Screening of Okra (*Abelmoschus esculentus* L. Moench) germplasm against Okra Yellow Vein Mosaic Virus disease under field condition

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By

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CERTIFICATE-I

This is to certify that the thesis entitled **"Screening of Okra (*Abelmoschus esculentus* L. Moench) germplasm against Okra Yellow Vein Mosaic Virus disease under field condition"** submitted in partial fulfillment of the requirements for the award of the degree of **MASTER OF SCIENCE IN AGRICULTURE (VEGETABLE SCIENCE)** to the Orissa University of Agriculture and Technology is a faithful record of *bona fide* and original research work carried out by **Hareesha G N** under my guidance and supervision. No part of this thesis has been submitted for any other degree or diploma.

It is further certified that the assistance and help received by him from various sources during the course of investigation has been duly acknowledged.

CHAIRMAN
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CERTIFICATE-II

This is to certify that the thesis entitled **"Screening of Okra (*Abelmoschus esculentus* L. Moench) germplasm against Okra Yellow Vein Mosaic Virus disease under field condition"** submitted by **Hareesha G N** to the Orissa University of Agriculture and Technology, Bhubaneswar in partial fulfillment of the requirements for the degree of **MASTER OF SCIENCE IN AGRICULTURE (VEGETABLE SCIENCE)** has been approved by the students' advisory committee and external examiner.

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Date: **Hareesha G N**
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ABSTRACT

The present investigation entitled, **"Screening of Okra (*Abelmoschus esculentus* L. Moench) germplasm against Okra Yellow Vein Mosaic Virus disease under field condition"** was conducted at All India Co-ordinated Research Project on Vegetable Crops of OUAT, Bhubaneswar, Odisha during summer season of 2015. The objective was to study the genetic variability and screening of okra germplasm against Yellow Vein Mosaic Virus (YVMV) disease under field conditions. The experiment was laid out with 10 okra germplasm by adopting Randomized Block Design replicated thrice in a plot size of 3.0 m X 3.0 m with a spacing of 45 cm X 30 cm. Observations of 26 parameters on vegetative growth, flowering, fruit yield and yield attributing, fruit quality traits and incidence of YVMV at 30, 45, 60, 75 and 90 days after sowing (DAS) were recorded and subjected to statistical analysis.

The results indicated significant variations for all the traits except ridges plant^{-1}, fruit girth and crop duration indicating the vast scope for selection. Among the germplasm, 2012/OKYVRES-1was identified as resistant genotype against YVMV (0.00%) followed by 2012/OKYVRES-2 (0.00 to 20.30%) at all the stages of crop growth (30 to 90 DAS).

The genotype, 2012/OKYVRES-5 recorded significantly highest fruits plant^{-1} (20.75), fruit length (13.88cm), fruit weight(20.20g), fruit weight plant^{-1}(141.59g), fruit dry weight (10.80g) and fruit yield(11.50kg plot^{-1} and 141.98qha^{-1}). The genotype also produced fruits of moderate quality in terms of reducing, non-reducing and total sugar (2.78, 0.55 and 3.33%, respectively) and crude protein content (8.75%). The genotypes showed significant tolerance to YVMV up to 45 to 60 DAS, except 2012/OKYVRES-1 and 2012/OKYVRES-2. The next best genotype identified was 2012/OKYVRES-2 with better growth, yield and yield attributes parameters along with resistance to YVMV (0.00 to 20.30%) under Bhubaneswar condition.

The genetical studies indicated that direct selection through traits like fruit weight plant^{-1} fruit, yield (qha^{-1}), incidence of YVMV at 45, 60, 75, 90 DAS will be effective for improvement in okra especially to develop a genotype having resistance and/or tolerance to YVMV. Being most divergent Cluster-II (2012/OKYVRES-5) and Cluster- IV (2012/OKYVRES-2), hence expected hybridization might result in highly heterotic hybrid and other segregants. Incidence of YVMV is contributing maximum towards divergence suggested that special attention should given to this character while designing crop improvement programme in okra.

Hence, it may be concluded that the genotype, 2012/OKYVRES-1 can be used as source of resistance to YVMV in crop improvement programme. Both 2012/OKYVRES-5 and 2012/OKYVRES-2 may be recommended for commercial cultivation with better growth, yield and tolerance to YVMV under field conditions.

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ABBREVIATIONS USED

%	:	Percentage
m	:	meter
cm	:	Centimeter
mm	:	Millimeter
kg	:	Kilogram
g	:	Gram
q	:	Quintal
ha	:	Hectare
DAS	:	Days after sowing
df	:	Degree of freedom
SEm (±)	:	Standard error mean
CD at 5%	:	Critical Difference with significance level
Fig.	:	Figure
PH	:	Plant height
DFH	:	Days to first harvest
NPP	:	Number of Nodes per plant
DFFL	:	Days to first fruiting
FL	:	Fruit length
NF	:	No. of fruits per plot
FG	:	Fruit girth
CDF	:	Crop Duration of fruiting
FW	:	Fruit weight
FP	:	Fruits per plant
FFN	:	First flowering node
YVMV	:	Yellow Vein Mosaic Virus
DFFL	:	Days to first flowering
DF	:	Days to 50% flowering
GAM	:	Genetic Advance as % of mean
GA	:	Genetic Advance
GCV	:	Genotypic coefficient of variation
PCV	:	Phenotypic coefficient of variation
h^2	:	Heritability
RH	:	Relative humidity
DW	:	Dry weight
CV	:	Co-efficient of variation

CHAPTER-I

INTRODUCTION

CHAPTER-II

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INTRODUCTION

Okra or Lady's finger (*Abelmoschus esculentus* L. Moench) is one of the most important warm season fruit vegetable grown in the tropical and sub-tropical regions of the world and is native to West Africa (Tindal, 1983). It belongs to the family Malvaceae. India is considered to be the secondary centre of diversity with a possibility of polyphyletic origin. The crop was introduced to other parts of the world by the Portuguese (Sinnadurai, 1992). In India, the major okra producing states are Uttar Pradesh, Bihar, West Bengal, Odisha, Assam, Andhra Pradesh and Karnataka. Okra has captured a prominent position among the export oriented vegetable crops and is exported to middle-east countries, Western Europe and USA. It has a vast potential as one of the foreign exchange earner crop of India.

India has the credibility of producing 169.478 million tonnes of vegetables from an area of 9.542 million hectares during 2014-15 (NHB, 2014-15) being the second among the vegetable producing countries in the world next only to China. The per capita availability of vegetables in India is low i.e.160 g per day as against the recommended 300 g per day .The prediction indicates that there is a further need of 27.2 million tonnes of vegetables other than potato and other tubers to meet the nutritional requirement of the growing population i.e. 1200 million people by the year 2020-21.In India, okra covered an area of 504 thousand hectares with production of 5709 thousand tonnes and productivity of 11.43 t/ha (NHB,2014-15).

Okra is an annual herbaceous crop, grown for its tender fruits consumed as vegetable (Chattopadhyay *et al.,* 2011). Fresh okra fruit contains 2.1 g protein, 0.2 g fat, 8.0 g carbohydrate, 36.0 calories, 1.7 g fiber, 175.2 mg minerals and 88 ml of water per 100g of edible portion (Tindal, 1983; Berry *et al.,* 1988). Okra mucilage has been used as a plasma replacement or blood volume expander, extracted alcohol for alleviation of renal tubular interstitial diseases and reduce proteinuria (Siemonsma & Koumane, 2004) as well as have good relieving effect in gastrointestinal ulcer by neutralizing digestive acid (Wamanada, 2007). The mature fruits and stems contain crude fibre, used in the paper industry. It is an excellent source of iodine besides other vitamins and minerals.

In India about eight *Abelmoschus* species are found, out of which only *Abelmoschus esculentus* is known cultivated species while the rest species are truly wild types in nature. Species resistant to Okra Yellow Vein Mosaic Virus (YVMV) are *Abelmoschus caillei, Abelmoschus manihot, Abelmoschus tetraphyllus* and *Abelmoschus crinitus*. Wild species have not been fully utilized in breeding programmes due to crossing barriers. Resistance to YVMV is not stable in the cultivated species and frequent breakdown of resistance has been observed in developed varieties. Therefore, there is an urgent need to adopt appropriate method of breeding programmes for the development of lines / varieties resistant in Okra to YVMV.

Cultivation of okra in India is challenged due to severe incidence of YVMV. It infects all stages of the crop and severely reduces not only the plant growth but also fruit yield. The virus produces typical vein yellowing and thickening of leaves forming a network of mottled veins and vein lets in the infected leaves. Initially, the leaves exhibit only mild yellow coloured veins but under the severe infection, the leaves become completely chlorotic and turn yellow. There is reduction of leaf chlorophyll and the infected plants give a stunted look and produce small-sized pale yellow fruits (Gupta and Paul, 2001). The virus is neither sap nor seed transmitted in nature, rather the virus transmission occurs through the insect vector white fly (*Bemisia tabaci*). It is the most important viral disease of okra causing huge yield loss. This Begomo virus belongs to family Geminiviradeae which covers many of the crop viruses. The production losses due to YVMV have been reported to range from 50-94 per cent (Sastry and Singh, 1974).

Unfortunately many of the existing released varieties of okra are showing the signs of susceptibility to YVMV. Several varieties exhibited resistance / tolerance to this virus at the time of release, but this resistance / tolerance have broken down with time. Since, there is no source of resistance to YVMV in *Abelmoschus esculentus*, inter-specific hybridization for YVMV resistance followed by selection in the segregating generations is an effective method for obtaining desirable recombinants. Several wild species of cultivated okra showed high degree of resistance to YVMV. However, resistant varieties developed by various research organizations by interspecific hybridization have also started showing signs of susceptibility probably

due to the development of new virus strains. Hence, it is imperative to find diverse sources of resistance to YVMV and evolve YVMV resistance / tolerant varieties in a continuous manner by suitable gene introgression programmes.

In the distant hybridization programmes, genetically diverse parents are involved, hence in the segregating generations there are more scope for the selection of desirable recombinants. Assessing the genetic variability among the advanced generation selections in comparison with parents will show their extent of possession of desirable genes. Molecular characterization will further ascertain the diversity and aid in finger printing of selected genotypes for registration of varieties and identification of trait specific markers for YVMV resistance will further helps in marker assisted selection and isolation of genes responsible for resistance. Considering the above facts the present research programme was designed to screen out the okra varieties or advanced lines against YVMV under natural field conditions with the following objectives

Objectives

1) To study the genetic variability in Okra

2) To screen out best okra line (s) resistant / tolerance to YVMV

3) To study the performance of okra for growth, fruit yield and fruit quality

REVIEW OF LITERATURE

Okra (*Abelmoschus esculentus* L. Moench) is one of the important tropical vegetable crops having diet value and also as medicinal and industrial importance. Okra produces fruits continuously for a long period of time and therefore, it need both the supply of nutrients, water with appropriate plant protection measures over a period to produce a good crop. The varieties, environment, soil fertility, advanced production and protection technologies influences the potential productivity of any crop. Scientists assert that the genetic quality of the variety contributes about 24% alone towards the total yield and other critical inputs (Sankaram, 1996). Susceptibility of the most okra varieties to Yellow Vein Mosaic Virus (YVMV) is a major problem limiting the production of the crop, not only in India but also in all the okra growing areas of the world. There is no source of resistance in *Abelmoschus esculentus*. Hence, there is a need to develop new okra varieties resistant &/or tolerance to YVMV by transferring resistance genes from diverse wild species by inter-specific hybridization followed by selection of promising lines.

The literature available pertinent to present studies on "**Screening of Okra (*Abelmoschus esculentus* L. Moench) germplasm against Okra Yellow Vein Mosaic Virus disease under field condition"** have been reviewed in this chapter under the following broad outlines.

2.1 Occurrence and distribution of YVMV
2.2 Transmission of YVMV
2.3 Factors affecting the transmission of YVMV
2.4 Screening of Okra varieties / lines against YVMV
2.5 Biochemical analysis of okra fruits
2.6 Genetical studies

2.1 Occurrence and distribution of YVMV

Kulkarni (1924) reported the disease from India for the first time in the world and designated it as yellow mosaic of okra. Later, this disease has been reported from different states of India and neighbouring countries with different names as mosaic of okra (Uppal *et al.,* 1940). Bertus (1942) from Sri Lanka named the disease as mosaic of okra. Fernando and Udurawana, (1942) again from Sri Lanka reported the disease as yellow vein banding of bhendi. The disease was also referred to as vein clearing of bhendi.

