRD) with three replications. There were 9 treatments combinations. The total numbers of unit pots were 60. Each treatment contains 6 pots with their individual plants.

3.7 Growing of indicator plants

The main objective to grow the indicator plant, was to ensure the availability of vectors, white fly *(Bemesia tabaci*), to maintain the inoculation process in the experimental plants. The Green finger seeds were used to grow the indicator plants. 10 individual pots were used to grow the indicator plants with the same cultural practices and the plants get infected through the vectors. When the main plants grow in the pots, the vectors were used to get inoculated with the main plants from the indicator plants.

Figure 1: Severely infected indicator okra plant by *Yellow Vein Clearing Mosaic Virus (YVCMV)*

3.8 Pot preparation and sowing of seeds

The pots were filled up with the soil collected from the SAU Farm. Before make 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. The seeds were soaked in water for 24 hours and then wrapped with a piece of thin cloth. The soaked seeds were then spreaded over polythene sheets for 2 hours to dry out the surface water. This treatment was given to help quick germination of seeds. The seeds were sown in the pots on 8 March, 2014. 2-3 seeds were sown in each of the pot of individual varieties. After seed germination, only one healthy plant was kept in each pot. The pot to pot and plant to plant distance was maintained.

3.9 Manure and fertilizer management

The entire quantity of cowdung (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 5 kg, 2 kg, 1.5 kg, 0.75 kg and 0.60 kg, respectively. TSP, Zinc sulphate, boron were given as basal during final pot preparation. Split application of urea and MoP done at 20, 40 and 60 days after sowing.

3.10 Intercultural operations

3.10.1 Gap filling

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

3.10.2 Weeding

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

3.10.3 Application of irrigation water

Irrigation water was added to each pot according to the critical stage. The experimental pots were irrigated through watering cans.

3.10.4 Drainage

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

3.11 Artificial inoculation with white fly

After establishment of plants in pot condition, the experimental plants were inoculated with white fly vector *(Bemesia tabaci)* from indicator okra plants. Before inoculation experimental plants were transferred inside the net chamber separately. The control plants or non inoculated plants were also protected by the net chamber.

3.12 Removal of Insect vector

After 7-10 days of inoculation, the white fly *(Bemesia tabaci)* vectors were removed by spraying with insecticide "Imidacloprid" @1ml/litter.

3.13 Bioassay

After 5-7 weeks of white fly removal, inoculated plants of each cultivar were analyzed on the basis of morphological features which are related to the disease incidence in okra against *YVCMV*. The physiological features of plants which are related to plant growth and development also analyzed in this study. *YVCMV* typical symptoms were allotted to appear in inoculated plant for comparison with non inoculated plant.

3.14 Identification of virus and Disease incidence of Okra *yellow vein clearing mosaic virus (YVCMV)*

Based on studying typical symptoms of *YVCMV* were described by Capoor and Verma (1955), Begum (2002) and Hossain (1998). The okra plants were inspected every day until harvest and the symptoms appeared in the okra plants was noted. The growth stage of the plants were categorized as follows-

1) Early stage - 5 weeks after seed sowing
2) Mid stage - 5 weeks after early stage, and
3) Late stage - after mid stage up to harvest.
4) The disease incidence was expressed in percentage on the basis of stage as well as total i.e., average of three stages. The percent prevalence 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 infected plants

Plants which did not show any symptoms developed by the virus i.e., remained asymptomatic up to last harvest were considered as the healthy resistant plants. If it is not otherwise stated the stage of infection was only interpreted for prevalence study of the virus.

3.15 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 infected leaves per plant
- % Disease incidence
- Number of flowers per plant
- Number of fruits per plant
- Fruit length
- Fruit girth
- Plant height
- Chlorophyll content in leaves per plant
- Net assimilation rate per plant
- Inter cellular CO_2 concentration per plant
- Respiration rate per plant
- Stomatal conductivity per plant

3.16 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-

3.16.1 Number of leaves per plant

Number of leaves of selected plants from each pot at 20, 40 and 60 days after sowing (DAS) was recorded. Only the smallest young leaves at the growing point of the plant were excluded from counting. Calculating the total number of leaves, the average number was recorded.

3.16.2 Number of infected leaves per plant

Number of infected leaves of selected plants from each pot at 20, 40 and 60 days after sowing (DAS) was recorded. Calculating the average number of infected leaves, the average number was recorded.

3.16.3 Number of flowers per plant

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

3.16.4 Number of fruits per plant

Mean number of green pods of selected plants from each pot as per treatment was recorded.

3.16.5 Fruit length

Green pods were collected from selected plants of each pot as per treatment and length was measured with the help of a meter scale in centimeter (cm).

3.16.6 Fruit girth

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

3.16.7 Plant height

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

3.16.8 Chlorophyll content in leaves per plant

The average chlorophyll content in the leaves of the selected plants was recorded with the help of "S-PAD" (Figure-2), which is an advanced technology to directly measure the chlorophyll content in plant leaf at 20, 40 and 60 days after sowing (DAS).

Figure 2: Recording net chlorophyll content in plant leaf by "S-PAD".

3.16.9 Net assimilation rate per plant

The average net assimilation rate per plant was recorded from the selected plants by using "LC-Pro+" (Figure-3) machine at 20, 40 and 60 days after sowing (DAS).

3.16.10 Intercellular CO_2 concentration per plant

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

3.16.11 Respiration rate per plant

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

3.16.12 Stomatal conductivity per plant

The average stomatal conductance per plant was recorded from the selected plants by using "LC-Pro+" machine at 20, 40 and 60 days after sowing (DAS).

Figure 3: Collection of data over physiological parameters by "LC-Pro^{+}" machine.

3.17 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. Bar diagram and graphs were used to interpret the data as and when required.

CHAPTER IV

RESULTS

This chapter includes the experimental results. Different cultivars viz. BARI dherosh 1, Green finger, Tower seed, Raja, Anguli, Parvani kranti, Yuvraj, Shyamol bangla, Orka onamika were assessed against *Yellow vein clearing mosaic virus* of Okra under pot condition. Results were compiled based on disease incidence, morphological and physiological parameters at different days after sowing (DAS) presented in this chapter.

4.1 The morphological features which are identical, in-relation to disease incidence in okra against *Yellow vein clearing mosaic virus*

4.1.1. Number of leaves per plant

The maximum number of leaves per plant was obtained in the cv BARI dherosh-1 (25.67) followed by cv Parvani kranti (24.33) and which are statistically identical with each other. The minimum number of leaves per plant was obtained in the cv Green finger (16.00) preceded by cv Raja (18.00), cv Anguli (18.33), cv Shyamol bangla (18.67), cv Yuvraj (19.33), respectively and these are statistically similar with each other. The moderate number of leaves per plant was recorded in the variety cv Orka onamika (20.67). The results are presented in Table-1.

4.1.2. Number of infected leaves per plant

The maximum number of infected leaves per plant was found in the cv Orka onamika (16.67) followed by cv Yuvraj (15.67), cv Shyamol bangla (14.67), cv Raja (13.67) and cv Anguli (13.67), respectively and these are statistically similar with each other. The minimum number of infected leaves per plant was obtained from the cv Parvani kranti (2.33) and cv BARI dherosh-1(2.66) and these are

statistically identical with each other. The moderate number of infected leaves per plant was obtained from the cv Green finger (10.33) and cv Tower seed (12.67) they are statistically different from each other. The results are presented in Table-1.

