SELECTION FOR RESISTANT VARIETIES OF OKRA TO *YELLOW VEIN CLEARING MOSAIC VIRUS* AND ITS MANAGEMENT THROUGH PEAK PERFORMANCE NUTRIENTS, IMIDACLOPRID AND SOBICRON

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*This is to certify that thesis entitled, "**SELECTION FOR RESISTANT VARIETIES OF OKRA TO YELLOW VEIN CLEARING MOSAIC VIRUS AND ITS MANAGEMENT THROUGH PEAK PERFORMANCE NUTRIENTS, IMIDACLOPRID AND SOBICRON** "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, **Md. Kazi Abu Sayed** Registration No. **14-06309** 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.

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Dated:
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(Dr. Md. Belal Hossain)
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Dedicated To

My

Beloved Parents

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ABSTRACT

A two factorial field experiment on okra was conducted at the Horticulture Farm of Sher-e-Bangla Agricultural University, Dhaka during April to August, 2015. The aim of the study was to find out the resistance of okra varieties against *Yellow vein clearing mosaic virus* (*YVCMV)* and it's management. Four varieties viz. BARI dherosh-1, Green finger, Orca onamika and Nufield were selected as first factor and two insecticides (Imidacloprid and Sobicron) and one botanical nutrient namely Peak performance nutrients (PPN) was used as second factor. The plants were grown and natural inoculum was relied upon for the infection of *YVCMV*. Growth parameters, yield attributes and physiological features were significantly affected by okra varieties and two selected insecticides and PPN combinations. *YVCMV* incidence was significantly varied with these combinations. Among the varieties, the lowest disease incidence was found in BARI dherosh-1 (8.44, 9.78 and 7.22% per plot and 43.39, 67.51 and 54.27% per plant at 40, 60 and 80 days after sowing, respectively) followed by Green finger (10.16, 10.02 and 10.53% per plot and 44.66, 69.40 and 67.46% per plant at 40, 60 and 80 days after sowing respectively) and the highest in Orca onamika (18.03, 42.10 and 45.92% per plot and 55.87, 75.34 and 88.79% per plant at 40, 60 and 80 days after sowing, respectively). The highest plant height, root length, dry weight of the root, number of fruit per plant, length of single fruit, single fruit weight, fruit yield, net chlorophyll content, net assimilation rate, intercellular carbon-di-oxide concentration, stomatal conductivity and respiration rate was recorded in Green finger followed by BARI dherosh-1 and the lowest in Orca onamika. Application of Sobicron with PPN gave the lowest disease incidence (9.63, 14.12 and 10.78% per plot and 40.74, 59.26 and 67.52% per plant at 40, 60 and 80 days after sowing, respectively) and the highest disease incidence (17.92, 27.73 and 32.32% per plot and 58.30, 84.58 and 85.07% per plant at 40, 60 and 80 days after sowing, respectively) was observed in control where no insecticides and PPN was applied. Sobicron with PPN also gave the highest plant height, root length, dry weight of the root, number of fruit per plant, length of single fruit, single fruit weight and fruit yield, net chlorophyll content, net assimilation rate, intercellular carbon-di-oxide concentration, stomatal conductivity and respiration rate and that of the lowest where no insecticides and PPN were used. Green finger applied with Sobicron and PPN showed moderate resistance and gave the highest plant height, root length, dry weight of the root, number of fruit per plant, length of single fruit, single fruit weight, fruit yield, net chlorophyll content, net assimilation rate, intercellular carbon-di-oxide concentration, stomatal conductivity and respiration rate as compared to other combinations.

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Introduction

CHAPTER I

INTRODUCTION

Okra **(*Abelmoschus esculentus* L.)** is an important vegetable crop belongs to the Malvaceae family, which is widely cultivated in different parts of the world. It is originated in West Africa as an annual vegetable crop grown from seed in tropical and subtropical parts of the world (Thakur and Arora, 1986). In Bangladesh it is known as 'dherosh' which is also called 'bhindi' in India and Pakistan (Rashid, 1999). It is well distributed in the Indian subcontinent and East Asia (Kochhar, 1986). Plants are indeterminate; erect having 2-3 branches, fruits are green with 5 marked ridges and 14-18 cm long at edible stage. Each plant produces 24-28 fruits (Chowdhury and Hassan, 2013). Okra is a nutritious vegetable, which plays an important role to meet the demand of vegetables in our country when vegetables are scanty in the market (Ahmad, 1995). It is used for food as a vegetable and industrially as a fibre. It is also the good sources of gum, starch, spice and medicinal (eg. diabetese and cancer) products. The green fruits of okra are rich sources of carbohydrate, proteins, vitamins, calcium, potassium and other minerals (Adeboye and Oputa, 1996).

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. The edible portion of pod (100 gm) has moderate levels of vitamin A (0.01 mg) and vitamin C (18 gm), calcium (90mg), 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). The essential and nonessential amino acids that okra contains are comparable to that of soybean. Okra contains special fiber which keeps 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 in 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 (oshims.com /herbdirectory/O/okra).

Okra 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).

Vegetable production is not uniform in Bangladesh 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 exigent one. At present, a total area of 48048 acres of land is under okra cultivation which produces about 25894 metric tons in Bangladesh (BBS, 2014). But, world okra production was 6,876,584 metric tons (FAOSTAT, 2010). In Bangladesh the yield of okra is very low due to lack of proper management and higher 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 ones as reported by Sastry and Singh (1974). The virus may cause more than 90% yield loss (Akanda, 1991). Kulkarni first reported the virus in 1924 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 (Capoor and Varma 1950, Kumar and Moorthy 2000, Singh 1990 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 and Saikia 1993, Sastry and Singh 1975 and Sinha 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 Akanda (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, Ali *et al.* 2000 and Rashid *et al.* 1999). 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).

There is no effective control measure against the virus in the field once it is established. The most effective method of controlling the disease is cultivation of resistant varieties, but availability of resistant variety and sustainability of resistance in okra are rare. The varieties so far cultivated in our country are susceptible to the virus. Controlling its vector by spraying insecticide may be a method of controlling this disease or it may be used as a component of integrated control. The application of insecticides from date of seed sowing upto flowering might have meaningful effect to reduce the early population build up of whitefly. This might be useful to avoid early and mid stage infection of the virus resulting economically viable harvest of the crop. The variabilities of okra varieties in relation to the population build-up of whitefly under natural conditions have been reported by Begum (2002).

An appreciable amount of works have been done in India to find out effective management package against okra *Yellow vein clearing mosaic virus* (Borah and Nath 1995, Dhal *et al.* 1992, Handa and Gupta 1993b, Nath and Saikia 1995 and Singh and

Singh 1989). Among the chemicals Systox, Folidol, Aldicarb, Phorate, Monocrotophos, Ekatox, Rogor, Dimethioate, Methyl-parathion, Oxydemetomethyl, Thimet, Dimecron, Carbofuran, Malathion, Metasystox, Bidrin, Ripcord, Sumithion etc. were used by different workers to control whitefly. Some insecticides and plant extracts have also been evaluated against the whitefly transmitting the virus in okra field (Anon. 1993, Hossain 1998 and Miah 1988).

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). The trend of research on okra in Bangladesh seems to be indiscriminate, random and inconclusive with very few exceptions.

In view of the above facts, the research work was carried out to achieve the following objectives:

- To evaluate the incidence level of ***Yellow Vein Clearing Mosaic Virus* (*YVCMV*)** against the tested okra varieties.
- To screen out the resistant okra varieties against the ***YVCMV*** under field condition.
- To manage the disease using Peak Performance Nutrients (PPN), Imidacloprid and Sobicron.

Chapter 2

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

Retrospect of *YVCMV*

Okra *yellow vein clearing mosaic virus (YVCMV)* is the most deleterious 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 Varma (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 spread by an insect vector (*Bemisia tabaci*) and through bud grafting (Capoor and Varma 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. Later on, Handa (1991) 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 geminivirus 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 1993b, 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 Okra 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 (*B. tabaci*) and also through grafting. It was also established that the virus is a member of geminivirus group (Handa and Gupta 1993b, Handa 1991, Harrison *et al.* 1991, Singh 1990, Capoor and Varma 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 Varma (1950), Harender *et al.* (1993), Nariani and Seth (1958), Nath and Saikia (1993) and Sastry and Singh (1975).

Symptoms of *YVCMV*

The operable 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, Capoor and Varma 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 Varma (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 (1993a) 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).*

Transmission and Impact of *YVCMV*

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.

Verma (1952) studied the relationship of Y.V.M.V. 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 Varma (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.

Verma (1955) observed that *Yellow vein mosaic virus* of okra perpetuates on several wild plants and it is spread by whitefly (*B. tabaci*) under natural condition.

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 opined 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 farmers' 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.*

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.*

A field experiment was conducted by Borad *et al.* (1993) to find out the relationship of *Bemesia tabaci* population density 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 wowing. The virus incidence was recorded as 41% and 90% in the crops of the 26 February and 8 April sowing respectively.

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 stage 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.

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 virus is mechanically non-transmitted, but transmitted by grafting and white fly (*B. tabaci*), which could be able to infect plants in any stage of plant growth as reported by Gupta (2000) and Parvin (2002).

Approaches to control *YVCMV*

Khan and Mukkopadhay (1985) recommended the practice of alternative cultural method to minimize the incidence of *Yellow vein mosaic virus* of Lady's finger (*Abelmoschus esculentus* L. Monech). They noted that the use of yellow-colored polyethylene mulch significantly delayed the appearance of (*Hibiscus esculentus* L.) *Yellow vein mosaic virus* symptoms in *Abelmoschus esculentus*. It was found that disease incidence in mulched crop was 24.3% compared to 58.6% in the control.

Singh and Singh (1989) observed that *Hibiscus yellow vein mosaic virus* was controlled by three sprays of phosphamidon (0.02%) or methyl demeton (demeton-S-methyl) (0.25%), a single soil application of Foratox (phorate) (15 kg/ha) or by early sowing (1 Mar.) or intercropping okra with cowpea (*Vigna unguiculata)* or mungbean *(V. radiata).* The insecticides reduced numbers of *Bemisia tabaci*/plant and increased yields more effectively than the other treatments.

Arora *et al.* (1990) reported that seeds of the cultivar Pusa Sawani, soaked for 24 h in solutions of Cycocel (chlormequat) at 50, 100, 250 or 500 ppm or in Napthalene Acetic Acid (NAA) at 5, 10, or 25 ppm, were dried for two hours and sown in the rainy seasons (June) or 1985 and 1986. In some cases the chemicals were also sprayed on the foliage 20 and 40 days after sowing. NAA at 25 ppm as seed + foliar treatment stimulated plant growth, whereas Cycocel at 100 ppm as seed + foliar treatment increased the number of shoots and leaves/plant. Cycocel at 50 ppm as afoliar spray alone gave the earliest flowering. The highest average fruit set and yield (176.9 q/ha, compared with 84.5 q/ha in the control) were obtained with Cycocel at 100 ppm as seed + foliar treatment. At 90

days after sowing the lowest occurrence of YVM (yellow vein mosaic) was observed on plants whose seeds and foliahge were treated with Cycocel at 500 ppm in each case.

Idris (1990) found that there are two main types of disease symptoms, small vein thickening and main vein thickening, possibly reflecting the existence of two strains of the virus; the disease, transmitted by *Bemisia tabaci*, always spreads in the direction of the wind; the highest disease rate coincides with the period of greatest plant growth and of highest vector population density; cotton intercropped with okra (*Abelmoschus esculentus)* exhibits higher disease incidence than cotton cultivated as a pure crop; and that cv. Barakat has a high level of disease resistance.

Atiri *et al.* (1991) observed the effects of three synthetic chemicals at recommended dosages on disease incidence, severity and total damage by the beetle transmitted *Okra mosaic tymovirus* (OMV) in okra (*Abelmoschus esculentus*) were compared with those of natural extracts from the seed of neem, *Azadirachta indica*. Only treatments with synthetic pyrethroid, lambacyhalothrin, at 15g a.i./ha and aqueous neem solution at 467 litres/ha significantly (P=0.05) reduced incidence, severity and total damage. Treatments with a cypermethrin + dimethoate mixture (3:25) at 280g a.i./ha apparently had the same effect on disease incidence and severity, but it had no effect on total damage relative to the untreated control. In all cases, the effects of neem oil at 60 litres/ha and carbaryl at 85g a.i./ha were not significantly different from the control. Metabolizing systems easily degrades Lambdacyhalothrin and aqueous neem solution.

Chowdhury *et al.* (1992) evaluated the inhibition of *Bhendi (Okra) yellow vein mosaic virus* (BYVMV) by different plant extracts and found that alcohol extracts were superior to aqueous ones in preventing infection by *Okra (Bhendi) yellow vein mosaic geminivirus* and those from Callistemon, Datura, Agave and ginger (*Zingiber officinale)* gave a good degree of suppression of symptoms on okra sprayed in the field. A lower rate of disease dissemination was recorded in treated plants than in the controls sprayed with water only. Mortality of the vectors (*Bemisia tabaci)* was 20-80% when they were confined for 30 minute in cage with plants treated with the extracts.

An experiment was conducted by Dhal *et al.* (1992) to test the effect of planting and insecticides on the incidence and spread of *Yellow vein mosaic virus* of okra in Nepal. The results suggested that the systematic insecticides neither delayed nor reduced the incidence of *Okra yellow vein bigeminivirus* in replicated field experiments. It was observed that the disease appeared after three weeks of sowing and the incidence reached to the comparable levels in both treated and untreated plots between 45 to 60 days. The rate of disease increase was similar in both treated and untreated plots, but significantly different among various dates of observations. They suggested that the initial incidence of spatial development of the disease varied with the planting time. The disease incidence was found to be lower in May sowing in comparison to Sowing in August.

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.

Significantly positive association between disease incidence and whitefly population, temperature, relative humidity and rainfall was recorded by Nath *et al.* (1992). They also observed the negative correlation of fruit yield with disease incidence.

Handa and Gupta (1993a) 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.

Handa and Gupta (1993b) applied Carbofuran 3G and Phorate 10G at the time of seed sowing and observed that two applications of both these insecticides were helpful in achieving a significant reduction in BYVMV disease incidence and consequent

improvement in yield. However, they noted that Carbofuran 3G performed better over Phorate 10G in controlling whitefly.

Singh *et al.* (1993) recorded *Okra yellow vein virus* infection for eight cultivars grown in the Tarai region of Uttar Pradesh during 1987-88. Mean yield over the two years was highest for Prabhani Kranti (9.1 t/ha) followed by Punjab 7 and Punjab Padmini (9 and 8.8 t/ha, respectively). The lowest levels of virus infection were recorded for Punjab 7 and Prabhani Kranti, of which 83.5 and 78.8% of the plants grown respectively, showed no viral infection.

Singh *et al.* (1994) conducted an experiment to find out the effects of sowing time on the incidence of *Yellow vein mosaic virus* of okra and seed yield of okra. They used two seeds of okra cv. Pusa Sawani were sown at weekly intervals during June and July in 1989 and 1990 in Uttar Pradesh. In general, plants from seeds sown later in the year exhibited a higher percentage of *Yellow vein mosaic virus* infection and a lower yield of seeds compared with plants from seeds sown earlier in the year.

Borah and Nath (1995) conducted field experiments at Diphu, Assam, India, during 1993-94 to investigate the efficacy of different spray schedules of carbofuran, dimethoate and malathion in the control of *B. tabaci* on okra and also therefore, for control of the virus for which it is a vector, *Yellow vein mosaic virus* (*Bhendi yellow vein mosaic geminivirus*) (BYVMV). Dimethoate 0.03% at 15 and 30 days after germination gave the best control of the insect pest and this treatment also had the least incidence of BYVMV and the greatest increase in yield over the untreated control.

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.