The YVMV of okra was mainly confined to the Indian sub-continent. Subsequently, its natural occurrence was reported from Sri Lanka (Fernando and Udurawana, 1942), Bangladesh (Ali *et al.*, 2000) and Pakistan (Rehman and Ahmed, 2002).

YVMV is the most serious disease of okra and is transmitted by white fly (*Bemisia tabaci* Gen.) (Ali *et al*., 2012). In India, the occurrence of this disease was first reported by Kulkarni (1924) in Bombay province. Subsequently, it was reported from Bihar (Jha and Mishra, 1955), Uttar Pradesh (Tripathi and Joshi, 1967), Gujarat (Tsering and Patel, 1990), Assam (Nath and Saikia,1992), Madhya Pradesh (Sagar,1977), West Bengal (Mukhopadhya *et al*.,1994). This disease was found to be in endemic and epidemic forms in the all growing states in India. The incidence of YVMV of okra has been reported to the tune of 50 to 70 % (Saikia and Bhagbati, 1994). Infection of 100% plants in a field is very usual and yield losses ranges from 50 to 94 % depending on the stage of crop growth at which infection occurs (Sastry and Singh, 1974).

2.2 Transmission of YVMV

Unlike other viruses, the virus causing YVMV in okra was reported to be transmitted only by the insect vector Whitefly; *Bemisia tabaci* (Verma, 1950; Raychaudhari and Narini, 1977 and Muniyappa, 1980).Varma (1952) studied the relationship of YVMV and its vector whitefly. Though a single insect was able to transmit the virus, the minimum number of flies required to produce 100 % infection was of 10. The visual symptom in the clearing of small veins which actually starts at various parts near the leaf margins in about 15-20 days after inoculation of plants. Both nymphs and adults have ability to transmit the virus in persistant manner (Verma, 1952; Muniyappa, 1980 and Mukhopadhyay *et al*., 1994).

Various workers had studied the virus acquisition, retention and inoculation by whiteflies. Acquisition access period of 4-6 hours (Raychaudhari and Narini, 1977) and 12-24 hours (Verma, 1952). The preliminary fasting for a period of four hours was reported to improve the efficiency of whiteflies as a vector (Verma, 1952). A high positive correlation was reported between YVMV disease incidence and whitefly population (Bhagabti and Goswami, 1992 and Nath and Saikia,1995).

Due to YVMV incidence, the initial symptoms on young leaves are a diffuse, mottled appearance while older leaves have irregular yellow interveinal areas. After

incidence of YVMV, about 15-20 days later, there will be a clearing of small veins starts near the leaf margins. The vein clearing develops into a vein chlorosis. The nearly developed leaves exhibit an inter woven of yellow vein, which enclose the green patches of the leaf (Solankey *et al.,* 2014). Bhendi plants infected by YVMV show persistent symptoms of vein clearing followed by yellowing. Leaves and fruits are reduced in size and there is a significant decrease in the production of the vegetable, up to 96% loss in yield has been reported (Pun and Doraiswamy, 1999)

The rate of infection of YVMV decreased as the age of the inoculated plants increased was recorded by Pun *et al.* (1999). It was observed that 100% infection of YVMV occurred when 7-days old okra plants were inoculated whereas, the infection percentage dropped down to 31.70% when 49-days old plants were inoculated. They found that the incubation period of virus was increased with increased plant age. Bhagat *et al*. (2001) reported that in okra, the maximum rate of YVMV disease development was recorded between 35 to 45 days, irrespective of varieties, initially there was increasing and thereafter decreasing. Dahal *et al.,* (1992) also recorded similar results.

Khan *et al.,* (2005) reported that the extent of damage by YVMV declines with delay in infection of the pathogens. Plants infected 50 and 65 days after germination, suffer a loss of 84 and 49%, respectively. In field conditions, infection of 100% plants is not an unusual sight. Therefore, the yield loss ranges between 50 to 94% depending up on the stage of the crop growth. Plants, if infected in the early stage *i.e.* within 20 days age, the loss may be up to 94 %. If the infection is between 50 and 65 days, the loss may be up to 64 % and 49 %, respectively (Ali *et al*., 2005).

2.3 Factors affecting the transmission of YVMV

Amongst the various climatic factors temperature, humidity, and rainfall have been identified to be the most important in deciding the development and spread of the plant diseases caused by different pathogens. The plant diseases caused by the viruses are not exception to this. However, climatic factors have no direct effect on the development of YVMV in okra but they affect the activities of the whiteflies and thus have indirect bearing on the development of disease.

Singh *et al*. (1977) studied the effect of weather on development of okra YVMV. Temperature between 30-32^{0}C during March-June was reported to be conducive for development of YVMV disease, while less incidence (10-30 %) during

rainy and winter season and a rapid variation in severity from 50-60% during summer were reported. Costa and Muller (1980) opined that the YVMV incidence was more in rainy season, due to elevated vector population of whitefly. Das *et al*. (2013) further added the reasons for high incidence of YVMV during rainy season due to the favourable environmental condition for the vector whitefly and the virus in okra. On the contrary, less disease incidence of YVMV okra during summer season might be due to non-availability of vector and environmental conditions prevailing during summer season (Mager *et al*., 2010). Seasonal fluctuations in YVMV disease incidence, symptoms expressions and severity of the disease were closely related to the fluctuation in seasonal abundance of the whitefly vector have been reported (Sharma *et al*., 1987 and Singh 1990). The development of the YVMV of okra has been reported to have positive correlation with rainfall and relative humidity. The dry and hot weather with little or no rainfall was formed very much congenial condition for disease development and spread (Singh, 1986 and Singh, 1990).

Selection during rainy environment will be more amenable. Field screening based on "Coefficient of infection" revealed that none of the cultivars were found to be highly resistant throughout the three phases of screening i.e. thirty, sixty and ninety days after sowing (Singh and Dutta, 1986). According to Singh (1990), hot weather with little rainfall was favourable for the development of YVMV and also for multiplication of the vector, *Bemisia tabaci.* Earlier other reports indicated that the incidence of YVMV was high during rainy season when relative humidity was very high (Sangar, 1997, Baghat *et al.,* 2001; Chattopadhyay, *et al.,* 2011; Das *et al*., 2013).

According to Bhagabti and Goswami (1992), whitefly population was maximum in May sown crop, causing maximum disease incidence (100 %) both in May and June sown crops. According to Nath and Saikia (1992), minimum disease incidence and whitefly population in the crop sown during February 10 to March 10 and as sowing dates advanced the disease incidence and whitefly population also increased. Similar results were also reported by Muzundar *et al*. (1996). They reported maximum incidence of YVMV disease of bhendi and whitefly population when the crop sown during February 25 to march 20, in comparison to the crop sown from April 15to July 25. Positive correlation between disease incidence and whitefly population was also reported.

The rate of spread of YVMV disease of okra was maximum in February/ March sown crop and minimum in April/May sown crops, depending upon the vector activity and weather conditions. RH (maximum and minimum) and rainfall were negatively correlated and maximum temperature was positively correlated to the vector population and disease incidence (Mukhopadhya *et al*., 1994).They also reported early sowing of okra crop in February favoured the first appearance of visible symptoms within 13-14 days, when temperature was slightly elevated whereas, the delay in symptoms expression up to 20 to 27 days in December sown crop when temperature was lowest. Muzumder *et al*. (1996) reported the positive significant association between disease incidence and whitefly population, temperature, relative humidity, rainfall and number of rainy days in okra.

Pun *et al*. (1999) reported that a highly positive correlation existed between sunshine hours and YVMV incidence; while morning RH and wind velocity had a highly significant negative association with disease. Non-significant association of maximum temperature and total rainfall with disease incidence was positive and negative, respectively. Simple correlation studies, however showed that maximum and minimum temperature also exerted a highly positive effect on the disease incidence.

Ali *et al*. (2005) studied the correlation of environmental conditions (maximum and minimum temperature, RH, rainfall, clouds and wind velocity) with okra YVMV disease severity and whitefly population on commercially grown varieties of okra i.e. Pahuja, Safal, Pari and SurakhBhindi. Minimum temperature and RH had significant correlation with YVMV disease severity and whitefly population. The disease incidence increased with the rise in minimum temperature and whitefly population decreased with increase in RH.

Mehra *et al.* (2008) revealed that Arka Abay and Arka Anamika were resistant, whereas Pusa Sawni was susceptible to YVMV during rainy season. Magar *et al.* (2010) reported that, the incidence of the disease was found to vary from location to location and season to season. The disease incidence was more in summer season (20.2 – 62.0 %) rather than in *kharif* season (0.0 -18.0 %). Similarly, Fajinmi and Fajinmi (2010) studied degree of okra mosaic virus at different growth stages of plants. Virus infection was severe at growth stages earlier than four weeks. Late infection of YVMV had little or no effect on performance of okra, but early infection had a significant effect on growth and yield.

Ali *et al*. (2012) stated that the rate of % of plant infection decreased with an increase in maximum temperature from 35^0C to 41^0C. The % of plant infection decreases with increase in average temperature from 30^0C to 33.50^0C.

Invariably, the outbreak of YVMV in okra was more severe during rainy season as compared to summer season (Kaveri and Acharya, 2012). They also reported that the okra cultivar which showed more incidence of YVMV at 30 and 60 DAS was found to have less in yield than those cultivar which were having the same intensity of YVMV disease at later stage of growth. Reddy and Sridevi (2014) had observed 0.00 % to 85.0 % of YVMV incidence in the advance breeding lines of okra. Arka Anamika and Arka Abhay were observed to be highly susceptible (85.0%) and (56.2 %), respectively.

Pawar and Varma (2014) reported that the YVMV incidence (%) as influenced by different varieties during rainy season least YVMV incidence (4%) was observed with variety Gujarat Okra-2 which was inferior to the varieties Arka Abhay, Gujarat Okra-1, Perkins Long Green and Parbhani Kranti, respectively. While, during summer season minimum YVMV incidence (1.24 %) was recorded with variety Gujarat Okra-2 and which was inferior to Gujarat Okra-1, Parbhani Kranti and Arka Anamika, respectively.

2.4 Screening of Okra varieties / lines against YVMV

Development of virus resistant varieties has been considered the most effective, economical and reliable means of controlling viral diseases. The first step in any virus resistance programme was to identify germplasm possessing immunity or resistance to the viruses. In okra, also use of resistant and tolerant varieties have been reported to be the best way to overcome YVMV in okra.

Varietal resistance of okra to YVMV have been reported by several researchers (Sharma and Sharma, 1984; Singh, 1985 and Sharma and Arora, 1989). Phenolic are known as antifungal, antibacterial and antiviral compounds occurring in plants (Vidyasekharan, 1988). Chandra (1997) reported that higher phenolic content of okra was responsible for resistance to YVMV incidence. He recorded higher phenolic content in YVMV resistant varieties like Selection 12 and Arka Anamika than susceptible Pusa Sawani. Similar reports of higher phenol content of Arka Anamika, Arka Abhay, okra no.6, AROH-2, HRB-55 and GOH-3 are resistant to YVMV incidence. Mathew *et al*. (1993) recommended AROH-1, Arka Anamika and Sel-4 for commercial cultivation

under Vellanikkara, Kerala condition having high yield potential. However, lower yield was recorded in Parbhani Kranti and Pusa Sawani. Evaluation of six okra varieties (CO-2, CO-3, MDU-1, Pusa Sawani, Parbhani Kranti and Arka Anamika) at Tamil Nadu condition indicated that Arka Anamika was the best variety having highest plant height, fruits plant^{-1} and fruit yield (145.95 g plant^{-1}) than other tested varieties. Under Madhya Pradesh condition, Sangar (1997) identified both Arka Anamika and Arka Abhay as highly resistant to YVMV having higher yield but both Parbhani Kranti and V-6 were found to be moderately resistant to YVMV. According to them the disease incidence was much higher in rainy season than summer okra.