4.1.3. Incidence of *Yellow vein clearing mosaic virus* in okra cultivars under pot condition (%)

The highest disease incidence was found in cv Yuvraj (81.14%) followed by cv Orka onamika (80.81%), cv Shyamol bangla (78.53%), cv Raja (75.92%) and cv Anguli (74.73%) and these are statistically similar. The lowest disease incidence was found in the cv Parvani kranti (9.74%) and cv BARI dherosh-1(7.87%) and they are statistically similar with each other. The moderate disease incidence was found in cv Green finger (64.14%) and cv Tower seed (70.36%) and they are statistically different from each other. The results are presented in Table-1.

Table 1: Morphological features related to the disease incidence in okra against *Yellow vein clearing mosaic virus*

Treatments	No. of leaves /plant	No. of infected leaves/plant	Disease incidence (%)
BARI Dherosh 1	25.67 a	2.667 d	7.870 d
Green finger	16.00 c	10.33 c	64.14 c
Tower seed	18.00 bc	12.67 bc	70.36 bc
Raja	18.00 bc	13.67 ab	75.92 ab
Anguli	18.33 bc	13.67 ab	74.73 ab
Parvani kranti	24.33 a	2.33 d	9.74 d
Yuvraj	19.33 bc	15.67 ab	81.14 a
Shyamol bangla	18.67 bc	14.67 ab	78.53 ab
Orka onamika	20.67 b	16.67 a	80.81 ab
$LSD_{0.05}$	3.525	2.916	9.514
CV%	10.33	14.95	9.19

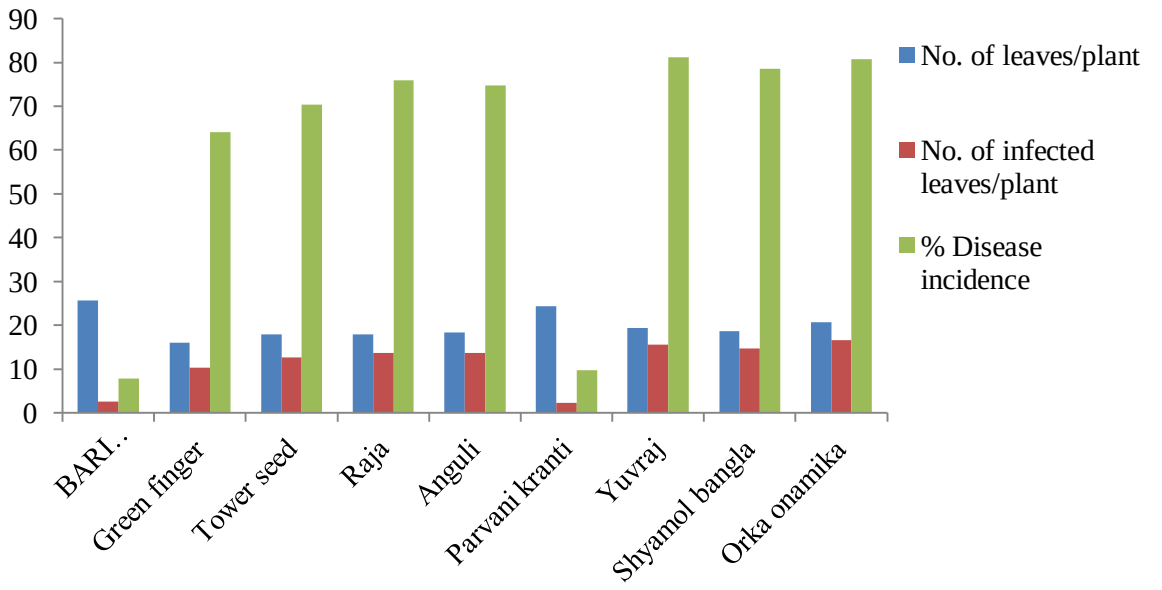

Figure 4: Graphical presentation on No. of leaves, No. of infected leaves and % Disease incidence in different *YVCMV* infected okra varieties.

4.2 The morphological features which are identical, in-relation to yield in okra against *Yellow clearing vein mosaic virus*

4.2.1. Number of flowers per plant

The maximum number of flowers per plant was recorded in the cv Parvani kranti (25.33) followed by cv BARI dherosh-1(22.33) and these are statistically different from each other. The minimum number of flowers per plant was found in the cv Shyamol bangla (13.33) preceded by cv Green finger (13.67), cv Raja (13.67), cv Yuvraj (13.67), cv Tower seed (14.67), cv Anguli (15.33) and cv Orka onamika (15.67), respectively and all they are statistically similar with each other. The results are presented in Table-2.

4.2.2. Number of fruits per plant

The highest numbers of fruits per plant were recorded in the cv Parvani kranti (22.00) followed by cv BARI dherosh-1(19.33) and these are statistically different from each other. The lowest numbers of fruits per plant were recorded from the cv Yuvraj (9.66) preceded by cv Shyamol bangla (10.00) and cv Green finger (10.00) these are statistically similar with each other. The moderate number of fruits per plant was obtained from the cv Anguli (13.67) and this result is statistically similar with cv Raja (11.33), cv Tower seed (11.67), and cv Orka onamika (12.33) respectively. The results are presented in Table-2.

4.2.3. Fruit length per plant (cm)

The average highest fruit length was recorded from the cv Parvani kranti (17.33) followed by cv BARI dherosh-1(16.87) and both are statistically identical. The average lowest fruit length was recorded in the cv Yuvraj (12.77) preceded by cv Tower seed (12.83) and these are statistically similar with each other. The moderate average fruit length was obtained in the cv Shyamol bangla (13.03), cvGreen finger (13.30), cv Anguli (13.43), cv Raja (13.60) and cv Orka onamika (13.83) respectively and all they were statistically similar. The results are presented in Table-2 and figure- 5.

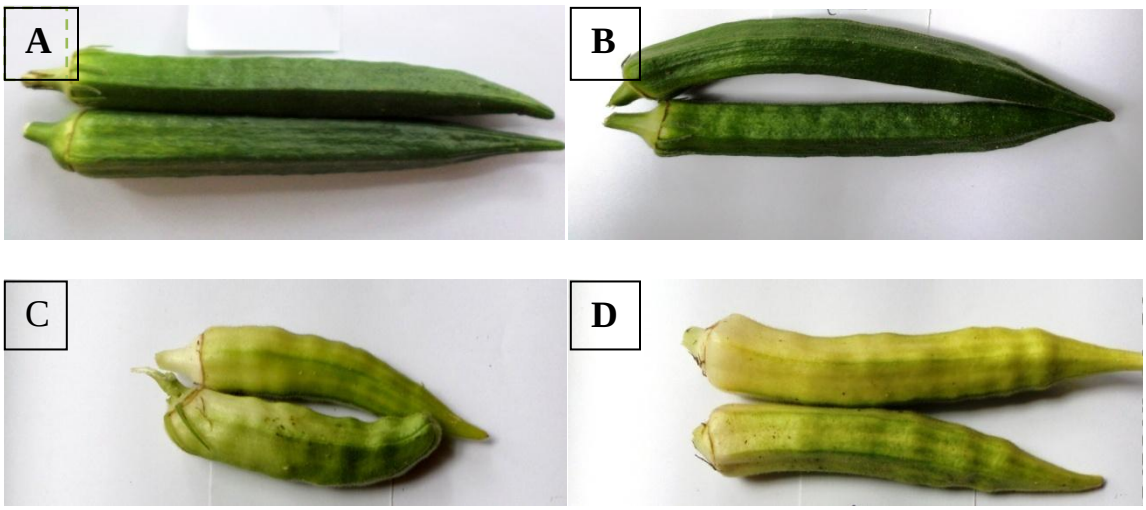

Figure 5: A) Green fruits of Parvani kranti B) Green fruits of BARI dherosh-1 C) Infected fruits of Yuvraj D) Infected fruits of Tower seed