Nath and Saikia (1995) studied the influence of 15 different sowing dates from February to March on *Bhendi yellow vein mosaic geminivirus* (BYVMV) disease of okra was studied during 1989-90. The incidence of BYVMV on okra cv. Pusa sawani varied from

75 to 91% in plots sown between early April and the end of June. Infection in plots sown during February to the end of March was progressively less. The lowest yield of okra was obtained from the plots sown in May and Jun. A strong positive correlation was obtained between percent of disease incidence and whitefly (*Bemisia tabaci*) population (r=0.085) whereas a strong negative correlation was obtained from disease incidence and fruit yield (r=-0.84).

Bhagabati *et al.* (1998) 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.

Singh *et al.* (1999) reported that the spraying of asafoetida plant extract to an okra crop in the rainy season was tested for the control of the viral vector, *Empoasca devastans (Amrasca biguttula biguttula)*. The asafoetida formulation at 1-3% conc. in vitro and in field trials in Allahabad, Uttar Pradesh, India, showed strong insect repellent activity against *A. biguttula biguttula*, leading to reduced yellow vein mosaic viral infection levels.

Alegbejo (2001) reported that the effect of sowing date (30 June, 15 July and 30 July) on the incidence of *Okra mosaic virus* (OkMV) was investigated during 1997 and 1998 at Samaru, Nigeria. Two okra cultivars were used in the study, the resistant ABK 102 and the highly susceptible JOKOSO. The average number of virus vectors caught per plot decreased with delay in sowing. These vectors were identified as *Podagrica spp., Syagrus calcaratus and Nisotra dilecta.* The percentage of OkMV infected plants increased with delay in sowing, while fruit yield decreased.

Studies on *YVCMV* in Bangladesh

In the ten years annual report published individually by Anonymous (1980-1990) by the Division of Plant Pathology of Bangladesh Agricultural Research Institute, Joydevpur, Gazipur included the works on survey, monitoring and screening of the viruse in respect

of OYVMB. The transmission studies were also tried including the management through sowing date manipulation and insecticidal spray. However, the researchers so far concluded seem to be discontinuous and inconclusive.

Ahmed and Hossain (1985) made a survey on disease of crops with and view to establish a herbarium at Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur. The survey was conducted for three cropping seasons 1982-83. 1983-84 and 1984-85. Disease severity was worked out on 62 crops in nine districts of Bangladesh. In all 296 diseases were recorded including okra yellow vein clearing disease as and commonly prevalent disease of okra.

An experiment was conducted by Sayeed (1988) in Bangladesh Agricultural University Farm, Mymensingh with a Japanese okra cultivar, Pentagreen to find out the effects of date of planting and insecticidal spray on the control of *Yellow vein mosaic virus* of Lady's finger. Three sowing dates viz. 17 April, 1 May and 17 May were used. The results suggested that the incidence of *Yellow vein mosaic virus* was 25%, 48% and 56% in the first, second and third planting, respectively.

The effect of insecticides and planting dates on *Yellow vein mosaic virus* of Lady's finger were evaluated by Mian *et al.* (1990). They planted okra variety Pentagreen (Japanese variety) in three different dates viz. 17 April, 2 May and 17 May in 1986 and applied three insecticides namely Bidrin Ripcord and Sumithion in their experiment in Bangladesh Agricultural University Farm, Mymensingh. Among the insecticides, Bidrin was found to be the most effective followed by Ripcord in controlling the yellow vein mosaic of Lady's finger disease incidence. Sumithion used in their experiment was found ineffective. The authors recorded a pronounced effect of planting dates on the disease incidence as well as growth and yield of the crop. The lowest disease incidence was obtained in the first planting while it was the highest in the third planting.

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.

A study on the control of yellow vein mosaic of Lady's finger in the experimental field Bangladesh Agricultural University, Mymensingh. The findings of the study showed an economic benefit though it was not successful enough to control the virus Anonymous (1993).

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.

Ali (1999) developed a resistant variety against *Okra yellow vein mosaic virus,* which was released in the name of IPSA Derosh-1.

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.

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).

Peak Performance Nutrients (PPN)

Heng (2013) defined Peak Performance Nutrients (PPN) is a liquid formulated from various botanies extract which include vegetable oil extracts, plant extracts and seed extracts etc. It is eco-friendly, non residue and non toxic, increases yield, shorter harvest cycle, increases plant vitality and robustness, improves soil condition, drought resistance, prevent virus attack and has inane insect repellent properties. He alluded some benefits of Peak Performance Nutrients-

• Enhances plant root system for better nutrition absorptions and deeper roots

• Increase of chlorophyll production resulting in healthier, high quality and full bodied

and therefore “sweeter” crops

• Increases period of flowering for higher pollination yield.

• Natural repellant for birds, insect and larva – no pesticide or fungicide needed

• Expedite seed germination with seeds soaked with concentration mix of 1:500

• Reduction of harvest cycle duration.

• Soil rejuvenation and revitalization of fatigued soils.

• Harmless to human and animals

• Can improve crops quality with stronger natural flavor and glossier leaves

•Crops enhancement for resistance ability to natural disaster and quick restoration growth effects.

He also reported that the leaves of okra plant became more green within 24 days after the application of PPN. The plants required 4 days for flowering and became 24cm long within 5 days after flowering. Another okra variety became more than 10 inches long, crunchy and sweet.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

In this chapter, a short description of location of the experimental plot, climatic conditions of the area where the plot was situated, materials used for the experiment, treatments, design of the experiment and method of cultivation, data collection and statistical analysis have been presented.

3.1. Location of the experimental field

The experiment was carried out at the Horticultural farm of Sher-e-Bangla Agricultural University (SAU), Dhaka during April to August, 2015. The location of the experimental site was at $23^0 46^1$ N latitude and $90^0 24^1$ E longitude with elevation of 9 meters above the sea level and have been presented in Appendix 1and 2.

3.2. Climate and Soil

The experimental site was under the sub-tropical monsoon climatic condition, which is characterized by heavy rainfall during kharif season (May-September) and scanty in the rabi season (October-March). There was very low or 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 26.60^0c. Details of the meterological data in respect of temperature, rainfall and relative humidity the period of experiment were collected from Bangladesh Meterological Department, Agargaon, Dhaka and have been presented in Appendix 3.

The soil of the experiment site is a medium high land belonging to the modhupur tract under the Agro Ecological Zone (AEZ) 28. The soil texture was silty loam, non-calcarious, 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 4.

3.3. Planting materials used for the experiment

Four okra varieties namely BARI dherosh-1, Green finger, Orca onamika and Nufield were used in the experiment. BARI dherosh-1, used as a resistant variety to *Yellow vein clearing mosaic virus (YVCMV)*, was collected from Bangladesh Agricultural Research Institute (BARI), Joydevpur, Gazipur. The other three varieties were collected from local market and used as the test cultivars.

3.4. Collection of selected insecticides and Peak Performance Nutrients (PPN)

The selected insecticides namely Imidacloprid and Sobicron were collected from local market and PPN was collected from China through representative country dealers.

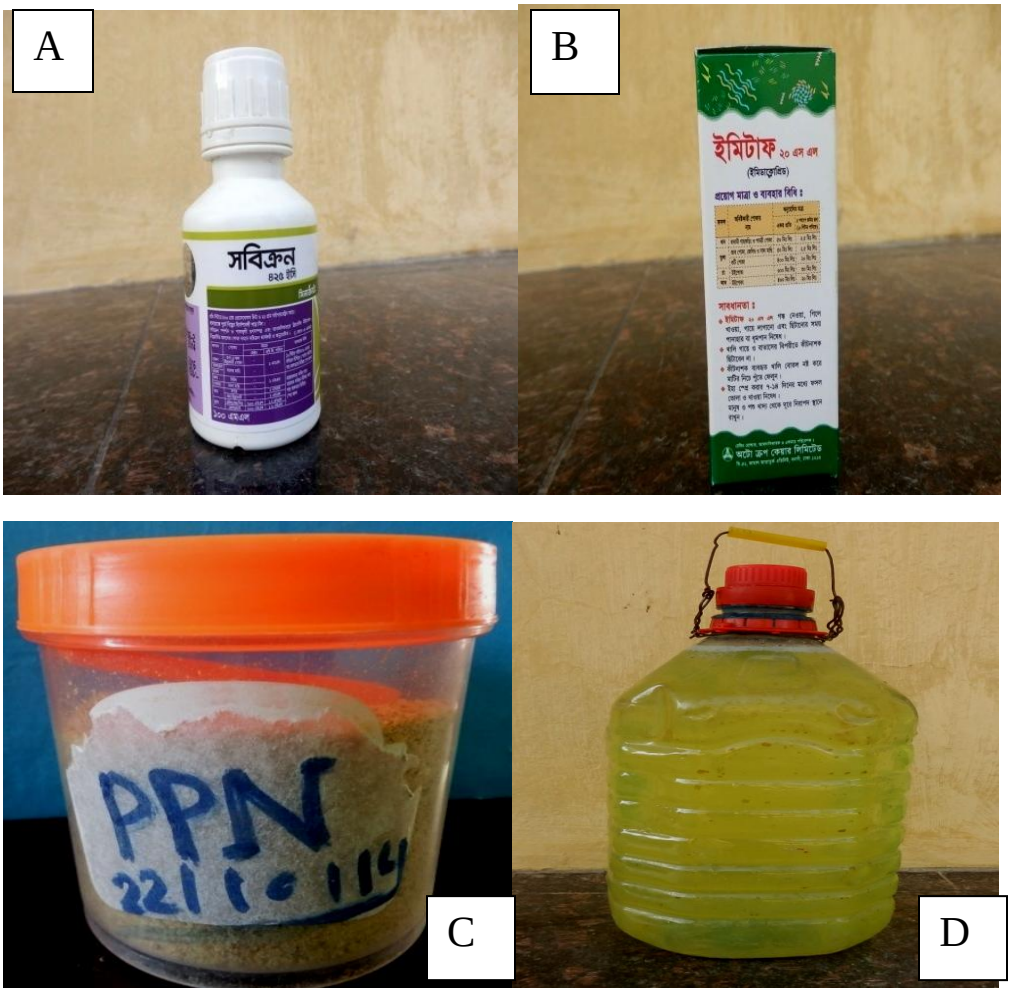

Figure 1. A) Insecticide Sobicron, B) Insecticide Imidacloprid, C) PPN and D) PPN (solution).

3.5. Specification of PPN

Product: Peak Performance Nutrients

Trade Name: PP Nutrients

Table 1. Specification of PPN

Typical	**Specification**
Visual appearance	Beige color (or other color as requested)
pH	8-10
Density	1.0-1.05 g/l
Nitrogen	4.0-7.0%
K_2O	1.0-2.5%
P_2O_5	1.0-2.0%
Ca	800 ppm-1.4%
MgO	700-4000 ppm
Na	3800-8000 ppm
Cu	20-300 ppm
Mn	150-1500 ppm
Zn	100-1000 ppm

3.6. Experimental treatments

There were two factors in this experiment, viz. varieties and insecticides with PPN and without PPN.

Considering varieties the treatments are-

V_1= BARI dherosh-1

V_2= Green finger

V_3= Orca onamika

V_4= Nufield

Considering insecticides and PPN the treatments are-

T_0= Control, i.e. without using of insecticides and PPN

T_1= Peak Performance Nutrients (PPN) at the rate of 2 g/l water

T_2= Imidacloprid (1 ml/l water) + PPN (2 g/l water)

T_3= Sobicron (1 ml/l water) + PPN (2 g/l water)

T_4= Imidacloprid (1 ml/l water)

T_5= Sobicron (1 ml/l water)

These treatments were applied at 15 days interval.

And, considering both the factors there were 24 treatments combinations together finally.

3.7. Design and layout of the experiment

The experiment was laid out in randomized complete block design (RCBD) with three replications. Blocks were representing the replication. Each block comprised 18 unit plot and total number of plots were 72 (18 X 4=72). Size of each unit plot was $5m^2$.The distances between unit plot was 0.70 m and block 1m.

3.8. Land preparation

The selected land for the experiment was first opened on 13 April 2015 by disc plough. After opening the land with a tractor it was ploughed and cross-ploughed six times with a power tiller and each ploughing was followed by laddering to break the clods to obtain good tilth and to level the land. All weeds and stubbles and dead roots were removed. After final land preparation, the experimental plot was laid out.

3.9. Manure and fertilizer application

The following doses of manure and fertilizers were applied to the plots for okra cultivation (Anon.,1998).

Table 2. Doses of manure and fertilizers used in the present study

Manures/Fertilizer	Doses
Cow dung	14 ton/ha
TSP	150 kg/ha
MP	150kg/ha
Urea	150 kg/ha

The entire amount of cow dung, TSP and MP @ 100 kg/ha were applied at the time of final land preparation. The remaining TSP and MP were applied after 30 days of seed. Urea was applied in three equal installments at 30, 45 and 60 (DAS).

3.10. Sowing of seeds

The okra seeds of different varieties were sown after soaking 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 rows of raised beds. Row to row and plant to plant spacing were maintained at 60 cm and 40cm. respectively and 2-3 seeds were placed in each hill. Then the seeds were covered with fine soil. After seed germination, only one healthy plant was kept in the hill.

3.11. Intercultural operation

The seedlings were always kept under careful observation. Necessary intercultural operations were done through the cropping season for proper growth and development of the experimental plants.

3.11.1. Thinning and gap filling

The seedlings were thinned out from the hill at 10 DAS keeping only one healthy seedling per hill. On the contrary, gap filling was done where needed with healthy seedling.

3.11.2. Irrigation

The plot was irrigated as and when needed.

3.11.3. Weeding and mulching

Weeding and mulching were necessary to keep the plots free from weeds for ease aeration and to conserve soil moisture. Total five weedings were done to keep the plots free from weeds.

3.11.4. Drainage

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

3.12. Harvesting

Green pods were harvested regularly when they attained edible stage. Harvesting was started from 45 days of seed sowing.

3.13. Identification and Disease incidence of Okra *Yellow vein clearing mosaic virus (YVCMV)*

Based on studying typical symptoms of *YVCMV* were observed as described by Capoor and Varma (1950). 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- 6 weeks after seed sowing
2) Mid stage- 3 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 disease incidence was calculated using the following formula Begum (2002).

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

Where,

X= Total number of plants

X_1= Number of infected plants

3.14. Disease rating scale

On the basis of disease incidence (%) of okra disease rating scale of *YVCMV* is as follows (Ali *et al., 2005a,b*).

Table 3. Disease rating scale of *YVCMV* of Okra

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

3.15. Parameters assessed

5 plants were selected for each plot and harvested from each plot totally from the total experimental site carefully and mean data on the following parameters were recorded-

- Number of plants per plot
- Number of infected plants per plot
- Disease incidence (%) per plot
- Number of leaves per infected plant
- Number of infected leaves per infected plant
- Disease incidence (%) per plant
- Number of fruits per plant
- Fruit length
- Fruit weight

- Plant height
- Yield
- Root length
- Dry weight of the root
- 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 plants per plot

Number of plants from each plot at 40, 60 and 80 days after sowing (DAS) was recorded.

3.16.2. Number of infected plants per plot

Number of infected plants from each plot at 40, 60 and 80 days after sowing (DAS) was recorded.

3.16.3. Number of leaves per infected plant

Number of leaves of selected infected plants from each plot at 40, 60 and 80 days after sowing (DAS) was recorded. Only the smallest young leaves at the growing point of the plant were excluded from counting. Calculating the average number of leaves, the average number was recorded.

3.16.4. Number of infected leaves per infected plant

Number of infected leaves of selected infected plants from each plot at 40, 60 and 80 days after sowing (DAS) was recorded. Calculating the average number of infected leaves, the average number was recorded.

3.16.5. Number of fruits per plant

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

3.16.6. Fruit length

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

3.16.7. Fruit weight

Green pods were collected from selected plants of each plot as per treatment combination and was weighed in gram (g).

3.16.8. Plant height

Average plant height of selected plants from each plot was recorded at 40, 60 and 80 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).

3.16.9. Yield

Yield of green pod (t/ha) was calculated by converting the mean green pod weight of each plot as per treatment combination.

3.16.10. Root length

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

3.16.11. Dry weight of the root

Roots were collected from selected plants of each plot as per treatment combination and then dried and weighed in gram (g).