Mohapatra *et al*. (1995) recorded the weekly incidence of YVMV 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. Arka Abhay was resistant to YVMV under field condition (Debernath *et al.*, 2006, Biswas *et al*., 2008). Mehra *et al*. (2008) also observed the resistance of Arka Anamika and Arka Abhay to YVMV.

Sanigrahi and Chaudhary (1998) reported maximum incidence of YVMV in Pusa Sawani (80%), followed by Parbhani Kranti (17%), BO-1(12%) and BO-2(7%). Bora *et al.* (1992) also identified Arka Anamika as resistant to YVMV under Assam condition.

Deo *et al*. (2000) identified Arka Anamika, Parbhani Kranti, BO-2 (Utkal Gourav), HRB-55, HRB-9 and Punjab-7 as highly resistant; Satadhari as moderately susceptible and BO-1 and Pusa Sawani as susceptible to YVMV infestations under Varanasi situation. Similarly, Panda and Singh (2003) also identified HRB-55, HRB-9-2, KS 404, Parbhani Kranti, Punjab-7, IC-10272 and Arka Anamika for both summer and *kharif* season; BO-2 for summer and Satadhari local and EC 90142 for rainy season as most tolerant variety to YVMV incidence.

Singh *et al*. (2002) reported that under Chhatisgarh condition, Parbhani Kranti was found to be very susceptible to YVMV (51.2%) whereas, Arka Anamika as moderately resistant to YVMV (32.2%) during *kharif* season. Vijay (2004) reported that VRO-5 exhibited lowest disease incidence of 2.7% and recorded yield of 58.6 q ha^{-1} during 2001 and no disease with yield of 60.57 q ha^{-1}. On the other hand,

Parbhani Kranti was found to be most susceptible to YVMV with 26.1% and 43.55% in both the years, respectively under Hyderabad condition.

Neeraj *et al.* (2004) screened okra hybrids against YVMV disease and reported that hybrid NOH-15 had the highest yield (74.8q ha^{-1}) with 11.9 % YVMV disease incidence. However, NOH-15, JNODH-1, AROH-47, and HYOH-1 were at par with each other for yield and YVMV disease incidence.

Yavdav *et al.* (2004), reported that Azad Bhendi-1 a new okra cultivar developed from Pusa Swani × Parbhani Kranti, exhibits higher yield (100-125 q ha^{-1}), earlier fruiting (40-42days) and more resistance to bhendi YVMV than Pusa Swani and Parbhani Kranti.

Biswas *et al.* (2008) reported that out of 14 tested lines, none was immune to the disease, which varied from 18.25 % (ZOH-3002) to 64.96% (VB-9801). Prasanth *et al.* (2008) revealed that out of 55 screened genotypes, 5 were highly resistant, 13 were resistant, 17 were moderately resistant, 13 were moderately susceptible, 5 were susceptible and 2 were highly susceptible based on coefficient of infection.

Tripathy *et al.* (2008) conducted screening experiment during summer and *kharif* season under reduced level of chemical fertilizers supplemented with organic manures. YVMV disease incidence was ranged from 22.48% (Arka Anamika) to 43.96% (Sansar selection). Fugro and Rajput (2008) screened 18 promising varieties of okra under field conditions. Cultivar, Pusa Sawani and Pusa Makhmalli used as highly susceptible and susceptible check, respectively. The result revealed that cultivars Arka Anamika, Arka Abhay, Punjab-7 were free from YVMV disease.

In a field screening experiment of five okra varieties, high degree of resistance was obtained in VRO-6 with 13.5% disease intensity, besides that two varieties i.e., VRO-3 and HRB-9 were found to be moderately resistant. The rest two varieties i.e., Pusa Makhamali and Pusa Sawani showed moderately susceptible and highly susceptible, respectively (Tiwari *et al.,* 2012).

A field experiment carried out to screen for YVMV resistance in okra, it was observed that in both the years, the entry VRO-6 has recorded mild incidence of YVMV(2.6%) and Akola Bahar has shown severe intensity of disease (63.9%) with respect to fruit yield , JOL-2KN-19 and VRO-6 recorded maximum yield.(Vijay and Joshi, 2013). Nataraja *et al.* (2013) concluded that out of 21 genotypes, genotypes

viz., IC 331217, IC 332453 and IC 342075 and cultivars viz., Monisha 211 and Arka Anamika showed tolerant reaction to YVMV.

The cultivar, Arka Abhay was highly preferred by whiteflies and hence susceptible to YVMV disease but registered fruit yield of 62.0 q ha^{-1}, this may be due to tolerant plant character. Variation in the amount of disease incidence and preference to insects in different genotypes/cultivars may be due to some secondary plant metabolites (terpinoids, phenoloics, flavonoids, quinones, alkaloids, cyanogenic glycosides, glucosinolatesetc) and volatile substances (Karban *et al.,* 1997; Mello and Silva-Filho, 2002; Baldwin, 2010) as they are known to impart resistance to herbivore insects. The plant characteristics are also known to affect vector (whitefly) population (Khan and Mukhopadhyay, 1986; Singh, 1990).

2.5 Biochemical analysis of okra fruits

Temperature stress enhances the okra pods to reach the maximum soluble solids level compared to the ambient temperature conditions. The slow increase of soluble solids in the pericarp during the early development may be due to the presence of chlorophyll in the pericarp which has a capacity for photosynthesis (Crafts and Crisp, 1971 and Singh and Pandey, 1980). Fibre content of the pericarp steadily increased during the development of okra pod after full bloom. Ketsa and Chutichudet (1994) showed that fibre content of the pericarp steadily increased during development of the pod.

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

Parimala *et al.* (2009) suggested that the changes in the level of total chlorophyll and carotenoid in control and YVMV infected leaves. When determined on the basis of unit fresh weight, the total chlorophyll and carotenoid concentrations in infected leaves were significantly reduced by 64% and 62%, respectively. In contrast to this, chlorophyll and carotenoid ratio and chlorophyll a/b ratio was significantly increased in infected leaves.

Similarly, content of solubilized starch was also slightly increased in YVMV infected leaves, but there was no significant difference between the control and infected one.

Sreeshma and Bindu (2013) suggested that, fresh fruits, 9-13 days after anthesis (the harvesting stage) are best for consumption, when the nutritional constituents such as proteins, carbohydrates, lipids and vitamins are at their maximum. The increase in total protein, carbohydrate and lipid is suggestive of an increase in nutritional quality of the fruits at harvest time and the subsequent decrease reflects the loss in nutritive value. Vitamin C, thiamine and riboflavin were found to increase steadily in the developing fruits of okra, which continued until dehiscence suggesting that okra could be used as a very good source of these Vitamins. Okra fruits are a good source of mucilage and can be used for mucilage extraction. The increase in crude fibre, antioxidant enzymes and phenol until fruit maturation suggests the protective role of these constituents throughout seed development until dehiscence.

2.6 Genetical studies

2.6.1 Genetic variability

Selection of superior genotypes at any stage is the most important aspect in any crop improvement programme and the effectiveness of the selection is dependent upon the existence of genetic variability within or among the population subjected to selection (Tikka *et al*., 1974; Patnaik and Tak, 1974). Therefore, a quantitative measure of genetic variability would be extremely beneficial in breeding for improvement of quantitative traits. Most of the economically important characters in crop plants are quantitative in nature which are controlled by polygenes and also influenced by the environment (Hirachand *et al*., 1975). The observable quantitative trait is only the phenotype which can be easily assessed but for purpose of selection, it is inadequate since plant is the resultant of the interaction of genotype and environment which creates difficulty to ascertain whether variability is heritable or non-heritable (environmental). This necessitates the partitioning of total variation or phenotypic variation into two groups such as heritable and non-heritable components.

Coefficient of variation is defined as the measure of variation and is independent of unit of measurement which is used for comparing different populations. It is provided by the standard deviation expressed as percentage of mean (Panse and Sukhatme, 1954). Genotypic coefficient of variation is the genotypic standard deviation expressed as percentage of mean and phenotypic coefficient of

variation is expressed as the phenotypic standard deviation expressed as the percentage of mean. A slight differences between phenotypic and genotypic standard deviation suggested negligible influence of environment on that character (Choudhary *et al*., 1973).

Heritability is an important parameter of great importance for the plant breeder as its magnitude indicates the accuracy with which a genotype can be recognized by its phenotypic expression. It is estimated as the ratio of genotypic variance to the total phenotypic variance that is due to genetic causes. The term heritability, is also used in more specific ways on consideration in response to selection e.g. narrow sense heritability measured as the ratio of additive genetic variance to the total phenotypic variance (Wright, 1921) and broad sense heritability is the ratio of total genotypic variance to the observed phenotypic variance (Lush, 1949). But Liang and Walter (1968) defined heritability as the transmission of character from parent to off-spring. Mohanty and Singh (1973) described the relative importance of genetic and a non-genetic factor on the expression of a quantitative character is commonly expressed by the term heritability. Robinson (1966) grouped the heritability estimates in crop plants into three categories such as Low heritability (5 to 10 %), moderate heritability (10 to 30 %) and higher heritability (30 to 60%).

If heritability is 100%, the phenotypic performance would be a perfect indication of genotypic value. However, in this hypothetical situation, the heritability values in it provide no indication of the amount of genetic progress that would result from selecting the best individuals. Therefore, the utility of heritability is increased when they are used in conjugation with selection differential and the genetic advance is completely predicted as the product of heritability ratio and selection differential (Johnson *et al*., 1955). Randhawa *et al*., (1975) suggested that, if the heritability of a character is high, better will be the opportunity for selecting a genetically good individual. Low value of heritability indicates high degree of non-heritable variability (Sharma *et al*., 1966). Further, difference in heritability values also differ greatly depending on the methods used to estimate the parameter (Robinson, 1963) the units for which the variance is considered (Johnson *et al*., 1955) and also the amount of genetic variation in population and environmental condition under which the population is evaluated (Allard, 1960). Therefore, the most important use of heritability lies in its predictive role, expressing the reliability of the phenotypic value as a guide to the breeding value. It also serves as a useful parameter in predicting genetic advance or response to selection.

The heritability alone conveys no indication of the amount of genetic progress that will result from selecting the best individual. But when they are used together with the selection differential, the utility is increased (Tikka *et al*., 1974). Genetic advance indicates the potentiality of selection at a particular level of selection intensity. The expected genetic advance from selection when expressed as a percent of mean is the product of the selection differential in terms of phenotypic standard deviation, genotypic co-efficient of variation and the square root of heritability ratio.

Heritability in narrow sense is the most important tool to estimate expected improvement due to selection or response to selection of genetic advance. Johnson *et al.* (1955) and Robinson (1963) suggested that heritability estimates along with genetic advance were more valuable than the heritability value alone in predicting the response to selection. High heritability does not necessarily mean that the character will show high genetic advance. But the case where the above association exists, additive genes comes into prominence. It is because no genetic advance was due to non-additive genes, whereas additive genes are responsible for high genetic advance.

Genetic variability and heritability in Okra

In a variability study, Patil *et al.* (1996) at Dharwad evaluated 171 lines of Okra genotypes for two season of diverse origin for genotypic and phenotypic variances, genotypic and phenotypic coefficient of variation and heritability. They reported that characters like pods plant^{-1}, pod weight plant^{-1}, number of borer infested pods and weight of borer infested pods plant $^{-1}$ showed seasonal variation during *kharif* than rabi. The estimates of PCV and GCV values ranged from 14.7% for days to flowering (*kharif*) to 71.6% for weight of borer infested pods (*kharif*). They also observed relatively high GA for plant height, pods plant^{-1} and pod weight plant^{-1}. Dhankhar and Dhankhar (2002) while evaluating 62 inbred lines of okra at Hissar found broader range of variation and high mean values in rainy season for fruits plant^{-1}, days to 50% flowering and branches plant^{-1} and in spring-summer season for fruit yield and plant height.

According to Patro and Ravisankar (2004) high GCV and PCV was observed for branches plant^{-1}, disease incidence (*Cercospora* leafspot, Powdery mildew, YVMV), ascorbic acid content, yield plant^{-1} and fruit weight in okra. They also found high heritability for branches plant^{-1} and yield plant^{-1} and high GA for yield plant^{-1}, plant height, germination % and branches plant^{-1}. Similar observation was also reported by Khan *et al.* (2005) in okra.