4.2.4. Fruit girth per plant (cm)

The average highest fruit girth was obtained in the cv Parvani kranti (6.36 cm) followed by cv BARI dherosh-1(6.13 cm) and both are statistically identical with each other. The average lowest fruit girth was recorded from the cv Yuvraj (3.93 cm) preceded by cv Tower seed (4.40 cm) and these are statistically similar with each other. The moderate average fruit girth per plant was obtained from the cv Anguli (4.63 cm), cv Shyamol bangla (4.66 cm), cv Orka onamika (4.86 cm), cv Green finger (4.96 cm) and cv Raja (5.20 cm) respectively and all they were statistically different from each other. The results are presented in Table-2.

4.2.5. Yield (gm)

The highest yield per plant was recorded in the cv Parvani kranti (616.0 gm) followed by cv BARI dherosh-1(542.3 gm) and these are statistically different from each other. The lowest yield per plant was recorded from the cv Yuvraj (270.0 gm) preceded by cv Shyamol bangla (280.0 gm) and cv Green finger (280.0 gm) these are statistically identical with each other. The moderate yield per plant was obtained from the cv Raja (317.3 gm) cv Tower seed (326.7 gm), cv Orka onamika (345.3 gm) and cv Anguli (382.7 gm) respectively and all they are statistically different. The results are presented in Table-2.

Table 2: Morphological features related to the yield and yield contributing characters in okra against *Yellow clearing vein mosaic virus*

Treatments	No. of flowers/plant	No. of fruits/plant	Average fruit length (cm)	Average fruit girth (cm)	Yield (gm)
BARI Dherosh 1	22.33 b	19.33 b	16.87 a	6.13 a	541.3 b
Green finger	13.67 c	10.00 d	13.30 b	4.96 bc	280.0 d
Tower seed	14.67 c	11.67 cd	12.83 b	4.40 cd	326.7 cd
Raja	13.67 c	11.33 cd	13.60 b	5.20 b	317.3 cd
Anguli	15.33 c	13.67 c	13.43 b	4.63 bcd	382.7 c
Parvani kranti	25.33 a	22.00 a	17.33 a	6.37 a	616.0 a
Yuvraj	13.67 c	9.67 d	12.77 b	3.93 d	270.7 d
Shyamol bangla	13.33 c	10.00 d	13.03 b	4.67 bcd	280.0 d
Orka onamika	15.67 c	12.33 cd	13.83 b	4.87 bc	345.3 cd
$LSD_{0.05}$	2.358	2.426	1.372	0.697	67.93
CV%	8.38	10.61	5.67	8.09	10.61

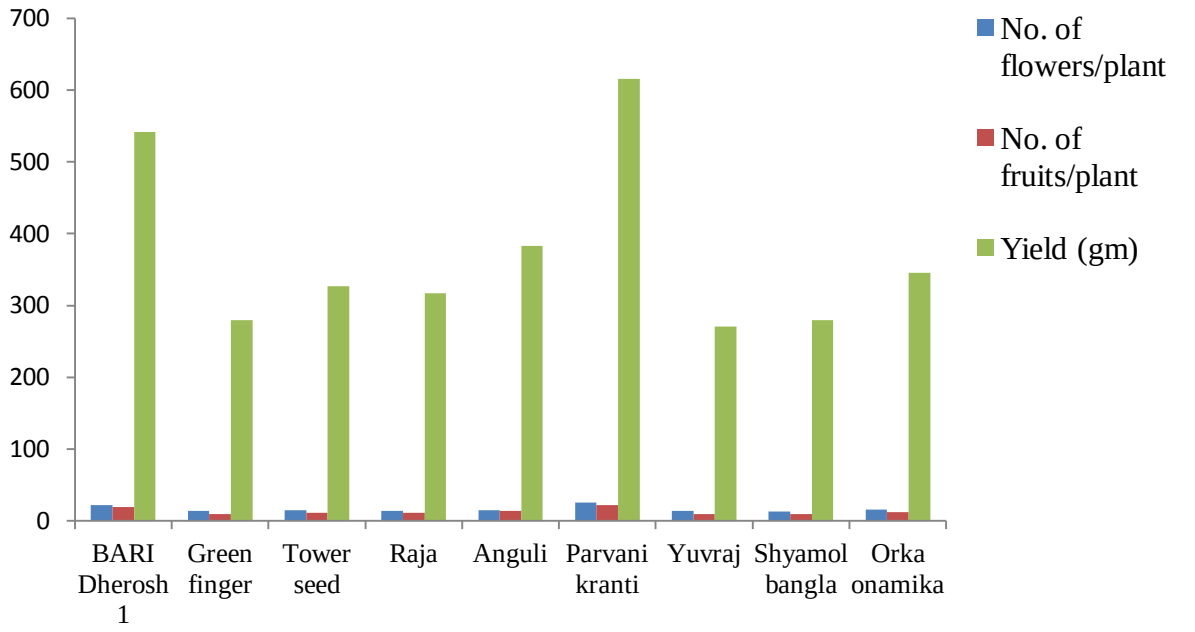

Figure 6: Graphical presentation of number of flowers, number of fruits and yield per plant in inoculated plants.

4.2.6. Plant height (cm)

The maximum plant height was recorded in the cv Parvani kranti (97.83 cm) followed by cv BARI dherosh-1 (95.73 cm) and both are statistically identical with each other. The minimum plant height was recorded in the cv Tower seed (81.50 cm) preceded by cv Shyamol bangla (83.67 cm), they are statistically different with each other. The moderate plant height was recorded in cv Raja (88.50 cm) followed by cv Anguli (86.60 cm), cv Yuvraj (86.00 cm), cv Orka onamika (85.37 cm) and cv Green finger (85.27 cm) respectively, and all they are statistically different from each other. The results are presented in Table-3 and also depicted in figure-7.

Figure 7: Comparison of plant height between the normal and infected okra plant

4.2.7. Net chlorophyll content per plant (µ mol m^{-2} s^{-1})

The net chlorophyll content in the leaves of the infected and non-infected plant was measured by the "S-Pad" machine. The highest net chlorophyll content per plant was recorded in the cv Parvani kranti (65.10) followed by cv BARI dherosh-1 (60.57) both are statistically identical. The lowest net chlorophyll content per plant was obtained in the cv Anguli (38.17) preceded by cv Tower seed (39.20) and these results are statistically similar with cv Orka onamika (39.97), cv Yuvraj (40.13), cv Raja (42.93), cv Green finger (43.20) and cv Shyamol bangla (45.93) respectively. These results are presented in Table-3.