3.16.12. 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", which is an advanced technology to directly measure the chlorophyll content in plant leaf at 40, 60 and 80 days after sowing (DAS). In each reading single leaf was held by the machine three times at three location of the same leaf then the machine automatically average the data and gave the value.

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

3.16.13. Net assimilation rate per plant

The average net assimilation rate per plant was recorded from the selected plants by using "LC-Pro+" machine at 40, 60 and 80 days after sowing (DAS).

3.16.14. 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 40, 60 and 80 days after sowing (DAS).

3.16.15. Respiration rate per plant

The average Respiration rate per plant was recorded from the selected plants by using "LC-Pro+" machine at 40, 60 and 80 days after sowing (DAS).

3.16.16. Stomatal conductivity per plant

The average Stomatal conductance per plant was recorded from the selected plants by using "LC-Pro+" machine at 40, 60 and 80 days after sowing (DAS).

Figure 3. "LC Pro$^+$" machine used to record the data of physiological features.

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 1% level of significance. Correlation and regression study was also done to check the relationship between disease incidence and chlorophyll content and chlorophyll content and yield. Tables, bar diagram and graphs were used to interpret the data as and when required.

Chapter 4

Results

CHAPTER IV

RESULTS

This chapter covers the experimental results. Four (4) cultivars viz. BARI dherosh 1, Green finger, Orca onamika and Nufield were assessed against *Yellow vein clearing mosaic virus* of Okra and to manage this disease through Peak Performance Nutrients (PPN), Imidacloprid and Sobicron under field condition. Results were compiled based on disease incidence, morphological and physiological parameters at different days after sowing (DAS) are presented in this chapter.

4.1. Effect of varieties on disease incidence (%) of *Yellow vein clearing mosaic* per plot and per plant at 40 DAS

At 40 DAS, the highest disease incidence per plot was found in Orca onamika (18.03%) followed by Nufield (14.79%) which are statistically different. The lowest disease incidence was found in the BARI dherosh-1 (8.44%) and Green finger (10.16%), and they are statistically similar with each other. The highest disease incidence per plant was found in Orca onamika (55.87%) followed by Nufield (52.65%) which are statistically different. The lowest disease incidence was found in the BARI dherosh-1 (43.39%) and Green finger (44.66%), and they are also statistically different with each other. The results are presented in Figure 4.

4.2. Effect of varieties on disease incidence (%) of *Yellow vein clearing mosaic* per plot and per plant at 60 DAS

At 60 DAS, the highest disease incidence per plot was found in Orca onamika (42.10%) followed by Nufield (18.58%) which are statistically different. The lowest disease incidence was found in the BARI dherosh-1 (9.78%) and Green finger (10.03%), and they are statistically similar with each other. The highest disease incidence per plant was found in Orca onamika (75.34%) followed by Nufield (72.07%) which are statistically different. The lowest disease incidence was found in the BARI dherosh-1 (67.51%) and Green finger (69.40%), and they are also statistically different with each other. The results are presented in Figure 4.

4.3. Effect of varieties on disease incidence (%) of *Yellow vein clearing mosaic* per plot and per plant at 80 DAS

At 80 DAS, the highest disease incidence per plot was found in Orca onamika (45.92%) followed by Nufield (25.82%) which are statistically different. The lowest disease incidence was found in the BARI dherosh-1 (7.22%) and Green finger (10.53%), and they are also statistically different with each other. The highest disease incidence per plant was found in Orca onamika (88.79%) followed by Nufield (87.51%) which are statistically different. The lowest disease incidence was found in the BARI dherosh-1 (54.27%) and Green finger (67.46%), and they are also statistically different with each other. The results are presented in Figure 4.

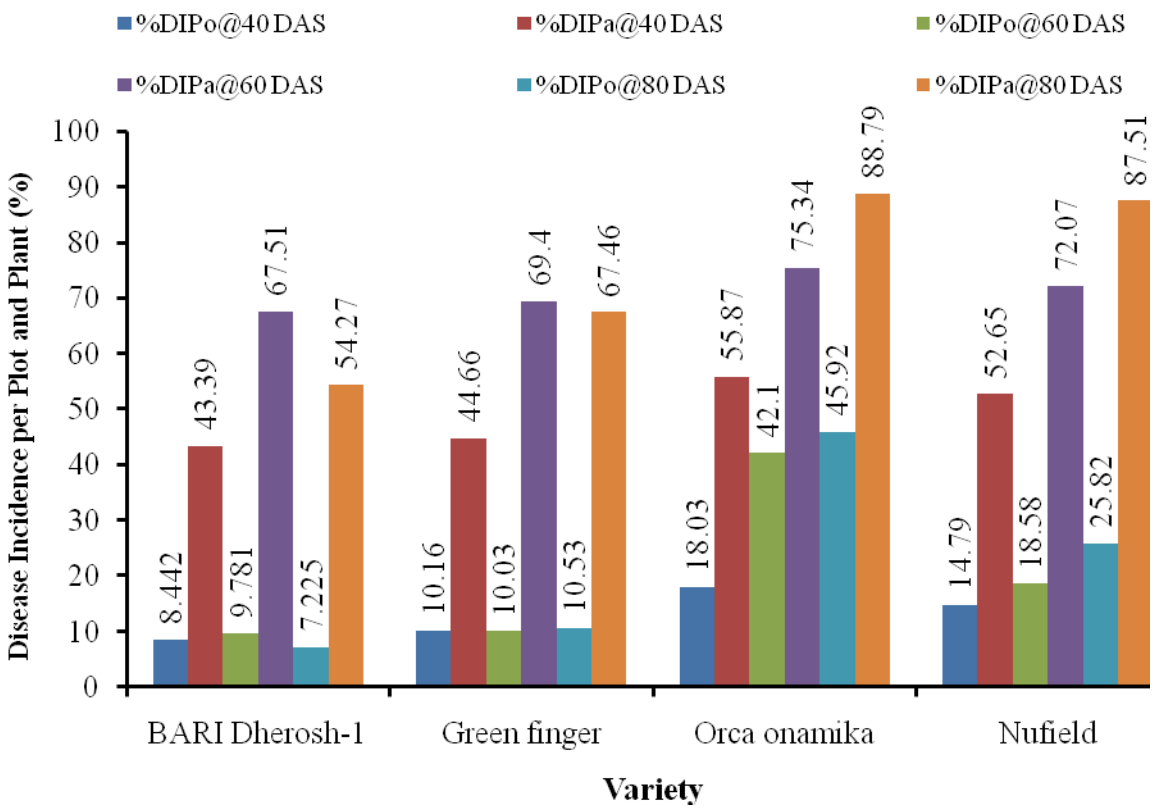

Figure 4. Disease incidence (%) of *YVCMV* due to varietal effect at different days after sowing (DAS).

%DIPo= Disease Incidence(%) per Plot and %DIPa= Disease Incidence(%) per Plant.

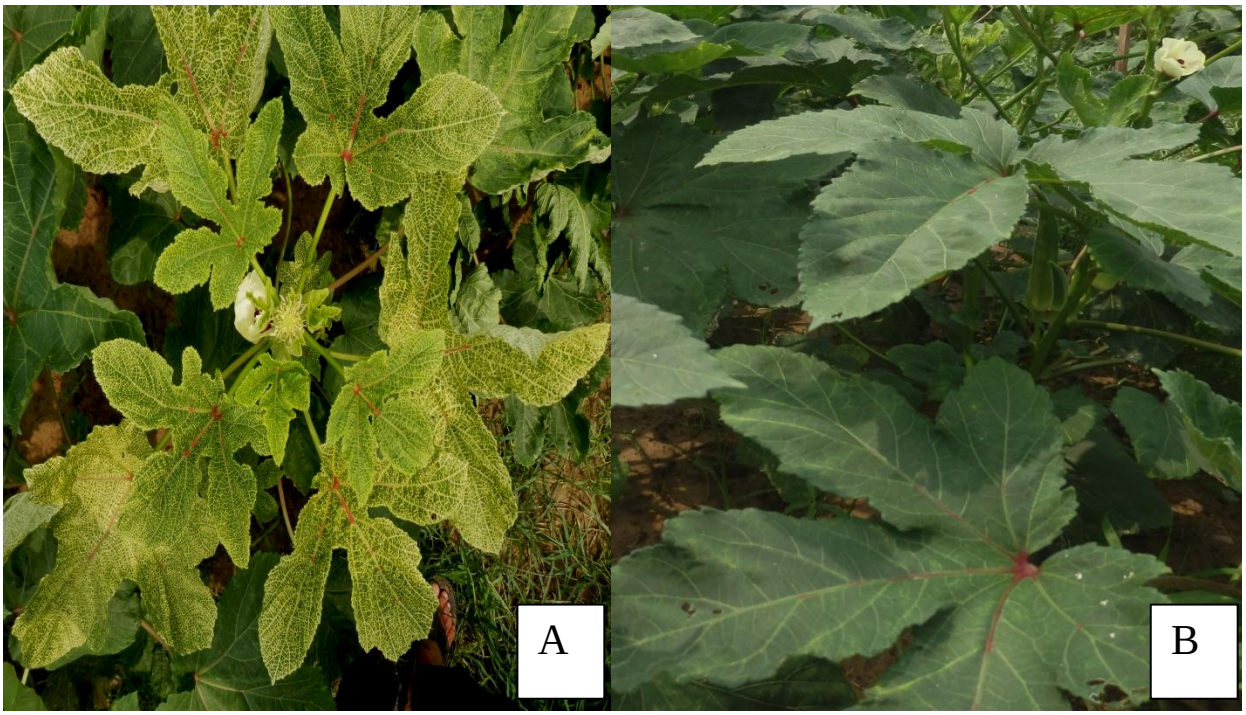

Figure 5. A) Infected plant (Orca onamika), B) Healthy plant (Green finger).

4.4. Effect of insecticides and Peak Performance Nutrients (PPN) on disease incidence (%) of *Yellow vein clearing mosaic* per plot and per plant at 40 DAS

At 40 DAS, the highest disease incidence per plot was found when no insecticides and PPN (17.92%) are used followed by only PPN (14.18%) used, which are statistically different. The moderate disease incidence was found in Imidacloprid (10.65%), Sobicron (12.36%) and Imidacloprid with PPN (12.38%) which are statistically similar with each other. The lowest disease incidence was found in Sobicron with PPN (9.63%) which is statistically different from the others. The highest disease incidence per plant was found when no insecticides and PPN (58.30%) are used. The lowest disease incidence was found in Sobicron with PPN (40.74%) preceded by Imidacloprid (45.89%), Imidacloprid with PPN (47.61%), Sobicron (48.90%), PPN (53.40%) and all of them are statistically different with each other. The results are presented in Figure 6.

4.5. Effect of insecticides and PPN on disease incidence (%) of *Yellow vein clearing mosaic* per plot and per plant at 60 DAS

At 60 DAS, the highest disease incidence per plot was found when no insecticides and PPN (27.73%) are used which is statistically different from PPN (23.62%) and Imidacloprid (21.42%) used, but they are statistically similar with each other. The moderate disease incidence was found in Imidacloprid with PPN (17.01%), in Sobicron (16.84%) and both are statistically similar. The lowest disease incidence was found in Sobicron with PPN (14.12%) which is statistically different from the others. The highest disease incidence per plant was found when no insecticides and PPN (84.58%) are used.. The lowest disease incidence was found in Sobicron with PPN (59.26%) preceded by Imidacloprid with PPN (65.25%), Sobicron (65.35%), Imidacloprid (70.45%), PPN (81.60%) and statistically different from others. The results are presented in Figure 6.

4.6. Effect of insecticides and PPN on disease incidence (%) of *Yellow vein clearing mosaic* per plot and per plant at 80 DAS

At 80 DAS, the highest disease incidence per plot was found when no insecticides and PPN (32.32%) are used followed by PPN (28.53%), Sobicron (25.69%), Imidacloprid (19.79%) they are statistically different from each other. The lowest disease incidence was found in Sobicron with PPN (10.78%) preceded by Imidacloprid with PPN (17.13%) which are statistically different from each other. The highest disease incidence per plant was found when no insecticides and PPN (85.07%) used which is statistically different from PPN (77.22%) and Imidacloprid (77.13%) used but both are statistically similar. The lowest disease incidence was found in Sobicron with PPN (67.52%) preceded by Imidacloprid with PPN (68.07%) and Sobicron (72.02%), both are statistically different from others. The results are presented in Figure 6.

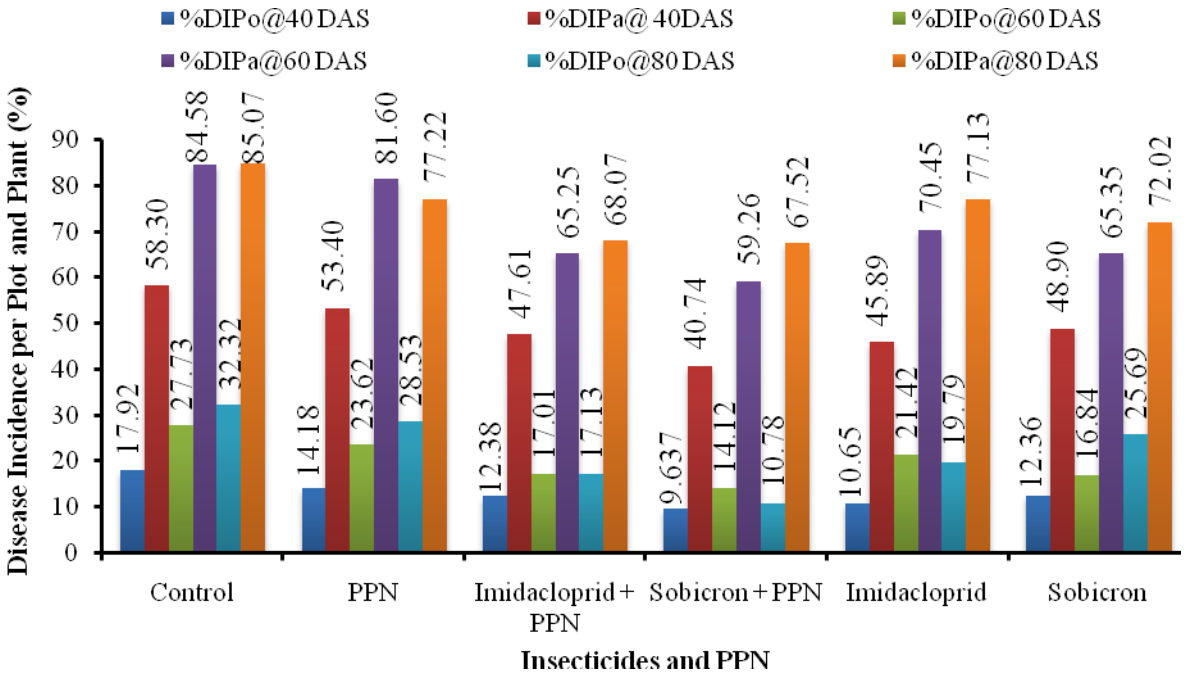

Figure 6. Disease incidence (%) of *YVCMV* due to insecticidal and PPN effect at different days after sowing (DAS).

%DIPo= Disease Incidence(%) per Plot, %DIPa= Disease Incidence(%) per Plant and Control= No insecticides and PPN.

4.7. Effect of insecticides and PPN on varieties in terms of disease incidence (%) of *Yellow vein clearing mosaic* per plot and per plant at 40 DAS

At 40 DAS, the highest disease incidence per plot was found in V_3T_0 (28.80%) combination followed by V_3T_1 (21.67%) combination which are statistically different. The lowest disease incidence was found in V_1T_0 (6.73%) and V_2T_3 (6.83%) combinations and both are statistically similar and preceded by V_1T_3 (7.48%), V_4T_3 (8.04%) combinations and both are also statistically similar. The highest disease incidence per plant was found in V_3T_0 (78.84%) combination followed by V_3T_1 (66.38%) combination which are statistically different from each other. The lowest disease incidence was found in V_1T_0 (30.42%) combination preceded by V_2T_3 (33.76%), V_4T_3 (36.70%) combinations and which are also statistically different. The results are presented in Table 4.