Singh *et al*. (2006) reported high PCV and GCV for inter-nodal length, branches plant^{-1}, fruits plant^{-1}, seeds pod^{-1} and fruit yield plant^{-1} in okra. They also observed high heritability along with high GA for seeds pod^{-1}, inter-nodal length, ranches plant^{-1}, fruit yield plant^{-1}, fruits plant^{-1}, plant height and 100 seed weight.

In okra, Dakahe *et al*. (2007) found that the estimates of heritability were of high magnitude for green fruit yield plant^{-1}, plant height at harvest, days to maturity and internodes plant^{-1}. They also found that maximum PCV and GCV for fruit length, fruits plant^{-1} and fruit girth. Alam and Hossain (2008) while evaluating 50 accessions of okra, observed wide range of variation for spread of plant, plant height, length of petiole, moderate variation for nodes plant^{-1}, leaves plant^{-1}, length of leaf , breadth of leaf and lesser variation for primary branches plant $^{-1}$. In an investigation on genetic variance with 44 okra genotypes, Prakash Kerure (2010), also observed high GCV and PCV for plant height, inter-nodal length, first flowering node, first fruit producing node, average fruit weight and seeds fruit^{-1}.

Prakash and Pitchaimuthu (2010), estimated high GCV and PCV in okra for plant height, inter-nodal length, first flowering node, first fruit producing node, height of first flowering node, average fruit weight and seeds fruit^{-1}. Similarly, high GCV and PCV in okra were noticed by Jindal *et al*. (2010), for primary branches plant^{-1}. They also observed high heritability coupled with GA for branches plant^{-1}, total yield plant^{-1} and marketable yield plant^{-1} and high heritability coupled with low GA for days to first picking, average fruit weight, plant height, inter-nodal length, fruits plant^{-1}, fruit diameter and fruit length. High heritability in okra were recorded for plant height, fruit width, fruit length, fruits plant^{-1} and weight of fruit plant^{-1} by Kumar *et al*. (2011). They also recorded varied genetic advance and genetic gain from 0.13 to 79.62 and 3.03 to 37.14, respectively.

From a variability study, Sateesh *et al*. (2011) observed that PCV were higher than GCV for all characters in okra. They also recorded high GCV, heritability and GA as % of mean for plant height, fruit yield plant^{-1}, fruit weight and days to 50% flowering.

In a genetic variability study on 100 genotypes of okra , Reddy *et al.* (2012), reported high magnitude of GCV (>20.00 %) for branches plant^{-1}, total fruits plant^{-1}, marketable fruits plant^{-1}, total yield plant $^{-1}$(g), marketable yield plant^{-1} (g) and YVMV infestation on plants (%). They also reported that the characters plant height (cm), number

of branches plant^{-1}, inter-nodal length(cm), days to 50% flowering, first flowering node, first fruiting node, fruit length ,fruit weight , total fruits plant^{-1}, marketable fruits plant^{-1}, total yield plant $^{-1}$, marketable yield plant^{-1} and YVMV infestation on plants (%) have high heritability (>60.00 %) coupled with high expected GA (>20.00 %).

Goswami *et al*. (2012) recorded high PCV and GCV for plant height and branches plant^{-1}. They also recorded high heritability for all characters studied except days to 50% flowering which exhibited moderate heritability. The characters like plant height, branches plant^{-1}, inter-nodal length, fruits plant^{-1}, seeds fruit^{-1}, harvest index and total yield plant^{-1} exhibited high heritability coupled with GA over mean.

Jagan *et al*. (2013), observed highest PCV and GCV in okra for node at which YVMV appears, days at 1st YVMV symptom appears and branches plant^{-1}. The heritability estimates in broad sense were high for branches plant^{-1}, days to maturity, fruit length, days to 50% flowering and node at which YVMV appears, while low for fruits plant^{-1} and node at which first flower appears. They also observed high GA as % of mean for node at which YVMV appear, days at 1st YVMV symptom appear and number of branches plant^{-1}and high heritability coupled with high GA for branches plant^{-1} and days to maturity. Gendy and Aziz (2013) also observed high or moderately high GCV, PCV, heritability and expected genetic advance GA% of mean in most crosses in okra.

Analysis of variance and other genetic analyses such as GCV and PCV were performed by Simon *et al*. (2013) and they found highly significant variation in all the genotype except days to 50% flowering, and characters measured such as pods plant^{-1} (54.36), branches plant^{-1} (8.206), leaves plant^{-1} (45.89), days to pod formation, pod length (6.652), pod width(54.31), seed index (20.78), seeds pod^{-1} (2.43),plant height at 50% flowering (2543.5), pod yield (45.39), seed yield(427.73), seed size (0.014) and internodes distance (0.66). In a heritability study, Yonas *et al*. (2014), reported high heritability (96.76 and 96.50 %) coupled with high GA as % of mean (106.32 and 97.25%) for internodes length and plant height, respectively.

2.6.2. Correlation Studies

Yield is the complex character hence it is necessary to know the importance and association of various yield contributing components with yield and within themselves. This is possible by determining the correlation coefficients (r) between the combining traits and yield.

Dhankar and Dhankar (2002) observed that fruit yield was significantly and positively correlated with the number of fruits and branches plant^{-1} and plant height but was negatively correlated with days to 50% flowering. The fruits plant^{-1} was positively associated with branches plant^{-1} and plant height was negatively correlated with days to 50% flowering. Fruit yield can be improved through selection for higher number of fruits and branches and medium height. According to Nimbalkar *et al*. (2002) fruit yield exhibited positive and significant correlation with days to maturity, plant height, seed yield plant^{-1} and fruits plant^{-1}, with seed yield recording the highest correlation (r=0.667) with fruit yield.

Kamal *et al*. (2003) observed that yield plant^{-1} was positive and highly significantly correlated with nodes plant^{-1}, width of fruit and fruits plant^{-1} in okra. Similarly, Jaiprakashnarayan and Mulge (2004) noticed that total yield plant^{-1} was positively and significantly correlated with fruits plant^{-1}, fruit weight, nodes main stem^{-1}, fruit length, plant height at 60 and 100 DAS and leaves plant^{-1} at 45 and 100 days, but negatively and significantly correlated with locules fruit^{-1}, nodes at first flowering and first fruiting.

Dhake *et al*. (2007) revealed that 50% flowering and maturity are significantly associated and also suggested that for increasing green pod yield due emphasis should be given to fruits plant^{-1}, number of internodes, plant height and fruit length, as all these characters possess highly significant positive correlation with fruit yield.

In okra, fruit yield had significant positive genotypic and phenotypic correlation with fruit plant^{-1}, fruit length and plant height. Fruit plant^{-1} showed significant positive genotypic and phenotypic associations with plant height and fruit length (Singh *et al.,* 2007). Ali *et al.* (2008) estimated the correlation coefficients among parents, F_1 hybrids and F_2 population separately. They observed significant and positive correlation in all the three population between fruit yield plant^{-1} and fruits plant^{-1}. The consistency was also observed in F_1 and F_2 generation between fruit yield plant^{-1} and plant height.

Significantly positive correlations were recorded between yields plant^{-1} with plant height, intermodal length, fruits plant^{-1}, branches plant^{-1}, fruit weight, fruit girth, nodes to 1st flower and fruit length (Sengupta and Verma, 2009). Balakrishnan and Sreenivasan (2010) in observed that fruit yield was positively associated with number of fruits & internodes,

fruit weight and fruit length. Shoot and fruit borer infestation recorded negative association with plant height, flowering period, fruit number, fruit yield and internodal length. Correlation and path analysis studies in 75 diverse Okra genotypes revealed that yield plant^{-1} exhibited positive and significant correlation with plant height, number of flowering nodes on main stem, fruits plant^{-1}, weight of fruit (Chaukhande *et al*., 2011).

Amoatey *et al.* (2015) studied the correlation coefficients in 29 local and exotic lines of okra. They found that 7 pairs of quantitative traits were positive and significantly correlated ($P \leq 0.05$) while three were highly significantly associated ($P \leq 0.01$). The highest correlation ($r = 0.95$) was between days to 50% flowering and days to 50% fruiting.

2.6.3. Path analysis

Yield is a complex trait resulting from the direct and indirect effects of several traits operating either in combination or individually. Selection for a trait in one direction may influence another trait by a direct or indirect effect via a third variable. The study of correlation only gives the extent of association among the various characters taken in pairs. This extent of association does not imply the cause and effect relationship. Therefore, the path co-efficient analysis is used to determine the direct and indirect effects of various plant characters on crop yield.

Bhalekar *et al.* (2005) carried out correlation and path analysis studies in okra for 14 yield attributing characters and suggested that the suitable genotype of okra for getting higher fruit yield should be YVMV disease-free, early, long-fruited, tall with maximum inter nodal length and higher number of fruits and nodes plant^{-1}.

Gangashetty *et al*. (2010) studied on association and path analysis for fruit yield plant^{-1} and its component traits .They reported that the fruit yield plant^{-1} had a significant positive phenotypic correlation with fruits plant^{-1}, plant height, fruit weight and fruit length. Path coefficient analysis depicted that fruits plant^{-1}, fruit weight and plant height has high direct effect on fruit yield plant^{-1}. Balakrishnan and Sreenivasan (2010) reported that fruit yield was positively associated with number of fruits & internodes, fruit weight and fruit length.

Path analysis study conducted by Chaukhande *et al.* (2011) indicated that fruits plant^{-1} exhibited maximum direct effect on yield plant^{-1} followed by average weight of fruit and inters nodal length. Saitwal *et al.* (2011) suggested negative and non-significant association with length of fruit, diameter of fruit and days to flower initiation in okra.

Laxman *et al.* (2012) studied the path of productivity analysis in okra for fruit yield and its components characters. Days to first flowering, days to 50 % flowering and fruit diameter exhibited least average expression. The genotypes had positive values for fruit yield hectare^{-1}, fruit weight, fruits plant^{-1}, plant height, fruit length, fruit diameter, and days to first flowering, while most of the genotypes showed least deviation for days to 50% flowering and fruit diameter.

Path analysis study in okra**,** Reddy *et al.* (2013) observed that fruit weight, fruits plant^{-1} and marketable fruits plant^{-1} had positively direct effect on marketable pod yield plant^{-1}. They also observed that the fruit weight, fruits plant^{-1} and marketable fruits plant^{-1} not only had positively significant association with marketable pod yield plant^{-1} but also had positively high direct effect on marketable pod yield plant^{-1} and are regarded as the main determinants of marketable pod yield.

Simon *et al.* (2013) reported that the path coefficients analysis in16 F_1 hybrids Okra. The results obtained showed highly significant variations in all the genotype except days to 50% flowering, and characters measured such as pods plant^{-1} (54.365), days to pod formation, pod length (6.6526), pod width (54.306), plant height at 50% flowering (2543.5), pod yield (45.395)and internodes distance (0.6602).

2.6.4. Genetic divergence

Selection of genetically divergent varieties is important in the exploitation of heterosis and in the development of transgressive segregates for an efficient breeding programme. The information regarding the nature and magnitude of genetic distance among the genotypes will help the breeder choosing the suitable diverse combinations.

According to Patro and Ravisankar (2004), cluster analysis in okra revealed a considerable variation among the genotypes. Forty one genotypes were grouped into 8 clusters. They reported that among all the clusters, cluster IV had a maximum number (8) of genotypes, D^2 values ranged from 205.03 to 32666.9. The cluster means revealed that plant height, yield plant^{-1} and germination percentage contributed towards divergence. Pradip *et al*. (2010) grouped 50 genotypes into 5 clusters. The plant height had the highest contribution towards the total genetic divergence.

Prakash and Pitchaimuthu (2010) while studying 44 genotypes in okra reported that days to 50% flowering 100 seed weight, seeds fruit^{-1} and fruit weight directly contributed towards maximum divergence and therefore, selection of

divergent parents based on this character is recommended for getting good hybrids or segregants in okra. Garg *et al*. (2011), evaluated 53 germplasm of okra to assess the genetic diversity. They reported that no parallelism between genetic and geographic divergence was observed. kaur *et al* (2013) assessed the genetic diversity and established phenetic relationships in a set of 70 okra germplasm lines using 40 RAPD primers for 8 quantitative traits. They reported that grouping of genotypes into different constellations did not follow any specific pattern suggesting independence of clustering pattern of the entries and their geographical origin.