Table 3: Morphological features related to the growth in okra against *Yellow vein clearing mosaic virus*

Treatments	Plant height (cm)	Net chlorophyll content/plant (μ mol m^{-2} s^{-1})
BARI Dherosh 1	95.73 a	60.57 a
Green finger	85.27 bcd	43.20 b
Tower seed	81.50 d	39.20 b
Raja	88.50 b	42.93 b
Anguli	86.80 bc	38.17 b
Parvani kranti	97.83 a	65.10 a
Yuvraj	86.00 bc	40.13 b
Shyamol bangla	83.67 cd	45.93 b
Orka onamika	85.37bcd	39.97 b
$LSD_{0.05}$	3.880	8.267
CV%	2.57	10.46

4.2.8 Correlation between chlorophyll content (μ mol m^{-2} s^{-1}) and Plant height (cm) of different varieties of okra

Correlation study was done to establish the relationship between the chlorophyll content (μ mol m^{-2} s^{-1}) and Plant height (cm) of infected okra plants. From the study it was revealed that significant correlation was observed between the parameters (Figure 8). It was evident from the Figure-8 that the equation $y = 0.408x + 69.2$ gave a good fit to the data, and the co-efficient of determination ($R^2 = 0.791$) showed that, fitted regression line had a significant regression co-efficient. From these relations it can be concluded that the plant height was good ($R^2 = 0.917$) as well as positively (slope= 0.814) correlated with the chlorophyll content of okra plants.

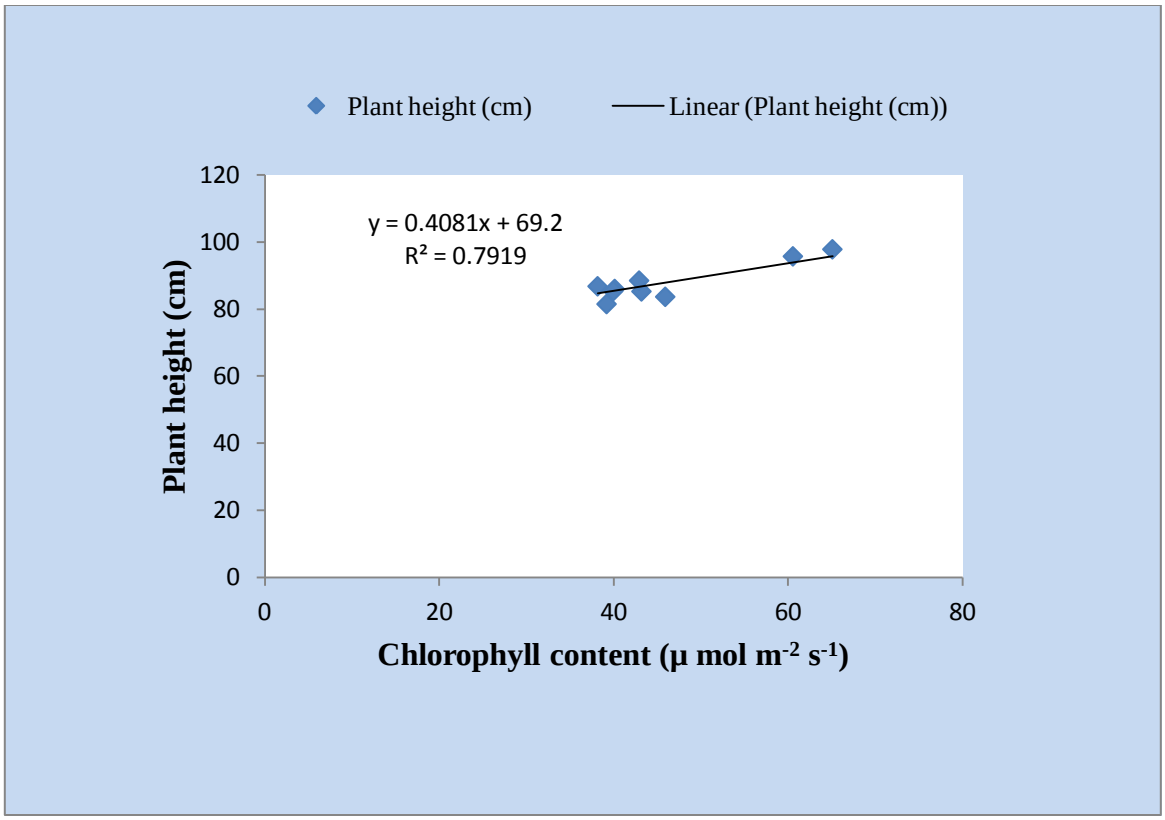

Figure 8: Relationship between Chlorophyll content and Plant height

4.2.9 Correlation between chlorophyll content (µ mol m^{-2} s^{-1}) and Yield (gm) of different varieties of okra

Correlation study was done to establish the relationship between the chlorophyll content (µ mol m^{-2} s^{-1}) and Yield (gm) of infected okra plants. From the study it was revealed that significant correlation was observed between the parameters (Figure 9). It was evident from the Figure-9 that the equation y = 8.519x - 15.01 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.735) showed that, fitted regression line had a significant regression co-efficient. From these relations it can be concluded that the yield of okra was strongly (R^2 = 0.917) as well as positively (slope= 0.823) correlated with the chlorophyll content of okra plants.

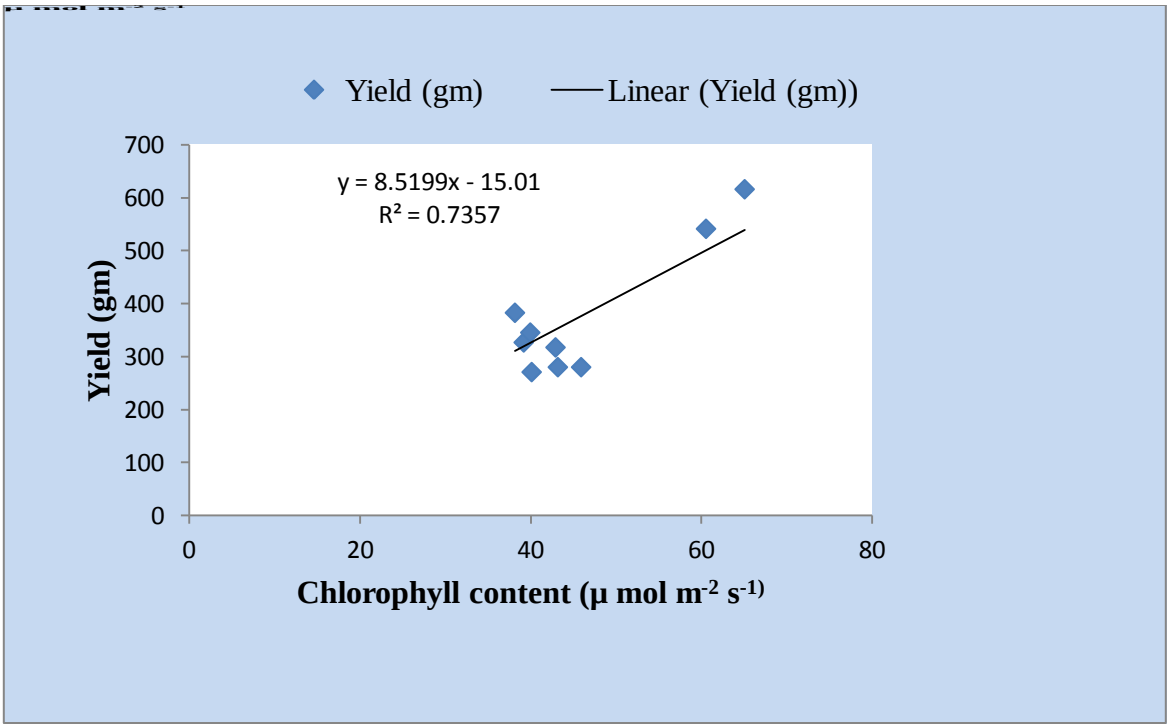

Figure 9: Relationship between Chlorophyll content and Yield

4.3 The physiological features which are identical, in-relation to plant growth and development in okra against *Yellow vein mosaic virus*