Table 4. Effect of insecticides and PPN on varieties in terms of disease incidence (%) of *Yellow vein clearing mosaic* per plot and per plant at 40 DAS

Interaction	Disease Incidence per Plot (%)	Disease Incidence per Plant (%)
V_1T_0	6.73 j	30.42 p
V_1T_1	15.47 cdef	49.50 h
V_1T_2	9.50 ghij	42.67 l
V_1T_3	7.48 ij	38.83 m
V_1T_4	9.12 ghij	48.60 hi
V_1T_5	9.40 ghij	42.97 l
V_2T_0	15.80 cdef	55.82 f
V_2T_1	13.80 cdefg	53.49 g
V_2T_2	9.51 ghij	44.76 jkl
V_2T_3	6.83 j	33.76 o
V_2T_4	8.91 ghij	46.75 ijk
V_2T_5	9.86 ghij	44.20 l
V_3T_0	28.80 a	78.84 a
V_3T_1	21.67 b	66.38 b
V_3T_2	11.50 defghij	63.26 c
V_3T_3	16.11 cde	49.81 h
V_3T_4	13.37 defgh	60.15 de
V_3T_5	16.72 cd	61.90 cd
V_4T_0	18.80 bc	58.50 e
V_4T_1	16.67 cd	46.90 ij
V_4T_2	10.80 fghij	40.11 m
V_4T_3	8.04 hij	36.70 n
V_4T_4	11.20 efghij	44.56 kl
V_4T_5	12.43 defghi	40.50 m
$LSD_{0.01}$	4.621	2.103
CV%	16.38	1.95

V_1= BARI dherosh-1, $V_{2=}$ Green finger, V_3= Orca onamika and V_4= Nufield
T_0= No insecticides and PPN, T_1= PPN, T_2= Imidacloprid + PPN, T_3= Sobicron + PPN, T_4= Imidacloprid, T_5= Sobicron
LSD= Least Significance Difference, CV%= Percent of Coefficient of Variance.

4.8. Effect of insecticides and PPN on varieties in terms of disease incidence (%) of *Yellow vein clearing mosaic* per plot and per plant at 60 DAS

At 60 DAS, the highest disease incidence per plot was found in V_3T_0 (61.90%) combination followed by V_3T_1 (55.33%) combination which are statistically different from each other. The lowest disease incidence was found in V_1T_0 (7.20%) preceded by V_2T_3 (7.60%) combinations, both are statistically similar and V_1T_3 (8.10%), V_4T_3 (9.84%) combinations which are also statistically similar. The highest disease incidence per plant was found in V_3T_0 (97.11%) combination followed by V_3T_1 (91.65%) combination which are statistically different from each other. The lowest disease incidence was found in V_1T_0 (39.47%) combination preceded by V_2T_3 (53.78%), both are statistically different from each other and by V_1T_3 (55.85%), V_4T_3 (56.97%) combinations and which are statistically similar. The results are presented in Table 5.

Table 5. Effect of insecticides and PPN on varieties in terms of disease incidence (%) of *Yellow vein clearing mosaic* per plot and per plant at 60 DAS

Interaction	Disease Incidence per Plot (%)	Disease Incidence per Plant (%)
V_1T_0	7.20 g	39.47 m
V_1T_1	19.04 ef	77.89 f
V_1T_2	9.84 fg	70.25 gh
V_1T_3	8.10 g	55.85 l
V_1T_4	11.27 fg	67.33 ghi
V_1T_5	9.32 fg	65.65 hij
V_2T_0	22.13 de	89.47 bc
V_2T_1	31.57 d	81.25 def
V_2T_2	9.66 fg	65.00 ij
V_2T_3	7.60 g	53.78 l
V_2T_4	11.73 fg	70.46 gh
V_2T_5	8.86 fg	61.91 j
V_3T_0	61.90 a	97.11 a
V_3T_1	55.33 b	91.65 b
V_3T_2	50.00 c	85.74 cd
V_3T_3	12.88 fg	70.52 gh
V_3T_4	31.57 d	80.71 ef
V_3T_5	14.87 efg	70.77 g
V_4T_0	35.00 d	84.04 de
V_4T_1	19.04 ef	81.39 def
V_4T_2	12.00 fg	60.78 jk
V_4T_3	9.84 fg	56.97 kl
V_4T_4	12.55 fg	64.95 ij
V_4T_5	11.89 fg	62.98 ij
$LSD_{0.01}$	5.307	4.565
CV%	12.02	2.93

V_1= BARI dherosh-1, $V_{2=}$ Green finger, V_3= Orca onamika and V_4= Nufield
T_0= No insecticides and PPN, T_1= PPN, T_2= Imidacloprid + PPN, T_3= Sobicron + PPN, T_4= Imidacloprid, T_5= Sobicron
LSD= Least Significance Difference, CV%= Percent of Coefficient of Variance.

4.9. Effect of insecticides with or without PPN on varieties in terms of disease incidence (%) of *Yellow vein clearing mosaic* per plot and per plant at 80 DAS

At 80 DAS, the highest disease incidence per plot was found in V_3T_0 (72.22%) combination followed by V_3T_1 (61.90%) combination which are statistically different from each other. The lowest disease incidence was found in V_1T_0 (3.40%) preceded by V_2T_3 (4.00%) combinations and both are statistically different with each other and by V_1T_3 (4.80%), V_1T_2 (5.00%) combinations and both are statistically similar. The highest disease incidence per plant was found in V_3T_0 (99.33%) combination followed by V_3T_1 (98.29%) combination which are statistically different from each other. The lowest disease incidence was found in V_1T_0 (27.90%) combination preceded by V_2T_3 (32.00%), V_1T_3 (53.98%), V_1T_2 (55.00%) combinations and they are statistically different from each other. The results are presented in Table 6.

Table 6. Effect of insecticides and PPN on varieties in terms of disease incidence (%) of *Yellow vein clearing mosaic* per plot and per plant at 80 DAS

Interaction	Disease Incidence per Plot (%)	Disease Incidence per Plant (%)
V_1T_0	3.40 s	27.90 s
V_1T_1	14.28 l	75.00 j
V_1T_2	5.00 q	55.00 p
V_1T_3	4.80 q	53.98 q
V_1T_4	5.75 p	60.00 n
V_1T_5	9.52 m	57.60 o
V_2T_0	19.04 i	83.81 h
V_2T_1	15.00 k	88.35 f
V_2T_2	6.70 o	67.80 m
V_2T_3	4.00 r	32.00 r
V_2T_4	9.52 m	71.50 k
V_2T_5	7.90 n	71.14 k
V_3T_0	72.22 a	99.33 a
V_3T_1	61.90 b	98.29 b
V_3T_2	40.00 d	96.76 c
V_3T_3	30.00 h	74.64 j
V_3T_4	55.56 c	88.58 f
V_3T_5	31.57 g	89.40 e
V_4T_0	36.84 f	96.76 c
V_4T_1	38.09 e	91.90 d
V_4T_2	15.00 k	74.83 j
V_4T_3	14.28 l	68.76 l
V_4T_4	19.04 i	84.82 g
V_4T_5	15.95 j	80.00 i
$LSD_{0.01}$	0.2194	0.5284
CV%	0.10	0.32

V_1= BARI dherosh-1, $V_{2=}$ Green finger, V_3= Orca onamika and V_4= Nufield
T_0= No insecticides and PPN, T_1= PPN, T_2= Imidacloprid + PPN, T_3= Sobicron + PPN, T_4= Imidacloprid, T_5= Sobicron.

Figure 7. Orca onamika (Left side) and BARI dherosh-1 (Right side) plots while no insecticides and PPN used.

4.10. Reaction of tested okra varieties against *YVCMV* in case of disease incidence (%) per plot

At 40, 60 and 80 DAS, the highest disease incidence per plot was found in Orca onamika (18.03, 42.10 and 45.92%) followed by variety Nufield (14.79, 18.58 and 25.82%) respectively. The lowest disease incidence was found in the BARI dherosh-1 (8.44, 9.78 and 7.22%) and Green finger (10.16, 10.02 and 10.53%) respectively. It revealed that, Orca onamika shows moderate resistance at 40 DAS and at 60 and 80 DAS showed tolerance. The highly resistance showed by BARI dherosh-1 in all observation at 40, 60 and 80 DAS. The results are presented in Table 7.

Table 7. Reaction of tested okra varieties against *YVCMV* in case of disease incidence (%) per plot

Variety	Disease Incidence (%) per Plot			Disease Reaction		
	40 DAS	60DAS	80 DAS	40 DAS	60DAS	80 DAS
BARI Dherosh-1	8.44	9.78	7.22	HR	HR	HR
Green finger	10.16	10.03	10.53	MR	MR	MR
Orca onamika	18.03	42.10	45.92	MR	T	T
Nufield	14.79	18.58	25.82	MR	MR	T

HR= Highly Resistant, MR= Moderate Resistant, T= Tolerant.

4.11. Reaction of tested okra varieties against *YVCMV* in case of disease incidence (%) per plant

At 40, 60 and 80 DAS, the highest disease incidence per plant was found in Orca onamika (55.87, 75.34 and 88.79%) followed by Nufield (52.65, 72.07 and 87.51%) respectively. The lowest disease incidence was found in the BARI dherosh-1 (43.39, 67.51 and 54.27%) and Green finger (44.66, 69.40 and 67.46%) respectively. So it may be concluded that, Orca onamika shows moderate susceptibility at 40 DAS and high susceptibility at 60 and 80 DAS. The tolerance, susceptibility and moderate susceptibility showed by BARI dherosh-1 at 40, 60 and 80 DAS respectively. The results are presented in Table 8.

Table 8. Reaction of tested okra varieties against *YVCMV* in case of disease incidence (%) per plant

Variety	Disease Incidence (%) per Plant			Disease Reaction		
	40 DAS	60DAS	80 DAS	40 DAS	60DAS	80 DAS
BARI Dherosh-1	43.39	67.51	54.27	T	S	MS
Green finger	44.66	69.40	67.46	T	S	S
Orca onamika	55.87	75.34	88.79	MS	HS	HS
Nufield	52.65	72.07	87.51	MS	HS	HS

T= Tolerant, S= Susceptibility, MS= Moderate susceptibility, HS= High susceptibility.

4.12. Reaction of selected insecticides and PPN against *YVCMV* in case of disease incidence (%) per plot

At 40 DAS, the highest disease incidence per plot was found when no insecticides and PPN (17.92%) were used followed by PPN (14.18%). The moderate disease incidence was found in Imidacloprid with PPN (12.38%), Sobicron (12.36%) and Imidacloprid (10.65%). The lowest disease incidence was found in Sobicron with PPN (9.63%). At 60 DAS, the highest disease incidence was found when no insecticides and PPN (27.73%) were used then PPN (23.62%) and Imidacloprid (21.42%).The moderate disease incidence was found in Imidacloprid with PPN (17.01%) and Sobicron (16.84%). The lowest disease incidence was found in Sobicron with PPN (14.12%). At 80 DAS, the highest disease incidence was found when no insecticides and PPN (32.32%) were used followed by PPN (28.53%), Sobicron (16.84%), Imidacloprid (21.42%). The lowest disease incidence was found in Sobicron with PPN (10.78%) and Imidacloprid with PPN (17.13%). It implies that moderate resistance at 40 DAS and tolerance at 60 and 80 DAS was showed when no insecticides and PPN used, respectively. The highly resistance at 40 DAS and moderate resistance at 60 and 80 DAS was appeared when Sobicron with PPN used, respectively. The results are presented in Table 9.

Table 9. Reaction of selected insecticides and PPN against *YVCMV* in case of disease incidence (%) per plot

Insecticides and PPN	Disease Incidence (%) per Plot			Disease Reaction		
	40 DAS	60DAS	80 DAS	40 DAS	60DAS	80 DAS
Control	17.92	27.73	32.32	MR	T	T
PPN	14.18	23.62	28.53	MR	MR	T
Imidacloprid + PPN	12.38	17.01	17.13	MR	MR	MR
Sobicron + PPN	9.63	14.12	10.78	HR	MR	MR
Imidacloprid	12.36	21.42	19.79	MR	MR	MR
Sobicron	10.56	16.84	25.69	MR	MR	T

4.13. Reaction of selected insecticides and PPN against *YVCMV* in case of disease incidence (%) per plant

At 40 DAS, the highest disease incidence per plant was found when no insecticides and PPN (58.30%). The lowest disease incidence was found in Sobicron with PPN (40.74%) preceded by Imidacloprid (45.89%), Imidacloprid with PPN (47.61%), Sobicron (48.90%), PPN (53.40%). At 60 DAS, the highest disease incidence was found when no insecticide and PPN (84.58%). The lowest disease incidence was found in Sobicron with PPN (59.26%) preceded by Imidacloprid with PPN (65.25%), Sobicron (65.35%), Imidacloprid (70.45%), PPN (81.60%). At 80 DAS, the highest disease incidence was found when no insecticides and PPN (85.07%) followed by PPN (77.22%) and Imidacloprid (77.13%). The lowest disease incidence was found in Sobicron with PPN (67.52%) preceded by Imidacloprid with PPN (68.07%), Sobicron (72.02%). It implies that moderate susceptibility at 40 DAS and high susceptibility at 60 and 80 DAS was shown when no insecticides and PPN used, respectively. The tolerance, moderate susceptibility and susceptibility at 40, 60 and 80 DAS, respectively, was appeared when Sobicron with PPN used. The results are presented in Table 10.

Table 10. Reaction of selected insecticides and PPN against *YVCMV* in case of disease incidence (%) per plant

Insecticides and PPN	Disease Incidence (%) per Plant			Disease Reaction		
	40 DAS	60DAS	80 DAS	40 DAS	60DAS	80 DAS
Control	58.30	84.58	85.07	MS	HS	HS
PPN	53.40	81.60	77.22	MS	HS	HS
Imidacloprid + PPN	47.61	65.25	68.07	T	S	S
Sobicron + PPN	40.74	59.26	67.52	T	MS	S
Imidacloprid	45.89	70.45	77.13	T	S	HS
Sobicron	48.90	65.35	72.02	T	S	HS

4.14. Reaction of varieties with insecticides and PPN against *YVCMV* in case of disease incidence (%) per plot

At 40 DAS, the highest disease incidence per plot was found in V_3T_0 (28.80%) combination followed by V_3T_1 (21.67%) combination. The lowest disease incidence was found in V_1T_0 (6.73%) and V_2T_3 (6.83%) combinations. At 60 DAS, the highest disease incidence was found in V_3T_0 (61.90%) combination followed by V_3T_1 (55.33%) combination. The lowest disease incidence was found in V_1T_0 (7.20%) preceded by V_2T_3 (7.60%) combinations. At 80 DAS, he highest disease incidence was found in V_3T_0 (72.22%) combination followed by V_3T_1 (61.90%) combination. The lowest disease incidence was found in V_1T_0 (3.40%) preceded by V_2T_3 (4.00%) combinations. So, it can be said that tolerance, susceptibility and high susceptibility was shown by V_3T_0 combination at 40, 60 and 80 DAS, respectively. The highly resistance was shown at 40, 60 and 80 DAS by V_1T_0 combination. The results are presented in Table 11.