Soyab *et al.* (2013) studied the genetic divergence among 25 okra germplasm lines using Mahalanobis D^2 analysis and they were grouped into 4 clusters. Cluster I and IV shown high cluster means for yield and yield components, therefore genotypes viz., IIVR- 11, HRB- 55, 134, 148 and Parbhani Kranti (Cluster I) and 315 (Cluster IV) of these diverse clusters may be used for further hybridization.

Goswami *et al.* (2015) studied the genetic divergence analysis in okra. Morphological studies in landrace collections were carried out in 20 parents developed for diversity analysis for the purpose of genetic improvement and their effect in populations. The D^2study brought out the fact that the maximum distance was $D^2 = 4.403$ and minimum distance $D^2 = 1.854$.

Mishra *et al*. (2015) A study conducted on 33 genotypes of okra. The result revealed wide genetic diversity and were grouped into 8 clusters based on 13 important characters. The cluster I was the largest containing 08 genotypes followed by cluster III with 07 genotypes. The diversity among the cluster was measured by inter-cluster distance, highest being observed in between cluster III and cluster VI (D2= 104.10) followed by cluster II and cluster VI (D2 = 100.54). selection of divergent parents of okra based on these cluster distance would be useful in selecting genotypes for hybridization, superior hybrids or variety (s) can obtained by crossing parents of two divergent groups, cluster III (OKHYB-4, OKHYB-13, OKHYB-6, OKHYB-7, OKHYB-8, OKHYB-10 and OKHYB-12) with cluster VI (Arka Anamika and Pusa Sawani).

MATERIALS AND METHODS

The present investigation entitled **"Screening of Okra (*Abelmoschus esculentus* L. Moench) germplasm against Okra Yellow Vein Mosaic Virus disease under field condition"** was carried out during summer, 2015 at All India Co-ordinated Research Project on Vegetable Crops, Horticultural Research Station, Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India. The experiment was carried to study the genetic variability in okra, screening of best okra line (s) resistant/tolerance to YVMV and identifying the best performing okra line (s) for growth, fruit yield and fruit quality. The seeds of the genotypes of okra were supplied by Project Co-ordinator, Indian Institute of Vegetable Research, Varanasi.

Cropping history of the plot

Prior to the present investigation, detailed information on cropping history of the experimental plot was collected & presented in Table 3.1, for two successive years.

Table 3.1 Cropping history of the experimental plot

Year	*Kharif*	*Rabi*	Summer
2013	Fallow	Broccoli	Okra
2014	Fallow	Broccoli	Okra
2015	Fallow	Broccoli	Okra (test crop)

Soil

A composite soil sample was taken from a depth of 15 cm surface from the experimental field before raising the crop for investigation. The sample was subjected to laboratory analysis to determine the physical and chemical compositions by following various standard methods. The soil of the experimental plot was sandy loam (Sand-75.24%, Silt-14.76%, Clay-10.76%) having pH 5.86. The chemical analysis of soil indicated that the available NPK content was 162.5:104.2:94.1kg ha^{-1}, respectively. The organic carbon content of soil was 1.01% while electrical conductivity of 0.188 dS m^{-1}.

Geographical location of the experimental site

Bhubaneswar is located at latitude of 20^0 15' N & 85^0 52' East longitude. It is about 60 km away from Bay of Bengal and at an altitude of 25.5 meter above mean sea level (MSL).

Climate

The experimental site comes under the eighteenth agro-climatic region of the country i.e. Eastern Coastal Plain and is termed as sub-humid characterized by warm moist climate with mild winter. The average annual rainfall of Bhubaneswar is 1552mm (Based on average of preceding 10 years). Most of the rainfall i.e. 85% is received from July to September. The rainfall code of the place is $D_1 E_3$ ($B_1A_2B_1$) $C_1D_1E_2$. The average temperature varies from 14^0C in winter to 40^0C in summer and relative humidity varies between 49 or 90% from June to December.

Monthly average meteorological data during cropping season was recorded at Meteorological Observatory of Orissa University of Agriculture and Technology, Bhubaneswar.

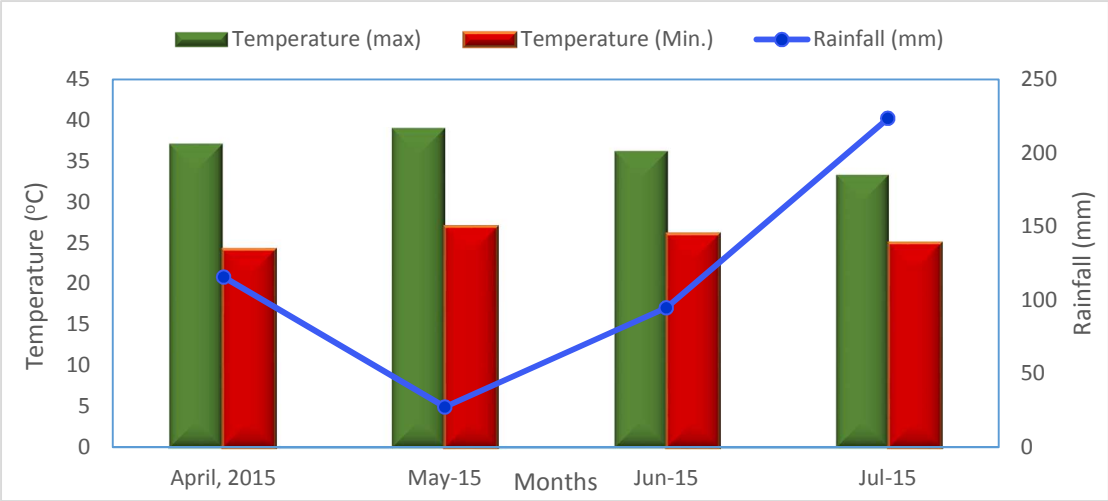


Fig. 3.1 Monthly average temperature and rainfall during crop season

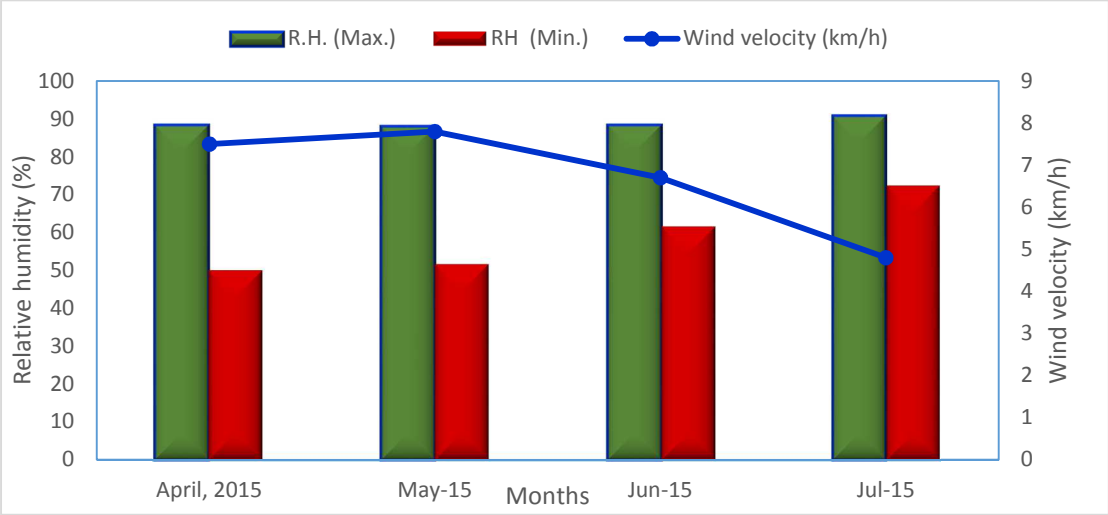
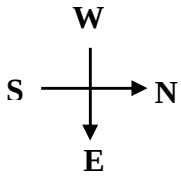


Fig. 3.2 Monthly average relative humidity and wind velocity during crop season

Experimental details

(i)	Design of Layout	:	Randomized Block Design (RBD) [Plan Layout Fig. 1]
(ii)	Number of Treatments	:	10 (Six advanced breeding lines with 4 check varieties)
(iii)	Number of Replication	:	3
(iv)	Total no. of plots	:	30
(v)	Plot size		
(vi)	Length	:	3.0m
(vii)	Width	:	3.0m
(viii)	Area	:	9 m^2
(ix)	Spacing	:	
(x)	Row to Row	:	45cm
(xi)	Plant to Plant	:	30cm
(xii)	Number of rows per plot	:	6
(xiii)	Number of plants per row	:	9
(xiv)	Number of plants per plot	:	54
(xv)	Width of the bund separating blocks	:	40 cm
(xvi)	Width of irrigation channel	:	100 cm



Design-RBD Plot size-3.0 m × 3.0m Treatments -10

REP-I	REP-II	REP-III
V1	V5	V9
V8	V2	V10
V7	V10	V8
V9	V6	V3
V4	V1	V5
V3	V8	V7
V6	V9	V2
V10	V7	V4
V2	V3	V6
V5	V4	V1

Fig.3.3 Layout plan of experimental field

Field operation and crop raising

The field was ploughed three times after incorporation of FYM during final land preparation @ 15 t ha^{-1} and levelled properly. Then the individual plots are laid out of scheduled size as per the plan of layout with required irrigation channel. Seeds were soaked in water over night to obtain better germination. The seed sowing was done on 29th April 2015. Six rows were made and there were nine plants in each row, thus accommodating 54 plants $plot^{-1}$. Light irrigation was given with rose cane for the first time in main field.

A fertilizer dose of 100:50:50 N:P_2O_5:K_2O kg ha^{-1} were applied. The total amount of phosphorous with 20 kg of nitrogen and 10 kg of potash was applied to the soil before sowing. Remaining 80 kg of nitrogen and 40 kg of potash was applied in two-splits, as 40kg of nitrogen along with 20 kg of potash after first weeding, and remaining 20 kg of potash was applied after second weeding and 40kg of nitrogen was applied. Subsequently irrigation was provided in the irrigation channel at a interval of 4-6 days during the cropping season.

Thinning was carried out for the closely germinated plants at one true-leaf stage. Hoeing, weeding and earthing up were done at periodic interval. Manually hoeing followed by weeding, top dressing and earthing up were done followed by irrigation. Okra fruits were harvested when they were at tender stage and attained marketable size i.e. edible maturity stage. Picking of fruits were done at every alternate day till the last marketable produce.

Biometric observations

Sampling Technique

Observations on various biometric characters were recorded by selecting randomly ten competitive plants of each genotype in a replication which were tagged properly. The border plants were excluded while selecting the sample plants. The observations of these tagged plants were taken time to time starting from initiation of first flowering to final harvesting of fruits.

Characters studied

1. Plant height (cm) at final harvesting stage (PH)

The height of ten sample plants was recorded in cm from the base to the tip of the plant after final harvest and their mean values were taken for analysis of this character.

2. Number of nodes plant^{-1} (NPP)

The ten sample plants selected for plant height were also used for recording nodes plant^{-1}. Nodes of each sample plant were counted and their mean values were taken for analysis of this character.

3. Node at which first flower appeared (FFN)

The node at which first flower appeared counted from the base and expressed in number.

4. **Days to first flowering- (DFFL)**

This was recorded by counting the number of days taken from sowing to initiation of first flower in each genotype.

5. Days to 50% flowering (DF)

This was recorded by counting the number of days taken from sowing to the flowering in 50% plants in each genotype.

6. Number of fruits plant^{-1}(FP)

This character was recorded by counting the total number of fruits harvested at different pickings in the sample plant till the final marketable harvest.

7. Fruit length (FL)

The length of 10 fruits randomly selected from selected plants in observational plot of each genotype, in each replication, were measured and expressed in cm from the attachment end to the tip using a Vernier caliper and the mean value was calculated as fruit length.

8. Fruit girth (FG)

Ten fruits selected randomly from each plot in a replication for recording of fruit length were also used for recording their girth at the point of maximum thickness which were averaged and expressed in cm.

9. Fruit weight (FW) (Avg. of 10 fruits entry^{-1})

Fruits selected for length and girth were also used for recording the weight of fruit. Fruits were weighed individually and average weight of ten fruits was calculated as weight of fruit and was expressed in grams.