The physiological features like Net assimilation rate, Carbon-di-oxide concentration, Respiration rate and Stomatal conductivity are very much important in-response to plant growth and development.

4.3.1. Net assimilation rate (g m^{-2} d^{-1})

The maximum net assimilation rate per plant was recorded in cv Parvani kranti (1.683) followed by cv BARI dherosh-1(1.593) both are statistically identical with each other. The minimum net assimilation rate per plant was recorded in cv Tower seed (0.923) preceded by cv Orka onamika (0.963), they are statistically similar with each other. The comparatively moderate net assimilation rate per plant was recorded in cv Shyamol bangla (1.047) followed by cv Yuvraj (1.070), cv Green finger (1.073), cv Raja (1.160) and cv Anguli (1.253) respectively, and all they are statistically similar. The results are presented in Table-4.

4.3.2. Intercellular Carbon-di-oxide concentration (ppm)

The maximum intercellular carbon-di-oxide concentration per plant was recorded in cv Parvani kranti (8.83) followed by cv BARI dherosh-1(8.86), both are statistically identical with each other. The minimum intercellular carbon-di-oxide concentration per plant was recorded in cv Raja (3.667) preceded by cv Orka onamika (3.667), cv Shyamol bangla (4.000), cv Tower seed (4.667) and cv Green finger (4.667) respectively, these are statistically similar with each other. The moderate intercellular carbon-di-oxide concentration per plant was recorded in the cv Yuvraj(6.66) followed by cv Anguli (5.33) and these are similar with each other. These results are presented in Table-4.

4.3.3. Respiration rate (ppt/s)

The highest respiration rate per plant was recorded in the cv BARI Dherosh-1 (61.93) followed by cv Parvani kranti (59.90), they are statistically identical. The lowest respiration rate per plant was recorded in the cv Shyamol bangla (36.17) preceded by cv Orka onamika (37.23), both results are statistically similar with cv Yuvraj (40.03), cv Tower seed (40.37), cv Raja (41.00) and cv Green finger (42.97) respectively. The results are presented in Table-4.

4.3.4 Stomatal conductivity (mol m^{-2} s^{-1})

The highest stomatal conductivity per plant was recorded in the cv Parvani kranti (0.6233) followed by cv BARI dherosh-1(0.6167), both are statistically identical with each other. The minimum stomatal conductivity per plant was recorded in the cv Orka onamika (0.3567) preceded by cv Raja (0.3633) and both results are statistically similar with each other. The moderate stomatal conductivity per plant was recorded in the cv Shyamol bangla (0.3900) and cv Anguli (0.3900) followed by cv Yuvraj (0.3963), cv Green finger (0.4000) and cv Tower seed (0.4100) respectively, and all they are statistically similar. The results are presented in Table-4.

Table 4: Physiological features related to plant growth and development in okra against *Yellow vein clearing mosaic virus*

Treatments	Net assimilation rate (g m^{-2} d^{-1})	Intercellular Carbon-di-oxide concentration (ppm)	Respiration rate (ppt/s)	Stomatal conductivity (mol m^{-2} $s^{-1)}$
BARI dherosh 1	1.59 a	8.66 a	61.93 a	0.61 a
Green finger	1.07 bc	4.66 c	42.97 b	0.40 b
Tower seed	0.92 c	4.66 c	40.37 b	0.41 b
Raja	1.16 bc	3.66 c	41.00 b	0.36 b
Anguli	1.25 b	5.33 bc	37.57 b	0.39 b
Parvani kranti	1.68 a	8.83 a	59.90 a	0.62 a
Yuvraj	1.07 bc	6.67 b	40.03 b	0.39 b
Shyamol bangla	1.04 bc	4.00 c	36.17 b	0.39 b
Orka onamika	0.93 bc	3.67 c	37.23 b	0.35 b
$LSD_{0.05}$	0.2766	1.708	8.184	0.07671
CV%	13.47	17.86	10.81	9.02

CHAPTER V

DISCUSSION

Okra (*Abelmoschus esculentus* L. Moench) is a member of Malvaceae and known as Lady's finger. Its tender green fruits are popular as vegetables among all classes of people in Bangladesh and elsewhere. Okra is a nutritious and delicious vegetable, fairly rich in vitamins and minerals. It is also a good source of gum, starch, spice etc. Okra is said to be very useful against genito-urinary disorders, spermatorrhoea and chronic dysentery. Its medicinal value has also been reported in curing ulcers and relief from hemorrhoids. The essential and nonessential amino acids that okra contains are comparable to that of soybean. Okra contains special fiber which takes sugar levels in blood under control, providing sugar quantity, acceptable for the bowels. Mucilage, found in okra, is responsible for washing away toxic substances and bad cholesterol, which loads the liver. Okra ensures recovery from psychological and mental conditions, like, depression and general weakness. Okra is additionally applied for pulmonary inflammations, bowel irritations and sore throat. The yearly okra production is 43.21 thousand metric tons from 10.35 thousand hectors of land in Bangladesh (BBS, 2011). The production is quite lower in comparison to our neighbor country like, in India it produces 7896.3 thousand metric tons from 1148.0 thousand hectors of lands (FAO, 2010). *Yellow vein clearing mosaic virus* is supposed to be the major constrain for the lower yield of okra in our country. This virus causes devastating effects on okra production, because most of the plant gets infected in the field level when *YVCMV* attacks in the field. Akanda *et al*., (1991) reported about 100% infection of *Yellow vein clearing mosaic virus (YVCMV)* in the okra field resulting yield loss as high as 90%. So far there are no varieties are reported in Bangladesh to resistant against *YVCMV.* The main objective of this study was to screening of okra cultivars against *Yellow vein clearing mosaic virus.* The experiment was conducted in the net house of the

department of plant pathology during March to July, 2014. The cultivars used in the experiment were BARI dherosh-1, Green finger, Shyamol bangla, Orka onamika, Anguli, Parvani kranti, Tower seed, Raja and Yuvraj.