Table 11. Reaction of varieties with insecticides and PPN against *YVCMV* in case of disease incidence (%) per plot

Interaction	Disease Incidence (%) per Plot			Disease Reaction		
	40 DAS	60DAS	80 DAS	40 DAS	60DAS	80 DAS
V_1T_0	6.73	7.20	3.40	HR	HR	HR
V_1T_1	15.47	19.04	14.28	MR	MR	MR
V_1T_2	9.50	9.84	5.00	HR	HR	HR
V_1T_3	7.48	8.10	4.80	HR	HR	HR
V_1T_4	9.12	11.27	5.75	HR	MR	HR
V_1T_5	9.40	9.32	9.52	HR	HR	HR
V_2T_0	15.80	22.13	19.04	MR	MR	MR
V_2T_1	13.80	31.57	15.00	MR	T	MR
V_2T_2	9.51	9.66	6.70	HR	HR	HR
V_2T_3	6.83	7.60	4.00	HR	HR	HR
V_2T_4	8.91	11.73	9.52	HR	MR	HR
V_2T_5	9.86	8.86	7.90	HR	HR	HR
V_3T_0	28.80	61.90	72.22	T	S	HS
V_3T_1	21.67	55.33	61.90	MR	MS	S
V_3T_2	11.50	50.00	40.00	MR	T	T
V_3T_3	16.11	12.88	30.00	MR	MR	T
V_3T_4	13.37	31.57	55.56	MR	T	MS
V_3T_5	16.72	14.87	31.57	MR	MR	T
V_4T_0	18.80	35.00	36.84	MR	T	T
V_4T_1	16.67	19.04	38.09	MR	MR	T
V_4T_2	10.80	12.00	15.00	MR	MR	MR
V_4T_3	8.04	9.84	14.28	HR	HR	MR
V_4T_4	11.20	12.55	19.04	MR	MR	MR
V_4T_5	12.43	11.89	15.95	MR	MR	MR

V_1= BARI dherosh-1, V_2= Green finger, V_3= Orca onamika, V_4= Nufield
T_0= No insecticides and PPN, T_1= Peak Performance Nutrients (PPN), T_2= Imidacloprid + PPN, T_3= Sobicron + PPN, T_4= Imidacloprid, T_5= Sobicron
HR= Highly Resistant, MR= Moderate Resistant, T= Tolerant, S= Susceptibility, HS= High Susceptibility, MS= Moderate Susceptibility

4.15. Reaction of varieties with insecticides and PPN against *YVCMV* in case of disease incidence (%) per plant

At 40 DAS, the highest disease incidence per plant was found in V_3T_0 (78.84%) combination followed by V_3T_1 (66.38%) combination. The lowest disease incidence was found in V_1T_0 (30.42%) combination preceded by V_2T_3 (33.76%), V_4T_3 (36.70%) combinations. At 60 DAS, the highest disease incidence was found in V_3T_0 (97.11%) combination followed by V_3T_1 (91.65%) combination. The lowest disease incidence was found in V_1T_0 (39.47%) preceded by V_2T_3 (53.78%) combination. At 80 DAS, the highest disease incidence was found in V_3T_0 (99.33%) combination followed by V_3T_1 (98.29%) combination. The lowest disease incidence was found in V_1T_0 (27.90%) combination preceded by V_2T_3 (32.00%), V_1T_3 (53.98%), V_1T_2 (55.00%) combinations. So, it revealed that high susceptibility was shown at 40, 60 and 80 DAS by V_3T_0 combination. The tolerance was shown by V_1T_0 combination at 40, 60 and 80 DAS. The results are presented in Table 12.

Table 12. Reaction of varieties with insecticides and PPN against *YVCMV* in case of disease incidence (%) per plant

Interaction	Disease Incidence (%) per Plant			Disease Reaction		
	40 DAS	60DAS	80 DAS	40 DAS	60DAS	80 DAS
V_1T_0	30.42	39.47	27.90	T	T	T
V_1T_1	49.50	77.89	75.00	T	HS	HS
V_1T_2	42.67	70.25	55.00	T	S	MS
V_1T_3	38.83	55.85	53.98	T	MS	MS
V_1T_4	48.60	67.33	60.00	T	S	MS
V_1T_5	42.97	65.65	57.60	T	S	MS
V_2T_0	55.82	89.47	83.81	MS	HS	HS
V_2T_1	53.49	81.25	88.35	MS	HS	HS
V_2T_2	44.76	65.00	67.80	T	S	S
V_2T_3	33.76	53.78	32.00	T	MS	T
V_2T_4	46.75	70.46	71.50	T	S	HS
V_2T_5	44.20	61.91	71.14	T	S	HS
V_3T_0	78.84	97.11	99.33	HS	HS	HS
V_3T_1	66.38	91.65	98.29	S	HS	HS
V_3T_2	63.26	85.74	96.76	S	HS	HS
V_3T_3	49.81	70.52	74.64	T	HS	HS
V_3T_4	60.15	80.71	88.58	MS	HS	HS
V_3T_5	61.90	70.77	89.40	S	HS	HS
V_4T_0	58.50	84.04	96.76	MS	HS	HS
V_4T_1	46.90	81.39	91.90	T	HS	HS
V_4T_2	40.11	60.78	74.83	T	S	HS
V_4T_3	36.70	56.97	68.76	T	S	S
V_4T_4	44.56	64.95	84.82	T	S	HS
V_4T_5	40.50	62.98	80.00	T	HS	HS

Figure 8. Green finger variety (Left side) and Orca onamika variety (Right side).

4.16. Effect of varieties on the plant height (cm), root length (cm) and dry weight of the root (g)

The maximum plant height was found in Green finger (126.3 cm) followed by BARI dherosh-1 (114.7 cm) which are statistically different from each other. The minimum plant height was found in Orca onamika (86.48 cm) preceded by Nufield (100.5 cm) and both are also statistically different. The highest root length was found in Green finger (32.37 cm) followed by BARI dherosh-1 (31.85 cm) and both are statistically similar. The lowest root length was found in Orca onamika (29.62 cm) preceded by Nufield (30.83 cm) which are statistically different from each other. The highest dry weight of root was found in Green finger (29.17 g) followed by BARI dherosh-1 (27.83 g), both are statistically similar. The lowest dry weight of root was found in Orca onamika (21.23 g) preceded by Nufield (23.83 g) which are statistically different from each other. The results are presented in Table 13.

Table 13. Effect of varieties on the plant height (cm), root length (cm) and dry weight of the root (g)

Variety	Plant height (cm)	Root length (cm)	Dry weight of root (g)
BARI Dherosh-1	114.7 b	31.85 a	27.83 a
Green finger	126.3 a	32.37 a	29.17 a
Orca onamika	86.48 d	29.62 c	21.23 c
Nufield	100.5 c	30.83 b	23.83 b
$LSD_{0.01}$	0.5396	0.9517	2.455
CV%	0.56	3.41	10.70

4.17. Effect of insecticides and PPN on the plant height (cm), root length (cm) and dry weight of the root (g)

The maximum plant height was found when Sobicron with PPN (118.0 cm) was used followed by Imidacloprid with PPN (116.5 cm), PPN (113.4 cm) and they are statistically different with each other. The minimum plant height was found when no insecticides and PPN (79.60 cm) were used preceded by Imidacloprid (105.3 cm), Sobicron (109.0 cm) which are also statistically different with each other. The highest root length was found when Sobicron with PPN (36.40 cm) was used followed by Imidacloprid with PPN (34.17 cm) which are statistically different with each other. The medium root length was found when PPN (31.65 cm) and Imidacloprid (31.65 cm) were used, both are statistically identical with each other. The lowest root length was found when no insecticides and PPN (25.23 cm) were used preceded by Sobicron (27.90 cm) which are statistically different with each other. The highest dry weight of root was found when Sobicron with PPN (33.00 g) was used followed by Sobicron (31.75 g) which are statistically similar with each other. The lowest dry weight of root was found when no insecticides and PPN (14.75 g) was used, which is statistically different from PPN (23.00

g), Imidacloprid with PPN (25.00 g), Imidacloprid (26.25 g), they are statistically similar with each other. The results are presented in Table 14.

Table 14. Effect of insecticides and PPN on the plant height (cm), root length (cm) and dry weight of the root (g)

Insecticides and PPN	Plant height (cm)	Root length (cm)	Dry weight of root (g)
Control	79.60 f	25.23 e	14.75 d
PPN	113.4 c	31.65 c	23.00 c
Imidacloprid + PPN	116.5 b	34.17 b	25.00 bc
Sobicron + PPN	118.0 a	36.40 a	33.00 a
Imidacloprid	105.3 e	31.65 c	26.25 b
Sobicron	109.0 d	27.90 d	31.75 a
$LSD_{0.01}$	0.6609	1.166	3.007
CV%	0.56	3.41	10.70

Control= No insecticides and PPN

4.18. Effect of insecticides and PPN on varieties in terms of the plant height (cm), root length (cm) and dry weight of the root (g)

The maximum plant height was found in V_2T_3 (142.1 cm) combination which is statistically different from V_1T_3 (138.6 cm), V_2T_2 (137.3 cm) combinations, both are statistically similar with each other. The minimum plant height was found in V_3T_0 (51.76 cm) preceded by V_1T_0 (68.85 cm), V_3T_4 (88.61 cm), V_3T_5 (87.32 cm), V_3T_1 (90.36 cm), they are statistically different from each other. The highest root length was found in V_2T_3 (40.80 cm) followed by V_2T_2 (39.00 cm), V_1T_3 (38.70 cm) combinations, and both are statistically similar. The lowest root length was found in V_3T_0 (17.60 cm) which is statistically different from V_1T_0 (24.30 cm), V_3T_1 (23.70 cm) combinations both are statistically similar. The highest dry weight of root was found in V_2T_3 (40.00 g) combination followed by V_1T_3 (36.00 g), V_4T_3 (36.00 g), they are statistically identical with each other, but statistically similar with V_1T_2 (32.00 g) combination. The lowest dry weight of root was found in V_3T_0 (11.00 g) combination preceded by V_1T_0 (12.00 g),

V_4T_0 (12.00 g), they are statistically identical with each other, but statistically similar with V_3T_1 (14.00 g) combination. These results are presented in the Table 15.

Table 15. Effect of insecticides and PPN on varieties in terms of the plant height (cm), root length (cm) and dry weight of the root (g)

Interaction	Plant height (cm)	Root length (cm)	Dry weight of root (g)
V_1T_0	68.85 q	24.30 j	12.00 h
V_1T_1	116.8 f	30.00 fg	30.00 bcd
V_1T_2	129.5 c	34.90 bc	32.00 bc
V_1T_3	138.6 b	38.70 a	36.00 ab
V_1T_4	105.9 i	33.30 cde	22.00 efg
V_1T_5	107.8 h	31.90 def	31.00 bc
V_2T_0	110.5 g	29.60 fgh	21.00 fg
V_2T_1	130.3 c	31.60 def	34.00 abc
V_2T_2	137.3 b	39.00 a	35.00 ab
V_2T_3	142.1 a	40.80 a	40.00 a
V_2T_4	121.0 e	31.00 defg	30.00 bcd
V_2T_5	119.9 e	35.90 b	31.00 bc
V_3T_0	51.76 r	17.60 k	11.00 h
V_3T_1	90.36 o	23.70 j	14.00 h
V_3T_2	94.43 mn	28.70 ghi	22.00 efg
V_3T_3	95.28 m	32.90 cde	24.00 def
V_3T_4	88.61 p	27.00 i	16.00 gh
V_3T_5	87.32 p	29.70 fgh	21.00 fg
V_4T_0	93.76 n	26.70 i	12.00 h
V_4T_1	102.8 j	27.20 hi	28.00 cde
V_4T_2	110.6 g	33.00 cde	30.00 bcd
V_4T_3	125.0 d	36.00 b	36.00 ab
V_4T_4	98.42 l	30.90 efg	23.00 ef
V_4T_5	101.0 k	33.60 bcd	24.00 def
$LSD_{0.01}$	1.322	2.331	6.014
CV%	0.56	3.41	10.70

4.19. Effect of varieties on the number of fruit per plant, length of single fruit (cm), single fruit weight (g) and fruit yield (kg) per plot

The maximum number of fruit per plant was found in Green finger (32) followed by BARI dherosh-1 (28) which are statistically different with each other. The minimum number of fruit per plant was found in Orca onamika (25) preceded by Nufield (27) which are also statistically different with each other. The highest length of single fruit was found in Green finger (19.06 cm) followed by BARI dherosh-1 (16.28 cm) which are statistically different with each other. The lowest length of single fruit was found in Orca onamika (14.67 cm) preceded by Nufield (16.06 cm) which are also statistically different with each other. The highest single fruit weight was found in Green finger (20.61 g) followed by BARI dherosh-1 (19.33 g) which are statistically similar. The lowest single fruit weight was found in Orca onamika (16.39 g) preceded by Nufield (17.94 g) and both are statistically different with each other. The highest fruit yield was found in Green finger (16.69 kg) followed by BARI dherosh-1 (11.22 kg) which are statistically different with each other. The lowest fruit yield was found in Orca onamika (9.25 kg) preceded by Nufield (9.78 kg) and both are statistically similar with each other. These results are presented in the Table 16.

Table 16. Effect of varieties on the number of fruit per plant, length of single fruit (cm), single fruit weight (g) and fruit yield (kg) per plot

Variety	Number of fruit per plant	length of single fruit (cm)	Single fruit weight (g)	Average fruit yield (kg)
BARI Dherosh-1	28 b	16.28 b	19.33 a	11.22 b
Green finger	32 a	19.06 a	20.61 a	16.69 a
Orca onamika	25 c	14.67 c	16.39 c	9.25 c
Nufield	27 b	16.06 b	17.94 b	9.78 c
$LSD_{0.01}$	1.558	1.367	1.384	4.97
CV%	6.17	9.24	8.32	5.68

4.20. Effect of insecticides and PPN on the number of fruit per plant, length of single fruit (cm), single fruit weight (g) and fruit yield (kg) per plot

The maximum number of fruit per plant was found when Sobicron with PPN (31) was used, which is statistically different from Imidacloprid with PPN (29) and PPN (28). The minimum number of fruit per plant was found when no insecticides and PPN (24) used which is statistically different from Imidacloprid (27) and Sobicron (28). The highest length of single fruit was found when Sobicron with PPN (19.92 cm) used which is statistically different from PPN (16.58 cm), Imidacloprid with PPN (16.42 cm). The lowest length of single fruit was found when no insecticides and PPN (13.92 cm) used which is statistically different from Sobicron (16.25 cm), Imidacloprid (16.00 cm). The highest single fruit weight was found when Sobicron with PPN (20.92 g) was used followed by Imidacloprid with PPN (19.67 g), PPN (18.83 g). The lowest single fruit weight was found when no insecticides and PPN (14.50 g) used which is statistically different from Imidacloprid (18.75 g) and Sobicron (18.75 g). The highest fruit yield was found when Sobicron with PPN (13.62 kg) used which is statistically different from Imidacloprid with PPN (12.43 kg), Sobicron (11.94 kg). The lowest fruit yield was found when no insecticides and PPN (8.93 kg) used which is statistically different from Imidacloprid (11.93 kg), PPN (11.57 kg). These results are presented in Table 17.