10. Avg. fruit weight (g plant^{-1})

The average of selected 10 plants fruits weight were taken.

11. Number of ridges per fruit

Ten fruits selected randomly from each plot in a replication for recording of fruit length and fruit girth were also used for recording the number of ridges in each of the fruits which was expressed in number.

12. Days to first harvest (DFH)

This was recorded by counting the number of days taken from sowing to the first harvest in each genotype.

13. Fruit yield plot^{-1} (kg)

Observations for this character were recorded by combining the marketable yield and unmarketable yield values of the 10 genotypes in each of the three replications and were expressed in kg.

14. Fruit yield (q ha^{-1})

This value for each of the genotypes was determined by multiplying the value of fruit yield plot^{-1} of each of the ten genotypes with 11.11 and calculated on hectare basis.

15. Dry weight (DW)

The 10 fruits randomly selected from selected plants in observational plot of each genotype, in each replication, were taken and this fruits were dried in oven until the moisture content is removed from the samples and this dried sample is expressed in gram and the mean value was calculated as Dry weight.

16. Crop Duration of fruiting (CDF)

This was recorded by counting the number of days taken from sowing to the final harvest in each genotype.

17. Crude protein content

The 10 fruits randomly selected from selected plants in observational plot of each genotype, in each replication, were taken for the estimation of protein in that 1g dry sample is taken for the Nitrogen analysis and multiplied by 6.25 with nitrogen content for the protein analysis and is expressed (mg) and mean values are used for analysis.

18. Reducing, non- reducing and total sugar content.

The 10 fruits randomly selected from selected plants in observational plot of each genotype, in each replication, were taken for the analyzing of reducing and non-reducing sugar and of okra by the colorimetric method and expressed in per cent and mean values are used for analysis. The both reducing and non-reducing are pooled to get the total sugar content of okra.

19. Hardness of fruits.

The 10 fruits randomly selected from selected plants in observational plot of each genotype, in each replication, were taken and measured hardness by using the penetrometer and expressed in mm and mean values are used for analysis.

20. YVMV incidence (30, 45, 60, 75 and 90 DAS)

Observations for this character were recorded by counting the number of plants infected with Yellow Vein Mosaic Virus (YVMV) disease at 30, 45, 60, 75 and 90 days, respectively in each replication and were expressed in percentage and analysis purpose its converted to its ASIN values for calculations.

Statistical analysis

The data recorded for various characters were subjected to statistical analysis based on their sample means (Gomez and Gomez, 1983). Observations of all the characters were analyzed for variability and other genetic parameters related to fruit yield were taken for character association studies. In case of YVMV incidence the angular value after transformation was taken for analysis.

Analysis of variances

The analysis of variances for each of the characters stated was done to find out varietals differences. The analysis was carried out separately for each trait following the procedure of randomized block design analysis (Panse and Sukhatme, 1954).

Analysis of variance was done on basis of following model.

$$Y_{ij} = m + g_i + r_j + e_{ij}$$

Where, Y_{ij} = Phenotypic observation in the i^{th} genotype and the j^{th} replication

m = General mean

g_i = Effect of the i^{th} genotype/treatment

r_j = Effect of j^{th} replication

e_{ij} = Random error associated with i^{th} genotype in j^{th} replication

Table 3.2 Analysis of variance and expected mean sum of square

SOURCE	Df	MSS	EXPECTED MEAN SUM OF SQUARE
Replication	(r-1)	M_R	$\sigma^2_e + g\sigma^2_r$
Genotype	(g-1)	M_G	$\sigma^2_e + r\sigma^2_g$
Error	(r-1)(g-1)	M_E	σ^2_e

Mean, range, standard error and critical differences

Sample mean values were calculated for each character by dividing the total by corresponding number of observations, while the highest and lowest values for each character were taken as the range. The S.E. and C.D. values were calculated by using the following formula.

Standard error mean (SEM) = $\sqrt{EMS/r}$

Critical difference (C.D.)

= $\sqrt{2EMS/r} \times$ t value at error d.f. at 5% and 1% level of significance

Where, r = number of replications

EMS = Error mean sum of square

Co-efficient of variation

For comparing the variability of two or more than two characters, co-efficient of variation were calculated by using the formula given below:

C.V. = S.D. / X ×100 = $\sqrt{EMS}$/ X ×100

Where,

S.D. = standard deviation which is the square root of mean square due to error (EMS)

X = Experimental mean

From the structure of the analysis of variance

Error variance = $\sigma e^2 = M_E$

Genotypic variance = $\sigma^2_g = M_G - M_e / r$

Phenotypic variance = $\sigma^2_p = M_G / r = \sigma^2_g + \sigma^2_e / r$

The genotypic co-efficient of variation (GCV) and the phenotypic co-efficient of variation (PCV) were calculated by the formula given by Burton (1952).

GCV = Genotypic standard deviation / Grand mean × 100

PCV = Phenotypic standard deviation / Grand mean × 100

The observable quantitative trait is the phenotype which can easily be assessed but for the purpose of selection, it is inadequate since phenotype is the resultant of the interaction of genotype and environment which creates difficulty to ascertain whether variability is heritable or non-heritable (environmental).This necessitates the partitioning of total variation or phenotypic variation into two groups such as heritable and non –heritable characters as follows:

a) Heritable or genotypic variation: It includes

Additive genetic variance (V_A), which results from additive or average effect of genes and it is heritable.

(i) Dominance variance (V_D), which arises from intra-allelic interaction (due to deviation of the heterozygote Aa from the average of homozygotes (AA and aa) and it is also heritable.

b) Non-heritable or non –genetic variation : It includes

(i) Epistatic variance (V_1) which results from the interaction of non-allelic and is referred to as inter-allelic interaction.

(ii) Environmental Variance ($V_{E)}$ which results from non-genetic factor such as environmental fluctuations, sampling error and difference in cultural practices.

3.5.1 Heritability

The heritability estimates were used to measure the degree of correspondence between phenotypic value and breeding value. It is worked out by using the formula suggested by Lush (1949) and Burton and Devance (1953) and expressed in percentage according to Weber and Moorty (1952).

h^2 (broad sense) = Genotypic variance / Phenotypic variance=$V_G/ (V_G+V_E) = V_G/V_P$

h^2 (broad sense in percentage) = Genotypic variance /Phenotypic variance × 100

h^2 (narrow sense) =$V_A/ (V_G+V_E) = V_A/V_P$

Variation in the quantitative traits occurs due to their degree of heritability. Robinson (1966) grouped the heritability estimates in crop plants into three categories:

i. Low heritability – 5 to 10 percent.

ii. Moderate heritability – 10 to 30 percent.

iii. Higher heritability – 30 to 60 percent.

This classification represents average of heritability estimates over various crop plants, types of population, procedures of determination and environments encountered in different locations and years. If heritability is 100% the phenotypic performance would be a perfect indication of genotypic value. However, in this hypothetical situation, the heritability values in itself provide no indication of the amount of genetic progress that would result from selecting the best individuals.

Expected genetic advance

Genetic advance was estimated as per the formula suggested by Johnson *et al* (1995).

$GA = K. h^2\sigma_p$

Where,

K = Selection differential in standard units (which is 2.06 per 5% selection intensity).

h^2 = Heritability in broad sense

σ_p = Phenotypic standard deviation

GA (expressed as percentage of mean) = GA / Mean × 100

The expected genetic advance from selection when expressed as a percent of mean is the product of

i. the selection differential in terms of phenotypic standard deviation
ii. genotypic co-efficient of variation
iii. the square-root of heritability ratio.

Estimation of correlation co-efficient

Simple correlation co-efficient were computed at phenotypic and genotypic levels between pairs of 14 important characters that contribute to fruit yield (number of fruits per plant) using the following formula.

Genotypic correlation $(r_g) = \sigma_g(xy) / \sigma_g(x) \times \sigma_g (y)$

Phenotypic correlation $(r_p) = \sigma_p(xy) / \sigma_p(x) \times \sigma_p (y)$

Where, $\sigma_g(xy)$ = Genotypic co-variance between the two traits x and y.

$\sigma_p(xy)$ = Phenotypic co-variance between the two traits x and y.

$\sigma_g(x)$ and $\sigma_g (y)$ = Genotypic standard deviation for x and y respectively.

$\sigma_p(x)$ and $\sigma_p (y)$ = Phenotypic standard deviation for x and y respectively.

The estimated values were compared with the table value at (n - 2) and at 5% and 1% levels of significance in order of test the significance of correlation co-efficients at phenotypic and genotypic level.

3.5.2 Path co-efficient analysis

The cause and effect relationship among the various correlated characters are determined by path co-efficient analysis. Path co-efficients were standardized by partial regression coefficients which individually provide a measure of direct effect of the casual factors on the effect variable. These permit partitioning of the correlation between casual factors and the effect of variables into components of direct and indirect effect and thus give a better picture of the association of the casual factors with the effect variable.

In the present investigation fruit yield per plant was taken as the effect with other characters like plant height, days to first flowering, node at which first flower appeared, days to 50% flowering, days to first fruiting, number of fruits per plant, fruit length, fruit girth, fruit weight and YVMV incidence related to this as the casual factor.

The path coefficients were obtained by solving the following the simultaneous equations which give the basic relationship between correlations and path coefficients in a system of correlated causes. (Dewey and Lu, 1959).

$$r_{112} = r_{11}p_{112} + r_{12}p_{112} + r_{13}p_{112} + \ldots\ldots\ldots\ldots\ldots\ldots + r_{111}p_{1112}$$

$$r_{212} = r_{21}p_{112} + r_{22}p_{112} + r_{23}p_{112} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + r_{211}p_{1112}$$

$$r_{312} = r_{31}p_{112} + r_{32}p_{112} + r_{33}p_{112} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots + r_{311}p_{1112}$$

$$r_{1112} = r_{111}p_{112} + r_{112}p_{212} + r_{113}p_{312} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots + p_{1112}$$

Where, r_{ij} is the coefficient of correlation between i^{th} and j^{th} characters and p_{qi} is the path coefficient (direct effect of i^{th} character on number of fruits per plant (1, 2)).

The solutions for path coefficients, direct and indirect effects of the casual factors were estimated as the values of the individual terms of the above equations in R.H.S.

The coefficient of determination (R^2) and the residual effect ($p_{12.R}$) were calculated as follows:

$$I = p^2_{12.R} + \sum p_{iy}r_{iy}$$

$$R^2 = \sum p_{iy}r_{iy}$$

$$= p_{112}r_{112} + p_{212}r_{212} + p_{312}r_{312} + \ldots\ldots\ldots\ldots\ldots\ldots + p_{1112}r_{1112}$$

$$P_{12.R} = \sqrt{I - R^2}$$

The path analysis at the phenotypic level with the same cause and effect relationship was computed using the phenotypic correlations as stated earlier.

3.7.7 Genetic divergence

Mahalanobis' (1928) generalized distance, D^2 statistics was used for computing genetic divergence as described by (Rao, 1952). The original measurements were transformed to standardized uncorrelated variables by pivotal condensation (Rao, 1952). The divergence between any two varieties was obtained as the sum of squares of the difference in the values of the corresponding transformed values (V_{ij})

$$D^2_{jk} = \sum^{n}_{i=1} Y_i j - Y_i k$$

Gives the D^2 between J^{th} and K^{th} germplasm for 'n' characters. The all possible 66 pairs of D^2 were calculated from the 12 varieties using the formula n(n - 1) / 2.

Following Tocher's method as described by Rao (1952), the genotypes were grouped into clusters. The criterion of grouping was that any two genotypes belonging to the same cluster should have a smaller D^2 value than those between genotypes belong to different clusters. Inter and intra-cluster distances were determined and represented.

Estimation of protein by Nitrogen method

Nitrogen was estimated by micro Kjeldahl method (Page, 1982). 1g dry weight of plant sample was taken in digestion tube. 20g digestion mixture, salicylic acid, Sodium thiosulphate and 20ml conc. H_2SO_4 was added to it. Then it was kept overnight. The digestion continued in a digestion tube until blue spray liquid was obtained without any bubbling. Then the digestion tube was cooled. After it was diluted to 100ml and this diluted extract was used for estimation of nitrogen.