5.1 Disease Incidence

The disease incidence due to *Yellow Vein Clearing Mosaic Virus (YVCMV)* was found in almost all the varieties. The highest disease incidence was found in the cv Yuvraj followed by Orka onamika, Shyamol bangla, Raja, Anguli, Tower seed and Green finger respectively. The lowest disease incidence was found in the variety cv BARI dherosh-1, which was previously released as a resistant variety against *YVCMV* by Bangladesh Agricultural Research Institute (BARI). Among the test varieties, cv Parvani kranti shows the lowest disease incidence. This result is similar to the previous report; study was conducted by, Bhagat (2000).

5.2 Number of Flowers, Number of Fruits and Yield

The yield of individual cultivars depends on the number of flowers and fruits per plant. The lowest number of flowers per plant was recorded in the cv Shyamol bangla followed by the cultivars Green finger, Raja, Yuvraj, Orka onamika, Tower seed and Anguli respectively. Whereas the highest number of flowers per plant were founded in cv Parvani kranti and cv BARI dherosh-1.

The lowest number of fruits per plant was recorded in the cv Shyamol bangla followed by the cultivars Green finger, Yuvraj, Raja, Tower seed, Orka onamika, and Anguli respectively. Whereas the highest number of fruits per plant were founded in cv Parvani kranti and cv BARI dherosh-1.

The lowest yield per plant was recorded in cv Shyamol bangla followed by the cultivars Green finger, Yuvraj, Raja, Tower seed, Orka onamika, and Anguli respectively. Whereas the highest yield per plant was founded in cv Parvani kranti and second highest in cv BARI dherosh-1.There are no previous report over yield of

okra against *YVCMV* in our country. However Bhagat (2000) also reported that cv Parvani kranti shows the best yield performance against *YVCMV*.

5.3 Relationship between Chlorophyll content with Plant height and Yield

The lowest chlorophyll content per plant was recorded in cv Anguli followed by cv Tower seed. The highest chlorophyll content per plant was recorded in cv Parvani kranti and cv BARI dherosh-1. The lowest plant height was recorded in cv Tower seed followed by cv Shyamol bangla. The highest plant height was recorded in cv Parvani kranti and cv BARI dherosh-1. There is a strong and positive correlation between chlorophyll content and plant height which shows that the equation $y = 0.408x + 69.2$ gave a good fit to the data, and the co-efficient of determination. From the correlation regression analysis it may be concluded that the plant height positively correlated with chlorophyll content of plant.

The lowest chlorophyll content per plant was recorded in cv Anguli followed by cv Tower seed. The highest chlorophyll content per plant was recorded in cv Parvani kranti and cv BARI dherosh-1. The lowest yield was recorded in the cv Tower seed followed by cv Shyamol bangla .The highest yield was recorded in cv Parvani kranti and cv BARI dherosh-1. There is a strong and positive correlation between chlorophyll content and plant height which shows that the equation $y = 8.519x - 15.01$ gave a good fit to the data, and the co-efficient of determination. From the correlation regression analysis it may be concluded that the yield positively correlated with chlorophyll content of plant.

5.4 Physiological features

The infected okra plant shows different physiological responses against different physiological features.

The minimum net assimilation rate per plant was recorded in cv Tower seed and cv Orka onamika. And the maximum net assimilation rate per plant was recorded from the cv Parvani kranti followed by cvBARI dherosh-1.

The minimum Intercellular Carbon-di-oxide concentration per plant was recorded in cv Raja and cv Orka onamika. And the maximum Intercellular Carbon-di-oxide concentration per plant was recorded in cv Parvani kranti and cv BARI dherosh-1.

The minimum respiration rate per plant was recorded in the cv Shyamol bangla and cv Orka onamika. The maximum respiration rate per plant was recorded in the cv BARI dherosh-1 and cv Parvani kranti .

The minimum Stomatal conductivity per plant was recorded in the cv Orka onamika and cv Raja. The maximum Stomatal conductivity per plant was recorded in the cv Parvani kranti followed by cv BARI dherosh-1.

From the findings of this study, it is raveled that two cultivars out of nine, Parvani kranti and BARI dherosh-1 showed better morphological and physiological performance as compared to other local and hybrid varieties against *Yellow Vein Clearing Mosaic Virus (YVCMV)*. The present findings agree with the reports of Rashid *et al.*, (1999) and Bhagat, (2000). Rashid *et al.*, (1999) reported about the development of a variety against *YVCMV* at Bangladesh Agricultural Research Institute (BARI) and released the variety in the name of BARI dherosh-1, and Bhagat reported that the cultivar Parvani kranti shows better performance on number of leaves, number of flower, fruit length, fruit girth, plant height, yield and different physiological parameters like net chlorophyll content, respiration rate, CO_2 concentration and stomatal conductivity over the other varieties against *YVCMV*.

CHAPTER VI

SUMMERY AND CONCLUSION

Okra is a popular vegetable among all classes of people in Bangladesh and elsewhere. Okra suffers from many diseases of which, *Yellow Vein Clearing Mosaic Virus (YVCMV)* is common and major one which devastating to yield and quality of fruits.

The prime aim of the present piece of research work was to screen out the resistant varieties of okra against *Yellow Vein Clearing Mosaic Virus (YVCMV)* which is transmitted by the white fly (*Bemesia tabaci*). Nine okra cultivars viz. BARI dherosh-1, Green finger, Anguli, Tower seed, Raja, Yuvraj, Shyamol bangla, Parvani kranti and Orka onamika were evaluated in the experiment. Among them the variety BARI dherosh-1 was previously released as resistant variety against *YVCMV* and the other varieties used as the test cultivars. The experiment was laid out in Complete Randomized Design (CRD) with three replications.

The okra varieties differed significantly among themselves in respect of disease incidence. The highest disease incidence was found in cv Yuvraj (81.14%) followed by cv Orka onamika (80.81%), cv Shyamol bangla (78.53%), cv Raja (75.92%) and cv Anguli (74.73%) and these are statistically similar. The lowest disease incidence was found in the cultivar cv Parvani kranti (9.74%) and cv BARI dherosh-1(7.87%) and they are statistically similar with each other. The moderate disease incidence was found in cv Green finger (64.14%) and cv Tower seed (70.36%) and they are statistically different from each other.

In case of number of flowers per plant, the maximum number of flowers per plant was recorded in the cv Parvani kranti (25.33) followed by cv BARI dherosh-1(22.33) and these are statistically different from each other. The minimum number of flower per plant was found in the cv Shyamol bangla (13.33) preceded by cv Green finger

(13.67), cv Raja (13.67), cv Yuvraj (13.67), cv Tower seed (14.67), cv Anguli (15.33) and cv Orka onamika(15.67) respectively and all they are statistically similar with each other.

In case of number of fruits per plant, the highest number of fruits per plant were recorded in the cv Parvani kranti (22.00) followed by cv BARI dherosh-1(19.33) and these are statistically different from each other. The lowest numbers of fruits per plant were recorded from the cv Yuvraj (9.66) preceded by cv Shyamol bangla (10.00) and cv Green finger (10.00) these are statistically similar with each other. The moderate number of fruits per plant was obtained from the cv Anguli (13.67) and this result is statistically similar with cv Raja (11.33), cv Tower seed (11.67), and cv Orka onamika (12.33) 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 cv Parvani kranti (616.0 gm) followed by cv BARI dherosh-1(542.3 gm) and these are statistically different from each other. The lowest yield per plant was recorded from the cv Yuvraj (270.0 gm) preceded by cv Shyamol bangla (280.0 gm) and Green finger (280.0 gm) these are statistically identical with each other. The moderate yield per plant was obtained from the cv Raja (317.3 gm) cv Tower seed (326.7 gm), cv Orka onamika (345.3 gm) and cv Anguli (382.7 gm) respectively and all they are statistically different.