Table 17. Effect of insecticides and PPN on the number of fruit per plant, length of single fruit (cm), single fruit weight (g) and fruit yield (kg) per plot

Insecticides and PPN	Number of fruit per plant	length of single fruit (cm)	Single fruit weight (g)	Average fruit yield (kg)
Control	24 c	13.92 c	14.50 c	8.93 d
PPN	28 b	16.58 b	18.83 b	11.57 c
Imidacloprid + PPN	29 b	16.42 b	19.67 ab	12.43 b
Sobicron + PPN	31 a	19.92 a	20.92 a	13.62 a
Imidacloprid	27 b	16.00 b	18.75 b	11.93 bc
Sobicron	28 b	16.25 b	18.75 b	11.94 bc
$LSD_{0.01}$	1.908	1.674	1.695	0.82
CV%	6.17	9.24	8.32	5.68

Control= No insecticide and PPN

4.21. Effect of insecticides and PPN on varieties in terms of the number of fruit per plant, length of single fruit (cm), single fruit weight (g) and fruit yield (kg) per plot

The maximum number of fruit per plant was found in V_2T_3 (35) combination which is statistically different from V_1T_3 (34), V_2T_2 (32), V_4T_3 (31) combinations. The minimum number of fruit per plant was found in V_3T_0 (21) preceded by V_1T_0 (22), V_3T_4 (24), V_4T_0 (24), V_3T_5 (25) combinations. The highest length of single fruit was found in V_2T_3 (22.67 cm) followed by V_2T_2 (20.33 cm), V_4T_3 (20.00 cm), V_1T_3 (19.67 cm) combinations which are statistically similar with each other. The lowest length of single fruit was found in V_3T_0 (12.00 cm) preceded by V_1T_0 (13.67 cm), V_3T_1 (14.00 cm), V_4T_0 (14.00 cm), V_4T_4 (14.33 cm), V_2T_0 (15.00 cm) combinations and they are also statistically similar. The highest single fruit weight was found in V_2T_3 (23.67 g) followed by V_2T_2 (21.67 g),

V_4T_3 (21.33 g), V_1T_3 (21.33 g), V_2T_5 (21.33 g), V_2T_1 (21.00 g), V_1T_2 (20.67 g) combinations which are statistically similar with each other. The lowest single fruit weight was found in V_3T_0 (13.00 g) preceded by V_1T_0 (14.00 g), V_4T_0 (15.00 g), V_3T_1 (15.67 g), V_2T_0 (16.00 g) combinations and they are also statistically similar with each other. The highest fruit yield was found in V_2T_3 (18.49 kg) combination, is statistically different from V_2T_2 (18.20 kg), V_1T_3 (16.92 kg), V_2T_1 (16.56 kg), V_4T_3 (16.24 kg), V_4T_2 (14.02 kg) combinations. The lowest fruit yield was found in V_3T_0 (3.57 kg) combination which is statistically different from V_1T_0 (8.21 kg), V_3T_4 (8.87 kg), V_4T_4 (9.14 kg), V_3T_5 (9.45 kg), V_2T_0 (9.64 kg) combinations. These results are presented in Table 18.

Table 18. Effect of insecticides and PPN on varieties in terms of the number of fruit per plant, length of single fruit (cm), single fruit weight (g) and fruit yield (kg) per plot

Interaction	Number of fruit per plant	length of single fruit (cm)	Single fruit weight (g)	Average fruit yield (kg)
V_1T_0	22 ij	13.67 gh	14.00 hi	8.21 k
V_1T_1	30 bcdef	16.00 cdefg	20.00 abcde	11.56 efgh
V_1T_2	30 bcde	17.33 bcdefg	20.67 abcd	12.08 ef
V_1T_3	34 ab	19.67 abc	21.33 abc	16.92 bc
V_1T_4	29 bcdef	15.67 defgh	19.00 bcdef	10.78 fghi
V_1T_5	28 cdefgh	15.67 defgh	20.33 abcd	10.73 fghi
V_2T_0	27 defgh	15.00 efgh	16.00 fghi	9.64 ijk
V_2T_1	30 bcdef	19.33 abcd	21.00 abc	16.56 c
V_2T_2	32 abc	20.33 ab	21.67 ab	16.97 b
V_2T_3	35 a	22.67 a	23.67 a	18.54 a
V_2T_4	31 bcd	18.67 bcde	20.00 abcde	12.34 ef
V_2T_5	31 bcd	17.67 bcdef	21.33 abc	12.56 e
V_3T_0	21 j	12.00 h	13.00 i	3.57 l
V_3T_1	25 ghij	14.00 fgh	15.67 fghi	10.18 ghij
V_3T_2	27 defghi	15.33 efgh	17.67 bcdefgh	11.57 efgh
V_3T_3	27 cdefgh	15.67 defgh	18.33 bcdefg	11.78 efg
V_3T_4	24 hij	14.00 fgh	16.33 efghi	8.87 jk
V_3T_5	25 fghij	14.00 fgh	17.00 defgh	9.45 ijk
V_4T_0	24 hij	14.00 fgh	15.00 ghi	9.14 ijk
V_4T_1	27 defghi	17.00 bcdefg	17.33 cdefgh	10.06 hij
V_4T_2	29 cdefg	17.33 bcdefg	19.00 bcdef	14.02 d
V_4T_3	31 bcd	20.00 ab	21.33 abc	16.24 c
V_4T_4	26 efghij	14.33 fgh	18.00 bcdefg	9.83 ijk
V_4T_5	26 efghij	17.00 bcdefg	18.00 bcdefg	10.10 hij
$LSD_{0.01}$	3.816	3.348	3.390	0.86
CV%	6.17	9.24	8.32	5.68

4.22. Effect of varieties on Net chlorophyll content (µ mol m^{-2} s^{-1}), Net assimilation rate (g m^{-2} d^{-1}) and Intercellular Carbon-di-oxide concentration (ppm)

The net chlorophyll content in the leaves per plant was measured by the "S-Pad" machine. The case of net chlorophyll content per plant, the highest was found in Green finger (50.39) followed by BARI dherosh-1 (48.24) which are statistically different with each other. The lowest was recorded in Orca onamika (39.11) preceded by Nufield (46.15) which are also statistically different with each other. The Net assimilation rate and Intercellular Carbon-di-oxide concentration was taken by using the advanced "LC-Pro^{+}" machine. The maximum net assimilation rate was found in Green finger (1.650) followed by BARI dherosh-1 (1.463) which are statistically different with each other. The minimum net assimilation rate was found in Orca onamika (1.140) preceded by Nufield (1.240) which are also statistically different with each other. The maximum intercellular carbon-di-oxide concentration was found in Green finger (5.833) followed by BARI dherosh-1 (4.833) which are statistically different with each other. The minimum intercellular carbon-di-oxide concentration was found in Orca onamika (4.000) preceded by Nufield (4.500) which are statistically similar with each other. These results are presented in Table 19.

Table 19. Effect of varieties on Net chlorophyll content (µ mol m^{-2} s^{-1}), Net assimilation rate (g m^{-2} d^{-1}) and Intercellular Carbon-di-oxide concentration (ppm)

Variety	Net chlorophyll content (µ mol m^{-2} s^{-1})	Net assimilation rate (g m^{-2} d^{-1})	Intercellular Carbon-di-oxide concentration (ppm)
BARI Dherosh-1	48.24 b	1.463 b	4.833 b
Green finger	50.39 a	1.650 a	5.833 a
Orca onamika	39.11 d	1.140 d	4.000 c
Nufield	46.15 c	1.240 c	4.500 bc
$LSD_{0.01}$	0.6521	0.02832	0.7689
CV%	1.58	1.78	17.92

4.23. Effect of insecticides and PPN on Net chlorophyll content (µ mol m^{-2} s^{-1}), Net assimilation rate (g m^{-2} d^{-1}) and Intercellular Carbon-di-oxide concentration (ppm)

The highest net chlorophyll content was found when Sobicron with PPN (48.56) was used followed by Imidacloprid with PPN (48.06) both are statistically similar with each other. The lowest net chlorophyll content was recorded when no insecticides and PPN (42.03) used which is statistically different from PPN (45.06), Imidacloprid (45.70), Sobicron (46.44). The maximum net assimilation rate was found when Sobicron with PPN (1.405) was used followed by Imidacloprid with PPN (1.385), Imidacloprid (1.378), Sobicron (1.375), they are statistically similar with each other. The minimum net assimilation rate was found when no insecticides and PPN (1.337) was used which is statistically similar with PPN (1.360). The maximum intercellular carbon-di-oxide concentration was found in Sobicron with PPN (7.250) was used which is statistically different from Imidacloprid with PPN (5.500) followed by PPN (4.750), Imidacloprid (4.000). The minimum intercellular carbon-di-oxide concentration was found when no insecticides and PPN (3.250) was used which is statistically similar with Sobicron (4.000). These results are presented in Table 20.

Table 20. Effect of insecticides and PPN on Net chlorophyll content (µ mol m^{-2} s^{-1}), Net assimilation rate (g m^{-2} d^{-1}) and Intercellular Carbon-di-oxide concentration (ppm)

Insecticides and PPN	Net chlorophyll content (µ mol m^{-2} s^{-1})	Net assimilation rate (g m^{-2} d^{-1})	Intercellular Carbon-di-oxide concentration (ppm)
Control	42.03 d	1.337 c	3.250 d
PPN	45.06 c	1.360 bc	4.750 bc
Imidacloprid + PPN	48.06 a	1.385 ab	5.500 b
Sobicron + PPN	48.56 a	1.405 a	7.250 a
Imidacloprid	45.70 bc	1.378 ab	4.000 cd
Sobicron	46.44 b	1.375 ab	4.000 cd
$LSD_{0.01}$	0.7986	0.03469	0.9417
CV%	1.58	1.78	17.92

Control= No insecticide and PPN

4.24. Effect of insecticides and PPN on varieties in terms of Net chlorophyll content (µ mol m^{-2} s^{-1}), Net assimilation rate (g m^{-2} d^{-1}) and Intercellular Carbon-di-oxide concentration (ppm)

The highest net chlorophyll content was found in V_2T_3 (52.96) followed by V_1T_3 (52.01), V_2T_2 (51.43), V_1T_2 (51.41), V_4T_3 (51.31) combinations, and they are statistically similar with each other. The lowest net chlorophyll content was found in V_3T_0 (32.66) combination which is statistically different from V_3T_4 (34.28), V_3T_5 (35.65), V_4T_0 (36.32) combinations. The maximum net assimilation rate was found in V_2T_3 (1.690) followed by V_1T_3 (1.680), V_2T_2 (1.660), V_1T_2 (1.640) and they are statistically similar. The lowest net assimilation rate was found in V_3T_0 (1.000) combination which is statistically different from V_3T_4 (1.120) preceded by V_2T_0 (1.140), V_3T_2 (1.150), V_3T_5 (1.160) combinations. The maximum intercellular carbon-di-oxide concentration was found in V_2T_3 (9.000) followed by V_4T_3 (7.000), V_1T_3 (7.000), they are statistically similar. The minimum intercellular carbon-di-oxide concentration was found in V_3T_0 (2.000) combination preceded by V_3T_4 (3.000), V_1T_0 (3.000) combinations. These results are presented in Table 21.

Table 21. Effect of insecticides and PPN on varieties in terms of Net chlorophyll content (µ mol m^{-2} s^{-1}), Net assimilation rate (g m^{-2} d^{-1}) and Intercellular Carbon-di-oxide concentration (ppm)

Interaction	Net chlorophyll content (µ mol m^{-2} s^{-1})	Net assimilation rate (g m^{-2} d^{-1})	Intercellular Carbon-di-oxide concentration (ppm)
V_1T_0	45.04 f	1.250 d	3.000 de
V_1T_1	50.14 bc	1.480 c	7.000 b
V_1T_2	51.41 ab	1.640 ab	4.000 cde
V_1T_3	52.01 a	1.680 a	7.000 b
V_1T_4	47.75 de	1.460 c	5.000 bcd
V_1T_5	49.19 cd	1.600 b	4.000 cde
V_2T_0	46.38 ef	1.140 gh	4.000 cde
V_2T_1	50.11 bc	1.470 c	6.000 bc
V_2T_2	51.43 ab	1.660 ab	6.000 bc
V_2T_3	52.96 a	1.690 a	9.000 a
V_2T_4	48.58 cd	1.440 c	5.000 bcd
V_2T_5	49.47 cd	1.630 ab	4.000 cde
V_3T_0	32.66 k	1.000 i	2.000 e
V_3T_1	38.58 h	1.170 efgh	4.000 cde
V_3T_2	42.97 g	1.150 fgh	6.000 bc
V_3T_3	46.53 ef	1.220 def	5.000 bcd
V_3T_4	34.28 j	1.120 h	3.000 de
V_3T_5	35.65 ij	1.160 efgh	4.000 cde
V_4T_0	36.32 i	1.210 defg	4.000 cde
V_4T_1	48.60 cd	1.270 d	4.000 cde
V_4T_2	49.33 cd	1.440 c	5.000 bcd
V_4T_3	51.31 ab	1.490 c	7.000 ab
V_4T_4	43.23 g	1.260 d	3.000 de
V_4T_5	48.40 cd	1.230 de	4.000 cde
$LSD_{0.01}$	1.597	0.06938	1.883
CV%	1.58	1.78	17.92

4.25. Effect of varieties on Stomatal conductivity (mol m^{-2} s^{-1}) and Respiration rate (ppt/s)

The highest stomatal conductivity was found in Green finger (0.2333) followed by BARI dherosh-1 (0.2206) which are statistically similar with each other. The lowest stomatal conductivity was found in Orca onamika (0.1867) precded by Nufield (0.2083) which are statistically similar also. The highest respiration rate was found in Green finger (40.82) followed by BARI dherosh-1 (36.57) which are statistically different with each other. The lowest respiration rate was found in Orca onamika (33.98) precded by Nufield (35.77) both are statistically different also. The results are presented in Table 22.

Table 22. Effect of varieties on Stomatal conductivity (mol m^{-2} s^{-1}) and Respiration rate (ppt/s)

Variety	Stomatal conductivity (mol m^{-2} s^{-1})	Respiration rate (ppt/s)
BARI Dherosh-1	0.2206 a	36.57 b
Green finger	0.2333 a	40.82 a
Orca onamika	0.1867 b	33.98 d
Nufield	0.2083 ab	35.77 c
$LSD_{0.01}$	0.02832	0.2157
CV%	11.29	0.66

4.26. Effect of insecticides and PPN on Stomatal conductivity (mol m^{-2} s^{-1}) and Respiration rate (ppt/s)

The highest stomatal conductivity was found when Sobicron with PPN (0.2458) was used followed by PPN (0.2183), Imidacloprid (0.2142), Sobicron (0.2125) which are statistically similar. The lowest stomatal conductivity was found when no insecticides and PPN (0.1775) was used preceded by Imidacloprid with PPN (0.2050). The highest respiration rate was found when Sobicron with PPN (39.78) was used which is statistically different from Imidacloprid with PPN (37.28), PPN (37.28) which are statistically identical. The lowest respiration rate was found when no insecticides and PPN (33.05) used preceded by Sobicron (36.35), Imidacloprid (36.97). The results are presented in Table 23.

Table 23. Effect of insecticides and PPN on Stomatal conductivity (mol m^{-2} s^{-1}) and Respiration rate (ppt/s)

Insecticides and PPN	Stomatal conductivity (mol m^{-2} s^{-1})	Respiration rate (ppt/s)
Control	0.1775 c	33.05 e
PPN	0.2183 ab	37.28 b
Imidacloprid + PPN	0.2050 bc	37.28 b
Sobicron + PPN	0.2458 a	39.78 a
Imidacloprid	0.2142 abc	36.97 c
Sobicron	0.2125 abc	36.35 d
$LSD_{0.01}$	0.03469	0.2642
CV%	11.29	0.66

4.27. Effect of insecticides and PPN on varieties in terms of Stomatal conductivity (mol m^{-2} s^{-1}) and Respiration rate (ppt/s)

The highest stomatal conductivity was found in V_2T_3 (0.2700) combination followed by V_1T_3 (0.2600), V_2T_1 (0.2533), V_4T_3 (0.2467) combinations, they are statistically similar. The lowest stomatal conductivity was found in V_3T_0 (0.1600) combination preceded by V_4T_0 (0.1667), V_1T_0 (0.1800), V_3T_4 (0.1800), V_3T_5 (0.1800), V_3T_2 (0.1933) combinations and they are also statistically similar. The highest respiration rate was found in V_2T_3 (44.90) combination followed by V_1T_3 (42.20), V_2T_2 (41.50), V_2T_5 (40.30), V_2T_1 (39.60) combinations, they are statistically different from each other. The lowest respiration rate was found in V_3T_0 (30.20) combination preceded by V_4T_0 (32.20), V_1T_0 (33.40), V_3T_4 (33.70), V_3T_5 (33.90). The results are presented in Table 24.