Transferred 20ml of diluted sample extract to distillation unit. Then added 20ml of 40% NaOH and continued distillation for 10 minutes. Collected the liberated Ammonia by absorbing 20ml boric acid present in 100ml conical flask containing 3drops of mixed indicator. After completion of digestion, dilute was titrated against 0.02385N HCL. The total nitrogen and its value multiplied with 6.25 we get the protein content.

$$\% \text{ Of Nitrogen} = \frac{0.014 \times 0.2385 \times 13.3 \times 5 \times 100}{\text{Wieght of sample (1g)}}$$

Reducing sugar

In order to determine the content of reducing sugar, the 10ml of sample was taken in 100ml volumetric flask. Fehling's solution A and B 5ml each were taken in conical flask

and added of 40ml distilled water and mixed thoroughly. Then the flask was heated, when first bubble came out 2-3 drops methylene blue indicator is added fairly and it was titrated against sample in burrette till the end point comes to brick red colour.

$$\% \text{ of Reducing sugar } = \frac{\text{Factor } \times \text{Dilution } \times 100}{\text{Titrate } \times \text{Volume of sample taken}} \times 100$$

Non reducing sugar

Ten ml filtered juice was taken in 100ml volumetric flask then 5ml of 1N HCL along with 30ml distilled water was added .then it was heated for 3-5 minutes and cooled (for inversion). the content was transferred to conical flask when the bubbles came out 2-3 drops of phenolphthalein indicator was added to it then it is titrated against 1N NaOH taken in the burette the appearance of pink color show the end point of titration where non-reducing sugar present in the fruit converted to reducing form. then this content was taken in a burette after making the volume to 40ml. Fehling's solution A and B each of 5ml was taken in conical flask and added 40 ml of distilled water and heated when first bubble appear it was titrated against the sample taken in the burette. The end point was noticed by brick red color.

Per cent of Non-reducing sugar = (% of total sugar - % of reducing sugar) ×0.95

Total sugar estimation: The addition of both reducing and non-reducing sugar it will gives the total sugar content

The per cent disease incidence calculation

$$\text{PDI } = \frac{\text{Number of diseased plants}}{\text{Total number of plants observed}} \times 100$$

RESULTS

The present investigation entitled, **"Screening of Okra (*Abelmoschus esculentus* L. Moench) germplasm against Okra Yellow Vein Mosaic Virus disease under field condition"** was conducted at All India Coordinated Research Project on Vegetable Crops operating under Orissa University of Agriculture & Technology at Bhubaneswar, Odisha, India during summer season of 2015 with an objective of screening of suitable lines or varieties resistance or tolerance to Yellow Vein Mosaic Virus (YVMV) disease under field condition.

In this chapter, careful explanations have been made relating to observations recorded on various aspects of investigation with suitable tables, graphs and photographs as and when required.

4.1 Analysis of variance

The mean square values, i.e. variance between the genotypes for 26 characters including the vegetative growth, flowering, fruit yield and yield attributing parameters, reaction to YVMV at different stages of crop growth as well as in fruit quality parameters are presented in Table.4.1. The data revealed the existence of significant variations among the tested genotypes for all the characters studied, except the fruit girth, ridges plant^{-1} and crop duration.

4.2 Mean performance of tested genotypes of okra

4.2.1 Vegetative growth parameters

A perusal of Table no.4.2 indicated significant variations in plant height at the time of harvesting among different genotypes including checks. The plant height varied significantly from minimum of 57.57 cm (2012/OKYVRES-5) to maximum of 120.83 cm (2012/OKYVRES-2). The genotype, 2012/OKYVRES-2 recorded significantly highest plant height of 120.83 cm than rest of the genotypes including checks. However, *statistical parity* was observed with the check varieties like Arka Anamika (114.43 cm) and Arka Abhay (115.27 cm).

Table 4.1 Analysis of variance (mean sum of squares) for different parameters of okra under study

Sl. No	Character	Replication	Genotypes	Error
	Degrees of freedom	**2**	**9**	**18**
A	**Vegetative growth parameters**			
1	Plant height (cm) at final harvesting stage	99.63	998.85**	66.95
2	Number of nodes per plant	6.49	9.13**	2.20
B	**Flowering parameters**			
1	Node at which first flower appeared	2.05	1.58**	0.62
2	Days to first flowering	2.53	28.24**	5.72
3	Days to 50 % flowering	0.10	9.07**	1.14
C	**Fruit parameters**			
1	Number of fruits per plant	3.01	74.36**	2.75
2	Fruit length (cm)	2.56	3.71**	1.36
3	Fruit girth (cm)	0.14	0.74 NS	0.16
4	Average fruit weight (g)(average 10 fruits entry^{-1})	12.49	18.18**	5.04
5	Average fruit weight (g) plant^{-1}	74.82	3083.12**	71.72
6	Number of ridges fruit^{-1}	0.003	1.20NS	0.002
D	**Yield parameters**			
1	Days to first harvesting	1.43	28.03**	6.43
2	Fruit yield kg plot^{-1}	0.15	22.42**	0.54
3	Fruit yield ha^{-1}	22.68	3417.56**	83.12
4	Dry weight of average 10 fruits entry^{-1}	1.46	3.36**	0.97
5	Crop duration from sowing to last harvesting	4.23	19.54 NS	5.189
E	**Quality parameters**			
1	Crude protein content of fruits	0.65	29.54**	0.74
2	Reducing sugar	0.04	0.59**	0.002
3	Non-Reducing sugar	0.09	0.28**	0.003
4	Total sugar	0.02	1.03**	0.004
5	Measuring of Hardness of fruits by using Penetrometer	1.60	3.84**	1.42
F	**YVMV Diseases % parameters**			
1	30 DAS	72.87 (31.77)	102.69** (245.50)	62.26 (56.84)
2	45 DAS	49.01 (38.38)	4360.55** (2243.33)	50.71 (53.62)
3	60 DAS	181.02 (207.41)	4206.78** (2705.65)	132.18 (96.44)
4	75 DAS	46.14 (103.04)	4389.94** (3018.02)	21.61 (40.41)
5	90 DAS	5.11 (3.42)	4356.00** (3142.80)	7.00 (4.41)

* Significant at 5 %(p=0.05) ** Significant at 1 % (p=0.01) NS: Non significant
Figures in the parentheses indicate corresponding YVMV angular values

Similarly, the significant variations were observed in nodes plant^{-1}, ranging from 17.26 (2012/OKYVRES-3) to 22.20 (2012/OKYVRES-5) with an average nodes plant $^{-1}$ of 19.76. Interestingly, the nodes plant^{-1} in all the check varieties *viz;* Kashi Pragati (20.80), Pusa Sawani (21.13), Arka Anamika (21.20) and Arka Abhay (21.00) were *statistically at par* with the highest value of 2012/OKYVRES-5 (Table 4.2).

Table 4.2 Performance of okra genotypes on vegetative growth and flowering parameters

Sl. No.	Genotypes	Plant height (cm)	Nodes plant^{-1}	1st flowering node	Days to 1st flowering (Days)	Days to 50% flowering (Days)
1	2012\OKYVRES-1	95.00	17.46	6.28	37.00	41.66
2	2012\OKYVRES-2	120.83	19.60	6.70	38.00	41.33
3	2012\OKYVRES-3	89.57	17.26	5.91	37.66	41.00
4	2012\OKYVRES-4	104.60	18.53	5.19	32.33	39.33
5	2012\OKYVRES-5	57.27	22.20	4.66	40.00	42.66
6	2012\OKYVRES-6	89.13	18.40	5.76	31.33	36.66
7	VRO-6 (Kashi Pragati)(C)	93.90	20.80	6.33	35.33	41.00
8	PusaSawani (SC)	103.47	21.13	6.30	32.66	39.66
9	Arka Anamika (C)	114.43	21.20	6.40	38.33	41.66
10	Arka Abhay (C)	115.27	21.00	7.16	39.00	42.00
	Grand mean	**98.36**	**19.76**	**6.07**	**36.06**	**40.70**
	SE (m)±	4.48	0.81	0.43	1.31	0.58
	CD(P=0.05)	14.04	2.54	1.35	4.10	1.83
	CV	8.33	7.52	12.99	6.61	2.62

4.2.2 Flowering parameters

Node at which 1st flower appeared

The results data on node of 1st flowering in okra revealed significant variations among the different genotypes including the checks (Table 4.2). Significantly lowest node of 1st flowering was recorded in 2012/OKYVRES-5 (4.66) than rest of the genotypes including checks, except 2012/OKYVRES-3 (5.91), 2012/OKYVRES-4 (5.19) and 2012/OKYVRES-6 (5.76), where *statistical parity* were observed with lowest value.

Days to 1st flowering

Days taken to 1st flowering, the result revealed significant variations, ranging from 31.33 in 2012/OKYVRES-6 to 40.00 in 2012/OKYVRES-5. Significantly minimum of 31.33 days was recorded in 2012/OKYVRES-6 and was *stastically at par* with 2012/OKYVRES-4 (32.33), Pusa Sawani (32.66) and Kashi Pragati (35.33).

Days to 50% flowering

Significantly earliest time was taken for 50% flowering in 2012/OKYVRES-6 (36.66) than rest of the genotypes including check varieties. On the other hand, the 2012/OKYVRES-5 took significantly maximum time to attained 50% flowering (42.66) and was *statistically at par* with rest of the genotypes except 2012/OKYVRES-6 (Table 4.2).

4.2.3. Fruit yield attributing parameters

Fruits plant^{-1}

The results data on number of fruits plant^{-1} in okra revealed significant variations among the different genotypes including the checks (Table 4.3). The production of fruits plant^{-1} among the genotypes varied from 4.78 (2012/OKYVRES3) to 20.75 (2012/OKYVRES-5). Lower fruits plant^{-1} observed was primarily due to heavy infestation of YVMV during the cropping season under natural conditions. Significantly maximum fruits plant^{-1} of 20.75 was recorded in 2012/OKYVRES-5 than rest of the tested genotypes. Similarly, 2012/OKYVRES-3 recorded significantly lowest fruits plant^{-1} (4.78).

Fruit length (cm)

The results on fruit length was ranging from 9.93 (2012/OKYVRES-3) to 13.88 cm (2012/OKYVRES-5). However, *statistical parity* was observed with 2012/OKYVRES-1, 2012/OKYVRES-2, 2012/OKYVRES-6, Kashi Pragati, Arka Anamika and Arka Abhay (11.68-12.73).

Fruits girth (cm)

The results on fruit girth revealed non-significant variations among the genotypes, varied from 5.55 cm (Arka Anamika) to 6.96 cm (2012/OKYVRES-2).

Table 4.3. Performance of okra genotypes for fruit yield and yield attributing parameters

SL NO	Genotypes	Fruits Plant^{-1}	Fruit length (cm)	Fruit girth (cm)	Av. Fruit weight (g)	Fruits weight plant	Days taken for 1st harvesting	Days taken to final harvesting	Yield plot $^{-1}$(kg)	Yield (qha^{-1})	Number of ridges/fruit	Fruit Dry weight (g)
1	2012\OKYVRES-1	10.00	12.72	6.67	18.67	55.36	48.67	83.00	5.49	67.78	5.00	9.17
2	2012\OKYVRES-2	20.23	12.73	6.96	17.23	77.69	46.33	83.00	9.46	116.79	5.00	8.43
3	2012\OKYVRES-3	4.78	9.93	6.85	16.20	22.25	45.00	74.00	2.15	26.54	5.00	7.90
4	2012\OKYVRES-4	13.93	11.13	5.94	16.14	65.30	45.00	79.33	6.90	85.19	5.00	7.90
5	2012\OKYVRES-5	20.75	13.88	6.07	23.20	141.59	54.67	80.00	11.50	141.98	7.00	10.80
6	2012\OKYVRES-6	12.68	11.68	5.69	16.53	61.97	46.33	78.00	6.33	78.15	5.00	7.97
7	VRO-6 (Kashi Pragati)(C)	11.13	11.93	6.04	17.85	52.49	45.00	78.67	5.16	63.70	5.00	8.70
8	PusaSawani (SC)	11.44	10.77	6.57	15.83	53.06	45.00	80.00	4.86	60.00	5.00	7.37
9	Arka Anamika (C)	10.38	12.07	5.55	14.97	46.18	47.33	80.00	4.73	58.40	5.00	7.67
10	Arka Abhay (C)	8.00	11.94	5.91	14.63	37.52	50.67	80.00	3.67	45.31	5.00	7.20
	Grand mean	**12.33**	**11.88**	**6.22**	**17.12**	**61.45**	**47.40**	**79.60**	**6.03**	**74.38**	**5.20**	**8.31**
	SE (m)±	0.91	0.64	0.35	1.23	4.63	1.39	1.24	0.40	4.99	0.09	0.54
	CD(P=0.05)	2.84	2.38	1.03	3.85	14.71	4.35	9.68	1.27	15.68	0.28	1.69
	CV	13.44	11.70	9.64	13.11	14.00	5.32	7.10	12.28	12.28	13.17	11.84

Average fruit weight (g)

The results on average fruit weight varied significantly among the genotypes, ranging from 14.63 g (Arka Abhay) to 23.20 g (2012/OKYVRES-5) with an average value of 17.12g, irrespective of genotypes (Table 4.3). The genotype, 2012/OKYVRES-5 recorded significantly heaviest fruit of 23.20g than rest of the genotypes. The result also indicated that advanced genotype recorded heavy fruits of 16.14g to 23.20 g than check varieties (14.63 g to 15.83g) with an average of 15.14g except the check variety, Kashi Pragati (17.85g) , indicating the better fruits by the tested genotype than the check varieties.