In case of plant height, the maximum plant height was recorded in the cv Parvani kranti (97.83 cm) followed by cv BARI dherosh-1 (95.73 cm) and both are statistically identical with each other. The minimum plant height was recorded in the cv Tower seed (81.50 cm) preceded by cv Shyamol bangla (83.67 cm), they are statistically different with each other. The moderate plant height was recorded in cv Raja (88.50 cm) followed by cv Anguli (86.60 cm), cv Yuvraj (86.00 cm), cv Orka

onamika (85.37 cm) and cv Green finger (85.27 cm) respectively, and all they are statistically different from each other.

In case of the physiological features, we also founded a significant difference among the different varieties. In case of net chlorophyll content, The highest net chlorophyll content per plant was recorded in the cv Parvani kranti (65.10 µ mol m^{-2} s^{-1}) followed by cv BARI dherosh-1 (60.57 µ mol m^{-2} s^{-1}) both are statistically identical. The lowest net chlorophyll content per plant was obtained in the cv Anguli (38.17 µ mol m^{-2} s^{-1}) preceded by cv Tower seed (39.20 µ mol m^{-2} s^{-1}) and these results are statistically similar with cv Orka onamika (39.97 µ mol m^{-2} s^{-1}), cv Yuvraj (40.1 µ mol m^{-2} s^{-1}3), cv Raja (42.93 µ mol m^{-2} s^{-1}), cv Green finger (43.20 µ mol m^{-2} s^{-1}) and cv Shyamol bangla (45.93 µ mol m^{-2} s^{-1}) respectively.

In case of net assimilation rate per plant, the maximum net assimilation rate per plant was recorded from the cv Parvani kranti (1.683 g m^{-2} d^{-1}) followed by cv BARI dherosh-1(1.593 g m^{-2} d^{-1}) both are statistically identical with each other. The minimum net assimilation rate per plant was recorded in the cv Tower seed (0.923 g m^{-2} d^{-1}) preceded by cv Orka onamika (0.963 g m^{-2} d^{-1}), they are statistically similar with each other. The comparatively moderate net assimilation rate per plant was recorded in cv Shyamol bangla (1.047 g m^{-2} d^{-1}) followed by cv Yuvraj (1.070 g m^{-2} d^{-1}), cv Green finger (1.073 g m^{-2} d^{-1}), cv Raja (1.160 g m^{-2} d^{-1}) and cv Anguli (1.253 g m^{-2} d^{-1}) respectively, and all they are statistically similar.

In case of intercellular carbon-di-oxide concentration, the maximum intercellular carbon-di-oxide concentration per plant was recorded in cv Parvani kranti (8.83 ppm) followed by cv BARI dherosh-1(8.86 ppm), both are statistically identical with each other. The minimum intercellular carbon-di-oxide concentration per plant was recorded in cv Raja (3.667 ppm) preceded by cv Orka onamika (3.667 ppm), cv Shyamol bangla (4.000 ppm), cv Tower seed (4.667 ppm) and cvGreen finger (4.667 ppm) respectively, these are statistically similar with each other. The moderate

intercellular carbon-di-oxide concentration per plant was recorded in the cv Yuvraj (6.66 ppm) followed by cv Anguli (5.33 ppm) and these are similar with each other.

In case of respiration rate per plant, the highest respiration rate per plant was recorded in the cv BARI dherosh-1 (61.93 ppt/s) followed by cv Parvani kranti (59.90 ppt/s), they are statistically identical. The lowest respiration rate per plant was recorded in the cv Shyamol bangla (36.17 ppt/s) preceded by cv Orka onamika (37.23 ppt/s), both results are statistically similar with cv Yuvraj (40.03 ppt/s), cv Tower seed (40.37 ppt/s), cv Raja (41.00 ppt/s) and cv Green finger (42.97 ppt/s) respectively.

And for the stomatal conductivity, the highest Stomatal conductivity per plant was recorded in the cv Parvani kranti (0.6233 mol m^{-2} s^{-1}) followed by cv BARI dherosh-1(0.6167 mol m^{-2} s^{-1}), both are statistically identical with each other. The minimum Stomatal conductivity per plant was recorded in the cv Orka onamika (0.3567 mol m^{-2} s^{-1}) preceded by cv Raja (0.3633 mol m^{-2} s^{-1}) and both results are statistically similar with each other. The moderate stomatal conductivity per plant was recorded in the cv Shyamol bangla (0.3900 mol m^{-2} s^{-1}) and cv Anguli (0.3900 mol m^{-2} s^{-1}) followed by cv Yuvraj (0.3963 mol m^{-2} s^{-1}), cv Green finger (0.4000) and cv Tower seed (0.4100 mol m^{-2} s^{-1}) respectively, and all they are statistically similar.

Considering the performance of okra cultivars it may be concluded that cv Parvani kranti was graded as resistant against *Yellow Vein Clearing Mosaic Virus (YVCMV).*The cv BARI dherosh-1 also showed resistancy, though it was previously stated as resistant against *YVCMV.* The cultivars Orka onamika and Anguli showed moderate resistancy, while the cultivars Green finger, Tower seed, Raja, Yuvraj and Shyamol bangla were susceptible against *Yellow Vein Clearing Mosaic Virus (YVCMV)* among the cultivars used in the experiment. However, screening program need to carry out for consecutive years in different agro ecological zones of the country to justify the present findings.