Table 24. Effect of insecticides and PPN on varieties in terms of Stomatal conductivity (mol m^{-2} s^{-1}) and Respiration rate (ppt/s)

Interaction	Stomatal conductivity (mol m^{-2} s^{-1})	Respiration rate (ppt/s)
V_1T_0	0.1800 bcd	33.40 q
V_1T_1	0.2267 abcd	38.50 f
V_1T_2	0.2367 abcd	39.60 e
V_1T_3	0.2600 ab	42.20 b
V_1T_4	0.2167 abcd	35.90 jk
V_1T_5	0.2033 abcd	34.10 op
V_2T_0	0.2033 abcd	36.40 ij
V_2T_1	0.2533 ab	39.60 e
V_2T_2	0.2300 abcd	41.50 c
V_2T_3	0.2700 a	44.90 a
V_2T_4	0.2200 abcd	37.90 g
V_2T_5	0.2233 abcd	40.30 d
V_3T_0	0.1600 d	30.20 s
V_3T_1	0.2000 abcd	36.10 j
V_3T_2	0.1933 abcd	34.80 mn
V_3T_3	0.2067 abcd	35.20 lm
V_3T_4	0.1800 bcd	33.70 pq
V_3T_5	0.1800 bcd	33.90 pq
V_4T_0	0.1667 cd	32.20 r
V_4T_1	0.2100 abcd	36.80 hi
V_4T_2	0.2167 abcd	37.10 h
V_4T_3	0.2467 abc	38.50 f
V_4T_4	0.2067 abcd	34.60 no
V_4T_5	0.2033 abcd	35.40 kl
$LSD_{0.01}$	0.06938	0.5284
CV%	11.29	0.66

4.28. Correlation between chlorophyll content (µ mol m^{-2} s^{-1}) and Disease Incidence (%) per Plot

Correlation study was done to establish the relationship between the chlorophyll content (µ mol m^{-2} s^{-1}) and disease incidence (%) per plot. 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 = -0.320x + 50.07 gave a good fit to the data, and the co-efficient of determination (R^2 = -0.594) showed that, fitted regression line had a significant regression co-efficient. From these relations it can be concluded that the disease incidence (%) per plot was negatively (slope= -0.183) correlated with the chlorophyll content of okra plants.

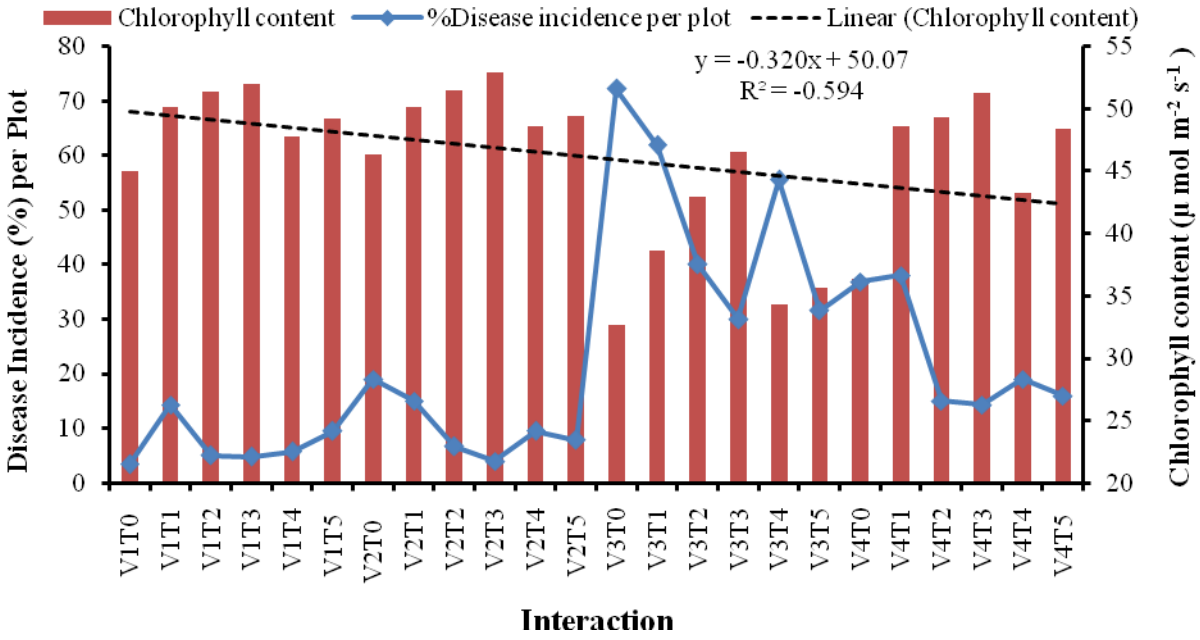

Figure 9. Relationship between Chlorophyll content and Disease incidence (%) per Plot.

V1= BARI dherosh-1, V2= Green finger, V3= Orca onamika, V4= Nufield
T0= No insecticide and PPN, T1= Peak Performance Nutrients (PPN), T2= Imidacloprid + PPN, T3= Sobicron + PPN, T4= Imidacloprid, T5= Sobicron

4.29. Correlation between chlorophyll content (µ mol m^{-2} s^{-1}) and Disease Incidence (%) per Plant

Correlation study was done to establish the relationship between the chlorophyll content (µ mol m^{-2} s^{-1}) and disease incidence (%) per plant. From the study it was revealed that significant correlation was observed between the parameters (Figure 10). It was evident from the Figure 10 that the equation y = -0.592x + 54.51 gave a good fit to the data, and the co-efficient of determination (R^2 = -0.372) showed that, fitted regression line had a significant regression co-efficient. From these relations it can be concluded that the disease incidence (%) per plant was negatively (slope= -0.115) correlated with the chlorophyll content of okra plants.

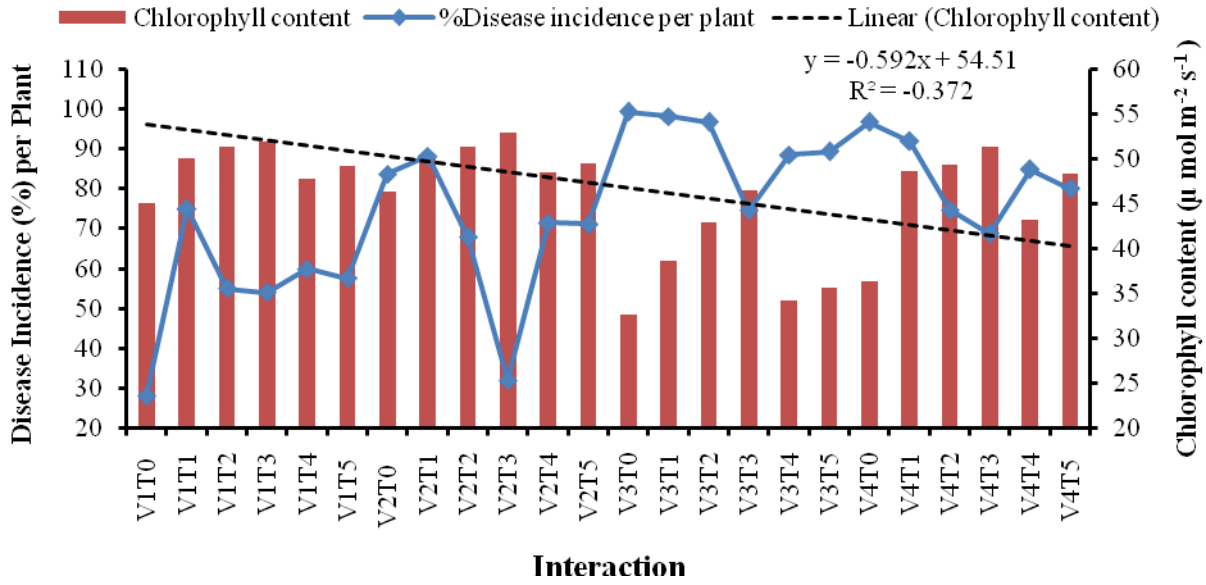

Figure 10. Relationship between Chlorophyll content and Disease incidence (%) per Plant.

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

Correlation study was done to establish the relationship between the chlorophyll content (µ mol m^{-2} s^{-1}) and Yield (kg) of okra plants. From the study it was revealed that significant correlation was observed between the parameters (Figure 11). It was evident from the Figure 11 that the equation y = 0.390x + 5.10 gave a good fit to the data, and the co-efficient of determination (R^2 = 0.62) showed that, fitted regression line had a significant regression co-efficient. From these relations it can be concluded that the

chlorophyll content of okra was positively (slope= 0.367) correlated with the yield of okra plants.

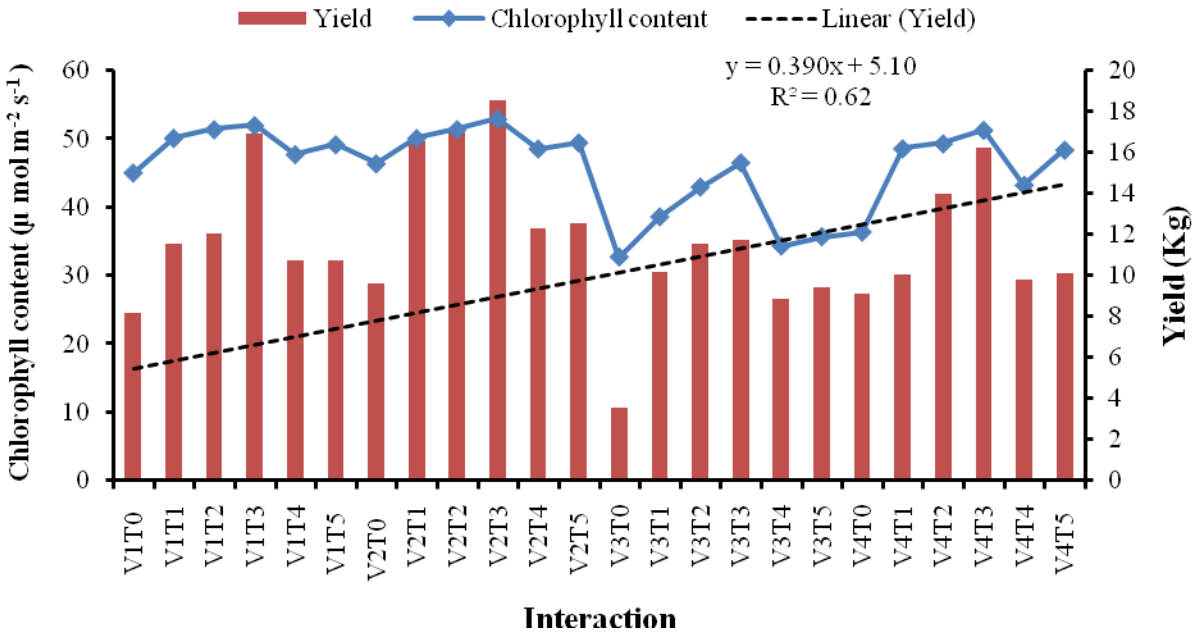

Figure 11. Relationship between Chlorophyll content and Yield.

Chapter 5

Discussion

CHAPTER V

DISCUSSION

Okra (*Abelmoschus esculentus* L. Moench) is a genre of Malvaceae and known as Lady's finger. The tender green fruits of this crop 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. The yearly okra production is 25894 metric tons from 48048 acres of land in Bangladesh (BBS, 2014). But, world okra production was 6,876,584 metric tons (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. The objectives of this study was to select resistant okra cultivars against *Yellow vein clearing mosaic virus* from the tested varieties and to manage *Yellow vein clearing mosaic* through selected two insecticides and one botanical nutrient namely Peak Performance Nutrients (PPN). The experiment was conducted in the horticultural farm of the Sher-e-Bangla Agricultural University during April to August, 2015.

5.1. Disease Incidence

The disease incidence due to *Yellow Vein Clearing Mosaic Virus (YVCMV)* of okra was found in almost all the varieties. The highest disease incidence was found in the variety Orca onamika followed by Nufield, Green finger and the lowest disease incidence was found in the BARI dherosh-1 per plot and per plant at 40, 60 and 80 days after sowing (DAS). In case of chemicals and botanical, the highest disease incidence was found when no insecticides and PPN is used followed by PPN and the lowest disease incidence was found when Sobicron with PPN is used per plot and per plant at 40, 60 and 80 (DAS). In case of both factors, the highest disease

incidence was found in the Orca onamika-no insecticide and PPN combination and the lowest disease incidence was found in BARI dherosh-1- no insecticide and PPN combination preceded by Green finger- Sobicron with PPN combination per plot and per plant at 40, 60 and 80 (DAS). Begum (2002) recorded 49 to 61% incidence of the same virus in five different varieties of okra in Bangladesh. The results of the present study are also in agreement with the findings of Bhagat *et al.* (2001), Sastry and Singh (1975) and Heng (2013).

5.2. Disease Reaction

In case of plot, among the experimented okra varieties BARI dherosh-1 is highly resistant than Orca onamika which showed moderate resistance and tolerance. Green finger showed moderate resistance at 40, 60 and 80 DAS. In case of the chemicals and PPN, Sobicron with PPN impels highly resistance and moderate resistance at 40, 60 and 80 DAS of okra varieties. Without using of insecticides and PPN, which impels moderate resistance and tolerance at 40, 60 and 80 DAS of the okra varieties. Among all the combinations, Orca onamika-no insecticide and PPN showed tolerance, susceptibility and high susceptibility at 40, 60 and 80 DAS. BARI dherosh-1-no insecticide and PPN combination showed highly resistance at 40, 60 and 80 DAS. In case of plant, among the tested okra varieties BARI dherosh-1 showed tolerance, susceptibility and moderate susceptibility and Orca onamika showed moderate susceptibility and susceptibility at 40, 60 and 80 DAS. Green finger showed tolerance and susceptibility at 40, 60 and 80 DAS. In case of the chemicals and botanical, Sobicron with PPN impels tolerance, moderate susceptibility and susceptibility of okra varieties at 40, 60 and 80 DAS. Without using of insecticides and PPN, which impels moderate susceptibility and high susceptibility of the okra varieties at 40, 60 and 80 DAS. Among all the combinations, Orca onamika-no insecticide and PPN showed high susceptibility at

40, 60 and 80 DAS. BARI dherosh-1-no insecticide and PPN combination showed tolerance at 40, 60 and 80 DAS. The results are in agreement with the findings of Benchasri (2011).

5.3. Morphological features

The maximum plant height, root length and dry weight of the root was found in Green finger and the lowest in Orca onamika variety. In case of insecticides and PPN, the maximum plant height, root length and dry weight of the root was found when Sobicron with PPN is used and the lowest when no insecticides and PPN is used. In case of two factors, the maximum plant height, root length and dry weight of the root was found in Green finger- Sobicron with PPN combination and the lowest in Orca onamika-no insecticide and PPN combination preceded by BARI dherosh-1- no insecticide and PPN combination. Almost similar findings were got in the previous works has done by A Kurunç and A Ünlükara (2009) and Begum (2002).

The yield of plants depends on the number of fruits per plant, length and weight of single fruit. The maximum number of fruits per plant, length and weight of single fruit was found in Green finger and the least number of fruits per plant, length and weight of single fruit was found in Orca onamika variety. Consequently, the highest fruit yield was found in Green finger and the lowest in Orca onamika. In case of insecticides and PPN, the maximum number of fruits per plant, length and weight of single fruit and fruit yield was found when Sobicron with PPN is used and the least number of fruits per plant, length and weight of single fruit and fruit yield was found when no insecticides and PPN is used. In case of both factors, the highest number of fruits per plant, length and weight of single fruit and fruit yield was found in Green finger- Sobicron with PPN combination and the lowest in Orca onamika-no insecticide and PPN combination preceded by BARI dherosh-1- no

insecticide and PPN combination. These results are in agreement with results of detailed works on growth and yield contributing characters as affected by the infection of *YVCMV* were conducted by Begum (2002). These findings are also in agreement with the findings of Islam *et al.* (2000) and Saifullah and Rabbani (2009).

5.4. Physiological features

The minimum chlorophyll content per plant was recorded in Orca onamika and the maximum chlorophyll content per plant was recorded from the Green finger followed by BARI dherosh-1. In case of insecticides and PPN, the minimum chlorophyll content per plant was recorded when no insecticides and PPN combination is used and the maximum chlorophyll content per plant was recorded when Sobicron with PPN is used. In case of both factors, the minimum chlorophyll content per plant was recorded in Orca onamika-no insecticide and PPN combination preceded by Orca onamika-Imidacloprid combination and the maximum chlorophyll content per plant was recorded from the Green finger-Sobicron with PPN combination.

The minimum net assimilation rate per plant was recorded in Orca onamika and the maximum net assimilation rate per plant was recorded from the Green finger followed by BARI dherosh-1. In case of insecticides and PPN, the minimum net assimilation rate per plant was recorded when no insecticides and PPN combination is used and the maximum net assimilation rate per plant was recorded when Sobicron with PPN is used. In case of both factors, the minimum net assimilation rate per plant was recorded in Orca onamika-no insecticide and PPN combination preceded by Orca onamika-Imidacloprid combination and the maximum net assimilation rate per plant was recorded from the Green finger-Sobicron with PPN combination.

The minimum Intercellular Carbon-di-oxide concentration per plant was recorded in Orca onamika. And the maximum Intercellular Carbon-di-oxide concentration per plant was recorded in Green finger and BARI dherosh-1. In case of insecticides and PPN, the minimum Intercellular Carbon-di-oxide concentration per plant was recorded when no insecticides and PPN combination is used and the maximum Intercellular Carbon-di-oxide concentration per plant was recorded when Sobicron with PPN is used. In case of both factors, the minimum Intercellular Carbon-di-oxide concentration per plant was recorded in Orca onamika-no insecticide and PPN combination and the maximum Intercellular Carbon-di-oxide concentration per plant was recorded from the Green finger- Sobicron with PPN combination.

The minimum Stomatal conductivity per plant was recorded in the Orca onamika. The maximum Stomatal conductivity per plant was recorded in the Green finger. In case of insecticides and PPN, the minimum Stomatal conductivity per plant was recorded when no insecticides and PPN combination is used and the maximum Stomatal conductivity per plant was recorded when Sobicron with PPN is used. In case of both factors, the minimum Stomatal conductivity per plant was recorded in Orca onamika-no insecticide and PPN combination and the maximum Stomatal conductivity per plant was recorded from the Green finger- Sobicron with PPN combination.

The minimum respiration rate per plant was recorded in the Orca onamika. The maximum respiration rate per plant was recorded in the Green finger and BARI dherosh-1. In case of insecticides and PPN, the minimum respiration rate per plant was recorded when no insecticides and PPN combination is used and the maximum respiration rate per plant was recorded when Sobicron with PPN is used. In case of both factors, the minimum respiration rate per plant was recorded in Orca onamika-no insecticide and PPN combination and the maximum respiration rate

per plant was recorded from the Green finger- Sobicron with PPN combination followed by BARI dherosh-1- Sobicron with PPN combination. These results are in agreement with the findings of Shil (2005).

5.5. Relationship of Chlorophyll content with Disease incidence (%) per plot and plant and Fruit yield

Correlation coefficient and regression equation were calculated to find out the effect of disease incidence per plot and plant on chlorophyll content and chlorophyll content on the fruit yield. The interaction or combination Orca onamika-no insecticide and PPN had highest disease incidence per plot with the lowest chlorophyll content. As the incidence decreasing the chlorophyll content become increased. The interaction or combination Orca onamika-no insecticide and PPN had highest disease incidence per plant with the lowest chlorophyll content. As the incidence decreasing the chlorophyll content become increased. The interaction or combination Orca onamika-no insecticide and PPN had lowest chlorophyll content with the lowest fruit yield of okra plants. As the chlorophyll content increasing the yield become increased. Correlation coefficient and linear regression were performed to determine the relationship between chlorophyll content with disease incidence per plot and plant and fruit yield. From the correlation studies it was revealed that the disease incidence per plot as well as plant was negatively correlated to the chlorophyll content and the chlorophyll content was positively correlated to the fruit yield. The results of the present study are in resemblance with the findings of Sarker (2014).

Summary and Conclusion

SUMMARY AND CONCLUSION

The study was conducted to evaluate the effect of different varieties of okra and two selected insecticides and Peak Performance Nutrients (PPN) on disease incidence of *YVCMV*. Yield and yield contributing characters and physiological features of okra plant that changes due to the disease infection which cause serious damages of okra production and reduce the market value was also the part of this study. Four okra varieties namely BARI dherosh-1, Orca onamika, Green finger and Nufield were grown in the field of Horticultural farm of Sher-e-Bangla Agricultural University, Dhaka during the period from April to August, 2015 with normal agronomic practices. The experiment was laid out in two factors Randomized Complete Block Design (RCBD) with three replications. The two factors are the varieties and selected insecticides + PPN.

The present study suggested that, in case of varietal effect on disease incidence of *YVCMV* per plot BARI dherosh-1 is highly resistant at 40,60 and 80 days after sowing and Orca onamika is moderate resistant at 40 days after sowing and tolerant at 60 and 80 days after sowing. Green finger is moderate resistant at 40, 60 and 80 days after sowing. In case of insecticidal and PPN effect highly resistant at 40 days after sowing and moderate resistant at 60 and 80 days after sowing showed when Sobicron with PPN used. Moderate resistant at 40 days after sowing and tolerant at 60 and 80 days after sowing when no insecticides and PPN used. Moderate resistant at 40 and 60 days after sowing and tolerant at 80 days after sowing when only PPN used. In case of both factors effect Green finger-Sobicron with PPN, BARI dherosh-1-no insecticide and PPN and BARI dherosh-1-Sobicron with PPN combinations showed highly resistant at 40, 60 and 80 days after sowing. Orca onamika-no insecticide and PPN combination showed tolerant, susceptible and high susceptible at 40, 60 and 80 days after sowing, respectively.

The study demonstrated that, in case of varietal effect on disease incidence of *YVCMV* per plant, BARI dherosh-1 is tolerant, susceptible and moderate susceptible at 40, 60 and 80 days after sowing, respectively. Green finger is tolerant at 40 days after sowing and

susceptible at 60 and 80 days after sowing. Orca onamika is moderate susceptible at 40 days after sowing and high susceptible at 60 and 80 days after sowing. In case of insecticidal and PPN effect tolerant, moderate susceptible and susceptible showed when Sobicron with PPN used at 40, 60 and 80 days after sowing. Moderate susceptible at 40 days after sowing and high susceptible at 60 and 80 days after sowing showed when only PPN and no insecticides and PPN used. In case of both factors effect Green finger-Sobicron with PPN combination is tolerant at 40 and 80 days after sowing and moderate susceptible at 60 days after sowing. BARI dherosh-1-no insecticide and PPN combination is tolerant at 40, 60 and 80 days after sowing. BARI dherosh-1-Sobicron with PPN combination is tolerant at 40 days after sowing and moderate susceptible at 60 and 80 days after sowing. Orca onamika-no insecticide and PPN combination is high susceptible at 40, 60 and 80 days after sowing.

This study revealed that, effect of variety on plant height, root length, dry weight of the root, number of fruit per plant, length of single fruit, single fruit weight and fruit yield Green finger showed highest then BARI dherosh-1 and lowest in Orca onamika. In case of insecticidal and PPN effect Sobicron with PPN impelled the highest and the lowest when no insecticides and PPN used. In case of both variety and insecticide and PPN effect Green finger-Sobicron with PPN combination showed highest than BARI dherosh-1-no insecticide combination and lowest in Orca onamika-no insecticide and PPN combination.

The study also exhibited that, effect of variety on net chlorophyll content, net assimilation rate, intercellular carbon-di-oxide concentration, stomatal conductivity and respiration rate Green finger showed the highest then BARI dherosh-1 and the lowest in Orca onamika. In case of insecticidal and PPN effect Sobicron with PPN impelled the highest and the lowest when no insecticides and PPN used. In case of both factors effect Green finger-Sobicron with PPN combination showed the highest than BARI dherosh-1-no insecticide combination and the lowest in Orca onamika-no insecticide and PPN combination. It has been also observed that, disease incidence per plot and plant was

negatively correlated with the chlorophyll content of okra plants. On the other hand the chlorophyll content was positively correlated with the fruit yield of okra plants. Thus low chlorophyll content increases disease incidence per plot and plant and highest fruit yield induced by highest chlorophyll content.

Considering the effect of variety, insecticides and PPN and both factors it may be concluded that, BARI dherosh-1 showed more resistant than Green finger but prior to Orca onamika. Sobicron with PPN combination induced more resistant than other insecticides. BARI dherosh1-no insecticide and PPN combination showed better resistant, as it was previously stated as resistant against *YVCMV*, than Green finger-Sobicron with PPN combination yet over on Orca onamika-no insecticide and PPN combination. But plant height, root length, dry weight of the root, number of fruit per plant, length of single fruit, single fruit weight and fruit yield and also the net chlorophyll content, net assimilation rate, intercellular carbon-di-oxide concentration, stomatal conductivity and respiration rate was the highest in Green finger over BARI dherosh-1 and the lowest in Orca onamika. These are the highest when Sobicron with PPN was used, which was far better when no insecticides and PPN used. These are also the highest in Green finger-Sobicron with PPN combination better than BARI dherosh-1-no insecticide and PPN combination and the lowest in Orca onamika-no insecticide and PPN combination.

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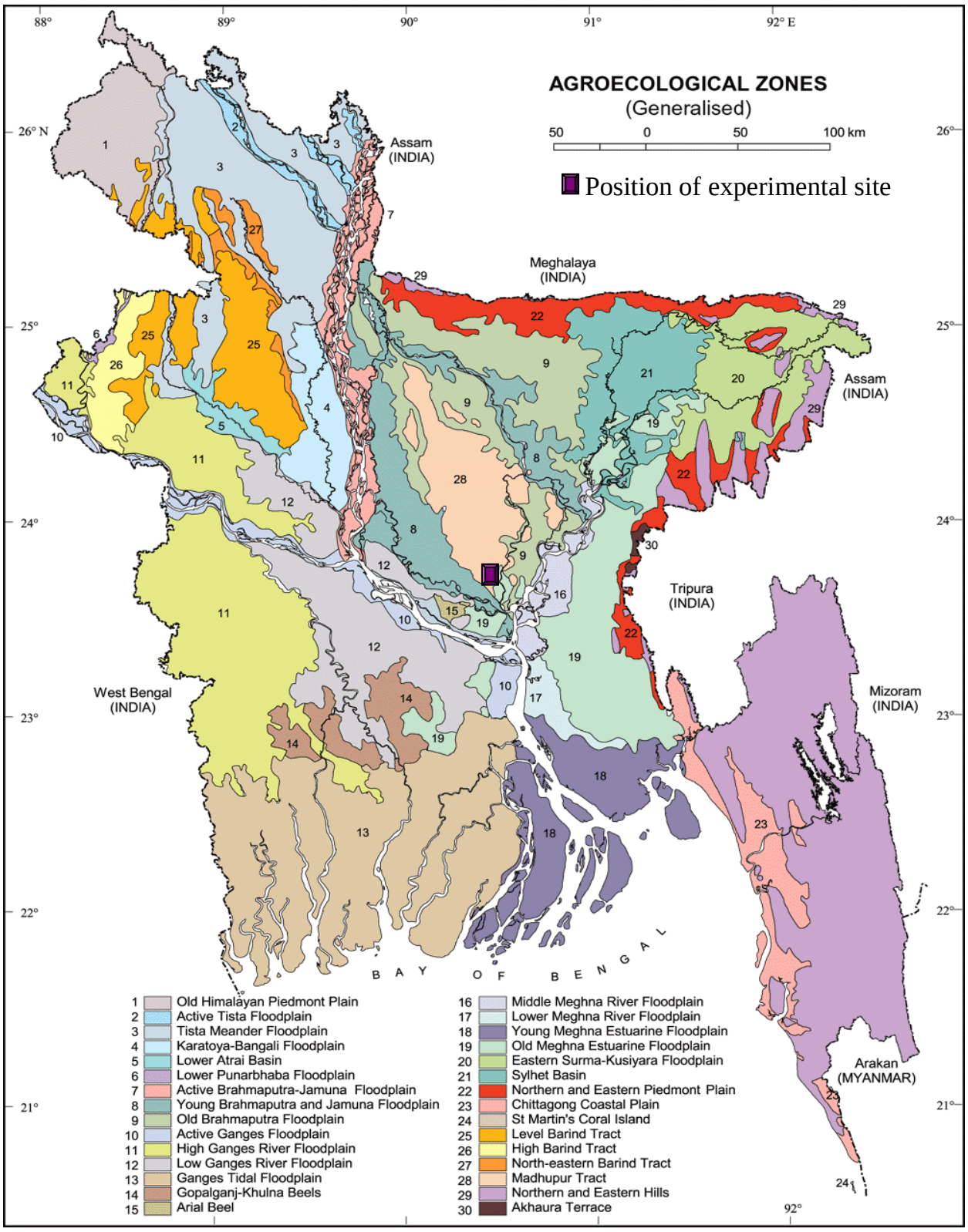
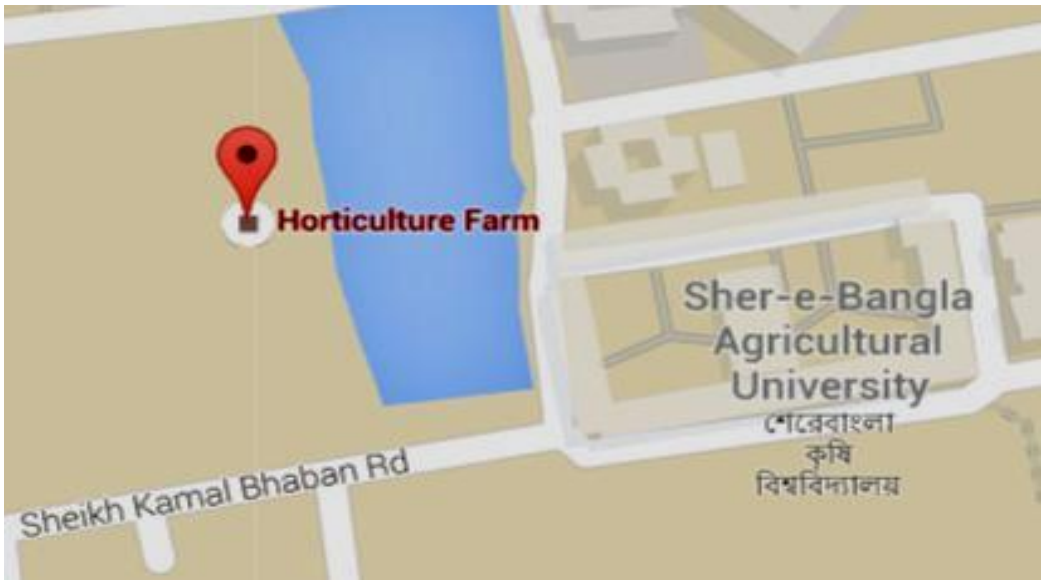
Appendix

APPENDICES

Appendix I. Map showing the experimental site under study.



Appendix II. Location showing the experimental site under study.



Appendix III. Monthly average relative humidity, maximum and minimum temperature, rainfall and sunshine hour of the experimental period (April 2015 to August 2015).

Month	Average RH (%)	Average Temperature (°C)		Total Rainfall (mm)	Average Sunshine Hours
		Minimum	Maximum		
April	68	23.6	34.1	165.8	4.8
May	82	24.7	33.3	325.3	4.6
June	84	25.1	35.2	414.4	4.8
July	86	26.9	34.6	500.6	4.7
August	85	27.8	33.8	493.4	4.4

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

Appendix IV. Physiochemical properties of soil, used in the experimental location.

Characteristics	Value
Particle size analysis	
% Sand	25.68
% Silt	53.85
% Clay	20.47
Textural class	Silt-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 V. A view of the experimental field at early stage.

Appendix VI. A view of the experimental field at later stage.

Appendix VII. A view of severely infected okra plant of Orca onamika variety by *Yellow Vein Clearing Mosaic Virus (YVCMV)*.

Appendix VIII. A view of healthy okra plants with fruits of Green finger variety.

Appendix IX. Existence of white fly (*Bemesia tabaci)* in the lower surface of infected leaf.