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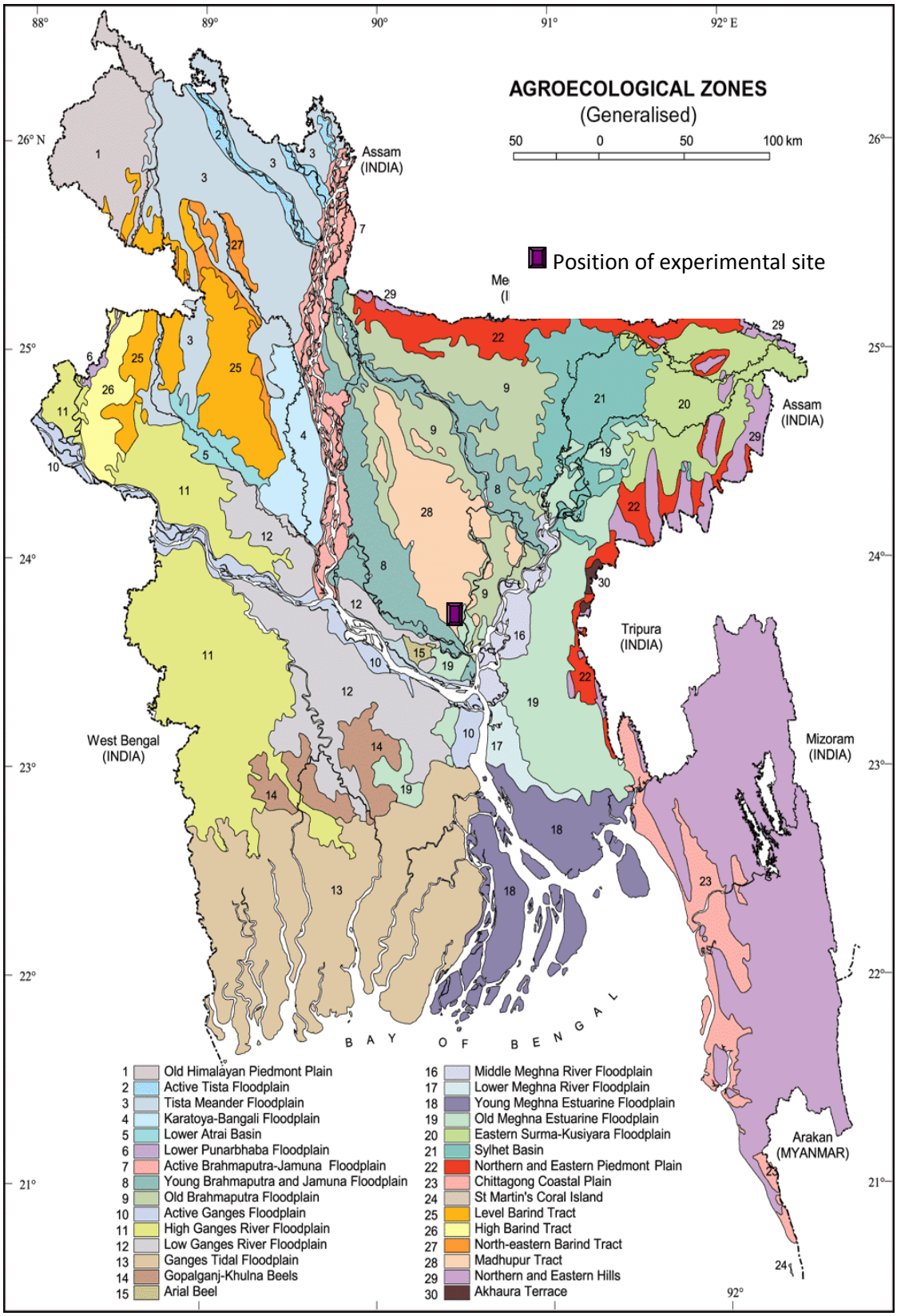
APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Monthly average relative humidity, maximum and minimum temperature, rainfall and sunshine hour during the experimental period (March 2014 to July 2014)

Month	Average RH (%)	Average Temperature (ºC)		Total Rainfall (mm)	Average Sunshine hours
		Min.	Max.		
March	64	20.4	32.5	65.8	5.2
April	69	23.6	33.7	165.3	4.9
May	81	24.5	32.9	339.4	4.7
June	84	25.4	33.7	415.6	4.8
July	89	27.5	34.8	512.4	4.7

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

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

Characteristics	Value
Partical 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

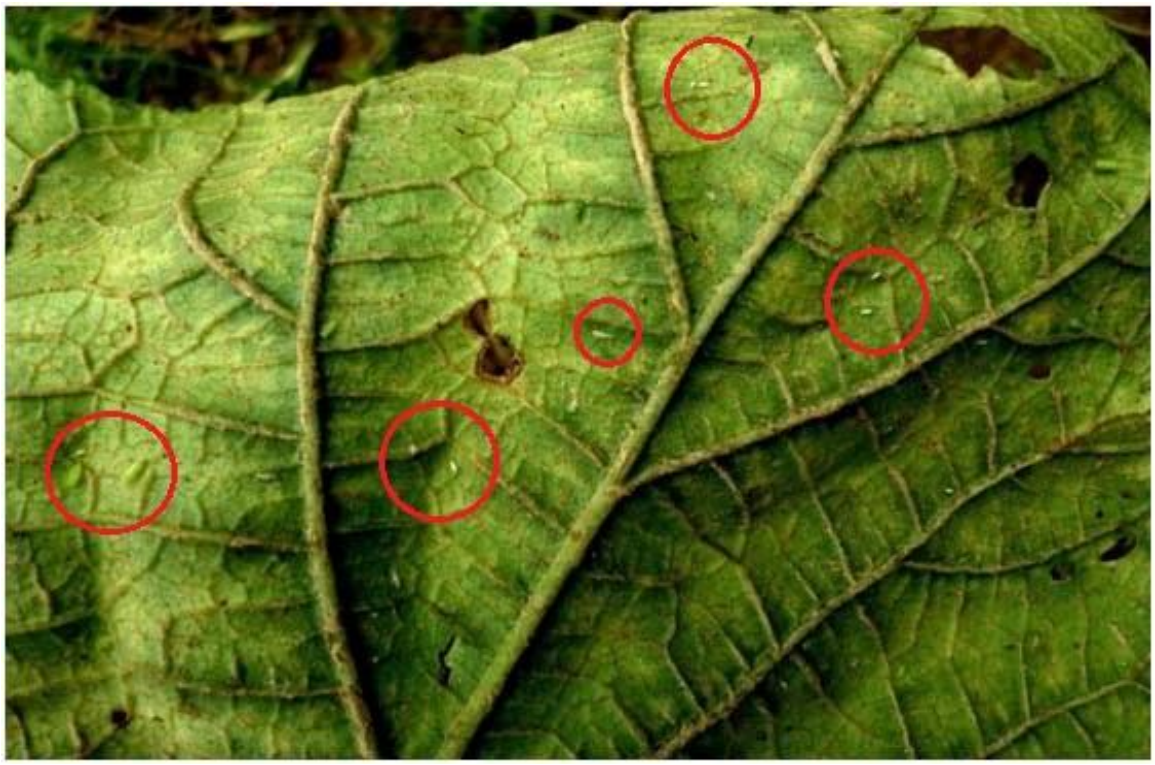
Source: Soil Resources Development Institute (SRDI), Dhaka-1207

Appendix IV. A view of the experimental site in an open condition

Appendix V. A view of the experimental site under net covering

Appendix VI. A view of severely infected okra plant by *Yellow Vein Clearing Mosaic Virus (YVCMV)*

Appendix VII. Another view of severely infected okra plant by *Yellow Vein Clearing Mosaic Virus (YVCMV)*



Appendix VIII. Existance of white fly (*Bemesia tabaci)* in the lower leaf surface of infected okra plant

Appendix IX. Normal okra plant with fruit

Appendix X. *Yellow Vein Clearing Mosaic Virus (YVCMV)* infected plant with fruit

Appendix XI. A view of the advanced "LC Pro^{+}" machine

ABBREVIATIONS AND ACRONYMS

ABBREVIATIONS	ACRONYMS
%	Percentage
@	At the rate of
°C	Degree Celsius
AIS	Agricultural Information System
ANOVA	Analysis of Variance
AEZ	Agro Ecological Zone
BARI	Bangladesh Agricultural Research Institute
B. *tabaci*	*Bemesia tabaci*
cm	Centimeter
CRD	Complete Randomized Design
cv	Cultivar
CV	Co-efficient of variance
DAS	Day After Sowing
DMRT	Duncan's Multiple Range Test
et al.	And Others
gm	Gram(s)
ml	Millilitre
LSD	Least Significant Difference
MoP	Murate of Potash
ppm	Parts per million
SRDI	Soil Resource Development Institute
TSP	Triple Super Phosphate