Fruit weight plant^{-1} (g)

The average fruit weight harvested plant^{-1} over the period indicated significant variations among the tested genotypes including checks which varied from 22.25g (2012/OKYVRES-3) to 141.59g (2012/OKYVRES-5) (Table 4.3). The genotype, 2012/OKYVRES-5 recorded significantly highest fruit weight plant $^{-1}$ (141.59g) than rest of the genotypes. The result also indicated that most of the genotypes recorded better fruit weight plant^{-1} (55.36g to 141.59g) than all checks (37.52g to 53.06g), except the line, 2012/OKYVRES-2 (22.25g).

Days taken for 1st harvesting

Significant variations was recorded for days taken to 1st harvesting among the tested genotypes (Table 4.3). Significantly minimum of 45.00 days was recorded in genotype, 2012/OKYVRES-3 and 2012/OKYVRES-4 including the check variety, Pusa Sawani and Kashi Pragati .On the other hand, the genotype, 2012/OKYVRES-5 recorded maximum time of 54.67 days to 1st harvesting than rest of the tested genotypes. However, the results showed *statistically parity* among all the genotypes except 2012/OKYVRES-5.

Days taken to final harvesting

The results on days taken from sowing to final harvesting of fruits in okra revealed variations among all the tested genotypes, however, the variations were non-significant statistically (Table no. 4.3). Among them, 2012/OKYVRES-3 recorded the lowest days for final harvesting of 74.00 days while that of 2012/OKYVRES-1 and

2012/OKYVRES-2 with maximum days of 83.00 for final harvesting. The study also indicated that due to severe incidence of YVMV, the crop duration was reduced drastically with a range of 74.00 to 83.00 days for marketable fruit yield.

Number of ridges fruit^{-1}

The results on ridges fruit^{-1} revealed non-significant variations among the genotypes. All the tested genotypes showing 5.00 ridges fruit^{-1} except 2012\OKYVRES-5 (7.00) (Table 4.3).

Dry weight of average 10 fruits

The results on dry weight of fruits showing significant variations ranging from 7.20g (Arka Abhay) to 10.80g (2012\OKYVRES-5). The genotype (2012\OKYVRES-5) showing highest dry weight *statistically at par* were observed in 2012\OKYVRES-1 (9.17g) and 2012\OKYVRES-2 (8.43g).

4.2.4 Incidence of YVMV at different stages of crop growth

The results on incidence of YVMV disease in okra at different stages of crop growth revealed significant variations among the different genotypes including check varieties (Table 4.4). The results revealed significantly lowest incidence of YVMV (0.00 %) in genotype, 2012/ OKYVRES-1 than rest of the genotypes at all stages of crop growth. However, at 30 DAS, *statistical parity* were observed with genotypes, 2012/ OKYVRES-2, 2012/ OKYVRES-5 and check variety, Arka Anamika (0.00 to 5.23%). Similarly, at 45 DAS, no significant variations was observed between the two tested genotype, 2012/ OKYVRES-1 and 2012/OKYVRES-2 as compared to rest of the genotypes. At 30 DAS of crop growth stage, significantly highest YVMV incidence was recorded with the check variety, Arka Abhay (14.26%) closely followed by 2012/ OKYVRES-6 (12.94%), 2012/ OKYVRES-3 (12.66%), 2012/ OKYVRES-4 (8.77%) and check variety, Kashi Pragati (8.26%) and Pusa Sawani (13.00%), where *statistical parity* were observed. Similarly at 45vDAS the susceptible check Kashi Pragati recorded significantly highest incidence of (88.36%) and *statistically at par* with 2012/OKYVRES-3, 2012/OKYVRES-4, and Pusa Sawani (79.98 to 84.19%). At 60 DAS, significantly 98.64% YVMV incidence was recorded in Pusa Sawani and *statistically at par* with 2012/OKYVRES-3, 2012/OKYVRES-4, 2012/OKYVRES-6, Kashi Pragati and Arka Abhay

(94.41 to 97.94%). Similar trend was recorded at 75 DAS with higher % towards the flag end of the commercial cultivation of okra, at 90 DAS , the susceptible lines along with the check varieties identified were 2012/ OKYVRES-3, 2012/ OKYVRES-4, 2012/ OKYVRES-6, Kashi Pragati, Pusa Sawani, Arka Anamika and Arka Abhaya than rest of the genotypes. The results also revealed that the genotypes, 2012/ OKYVRES-1, 2012/ OKYVRES-2 and 2012/ OKYVRES-5 showed significantly better resistance and or tolerance to YVMV incidence as compared to other genotypes including the other check varieties.

Table 4.4 Performance of okra genotypes against incidence of YVMV (%)

Sl. No.	Genotypes	Days after incidence of YVMV				
		30	45	60	75	90
1	2012\OKYVRES-1	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
2	2012\OKYVRES-2	0.00 (0.00)	3.98 (9.34)	11.08 (19.24)	15.58 (23.16)	20.30 (26.82)
3	2012\OKYVRES-3	12.66 (20.81)	80.18 (64.73)	97.94 (83.39)	100.00 (90.02)	100.00 (90.02)
4	2012\OKYVRES-4	8.77 (16.45)	79.98 (65.75)	97.52 (82.84)	98.77 (86.32)	96.10 (86.79)
5	2012\OKYVRES-5	0.00 (0.00)	8.79 (17.02)	75.53 (65.74)	88.64 (74.16)	100.00 (90.02)
6	2012\OKYVRES-6	12.94 (20.15)	87.66 (69.61)	96.79 (81.61)	98.72 (84.70)	100.00 (90.02)
7	VRO-6 (Kashi Pragati) (C)	8.26 (15.80)	88.36 (70.48)	95.22 (77.75)	99.28 (87.19)	100.00 (90.02)
8	PusaSawani (SC)	13.00 (20.75)	84.19 (66.72)	98.64 (86.13)	100.00 (90.02)	100.00 (90.02)
9	Arka Anamika (C)	5.23 (10.76)	33.80 (35.52)	66.19 (55.00)	93.50 (78.13)	100.00 (90.02)
10	Arka Abhay (C)	14.26 (19.04)	56.58 (48.81)	94.41 (78.89)	99.29 (87.22)	100.00 (90.02)
	Grand mean	7.51 (12.38)	52.35 (44.80)	73.33 (63.06)	79.38 (70.09)	81.64 (74.37)
	SE (m)±	4.35	4.23	5.67	3.67	1.87
	CD(P=0.05)	12.93	12.56	16.84	10.90	4.43
	CV	60.92	16.35	15.57	9.07	3.50

*Figures in the parenthesis indicates corresponding angular values

Fig. 4.1 Overall field view of experimental plot

Fig.4.2 The best genotype with resistance to YVMV for all stages of crop growth

Fig. 4.3 Promising genotype with moderate resistance to YVMV (a) 2012/OKYVRES-2 and (b) 2012/OKYVRES-5

Fig. 4.4 The susceptible genotype to YVMV

Fig. 4.5. The susceptible genotypes to YVMV

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Fig.4.6 The Promising genotypes with good quality fruits except check variety Pusa Sawani

4.2.5 Fruit yield parameters

Fruit yield plot^{-1} (kg)

The results on fruit yield revealed that significant variations among different genotypes including the check varieties (Table 4.3). The fruit yield plot^{-1} (kg) in okra varied from 2.15 (2012/OKYVRES-3) to 11.50 (2012/OKYVRES-5) with an average value of 6.03 kg. Significantly highest fruit yield of 11.50 kg plot^{-1} was recorded in, 2012/OKYVRES-5 than rest of the tested genotypes. The study also revealed that, invariably the tested lines recorded relatively higher fruit yield plot^{-1} (5.49 kg to 11.50 kg, average of 7.94 kg) over the check varieties (3.67 kg to 5.16 kg, average of 4.61kg), except the tested line, 2012/OKYVRES -3 (2.15kg).

Fruit yield (q ha^{-1})

The results presented on total fruit yield (q ha^{-1}) revealed significant variations among different tested genotypes including the check varieties (Table 4.3). The total fruit yield (q ha^{-1}) in okra varied from 26.54 (2012/OKYVRES-3) to 141.98 (2012/OKYVRES-5) with an average value of 74.38 q ha^{-1}. Significantly highest total fruit yield of 141.98 q ha^{-1} was recorded in, 2012/OKYVRES -5 than rest of the tested genotypes. Invariably, the tested lines recorded relatively higher total fruit yield (67.78 qha^{-1} to 141.98 qha^{-1}, average of 97.92 qha^{-1}) over the check varieties (45.31 qha^{-1} to 63.70 qha^{-1}, average of 56.85 qha^{-1}), except the tested line, 2012/OKYVRES-3 (26.54 qha^{-1}). These results clearly demonstrated the superiority of advanced breeding lines over the four check varieties with respect to total fruit yield.

4.2.6 Fruit quality parameters

Fruit sugar content (%)

The results on reducing, non-reducing and total sugar content of fresh fruits of different tested genotypes revealed significant variations among them (Table no. 4.5). The reducing sugar content of fruits varied from 2.06 %, (Pusa Sawani) to 3.54 %, (2012/OKYVRES-1) with an average value of 2.76 %. However, significantly maximum reducing sugar content was recorded in 2012/OKYVRES-1 than rest of the genotypes. On the other hand, the non-reducing sugar content of fruits varied significantly from 0.33% in (2012/OKYVRES-2) to 1.21% (2012/OKYVRES-6) with a mean value of 0.79%.

Significantly highest total sugar of fruits was recorded in the 2012/OKYVRES-6 (4.49%), closely followed by 2012/OKVYRES-1 (4.46%). Similarly, significantly lowest total sugar was observed Kashi Pragati (2.62%).

Fruit hardness

A perusal of result presented in (Table 4.5) indicated significant variations for the hardness of fruits measured by the penetrometer, varied from 81.33 mm (Arka Abhay) to 84.67 mm (2012/OKYVRES-5). Significantly minimum hardness was recorded in Arka Abhay (81.33 mm) than rest of the genotypes. However, *statistical parity* was observed with 2012/OKYVRES-1 (81.67 mm), 2012/OKYVRES-6 (83.00 mm) and the check variety, Pusa Sawani (83.00 mm).

Table 4.5 Performance of okra genotypes for fruit quality

Sl. No.	Genotypes	% of reducing sugar	% of non-reducing sugar	Total sugar (%)	Protein (%)	Hardness by Penitrometer (mm)
1	2012\OKYVRES-1	3.54	0.92	4.46	7.09	81.67
2	2012\OKYVRES-2	3.03	0.33	3.36	9.34	84.00
3	2012\OKYVRES-3	2.46	1.02	3.48	16.34	84.00
4	2012\OKYVRES-4	2.75	1.03	3.79	12.79	84.00
5	2012\OKYVRES-5	2.78	0.55	3.33	8.75	84.67
6	2012\OKYVRES-6	3.28	1.21	4.49	10.56	83.00
7	VRO-6 (Kashi Pragati) (C)	2.28	0.34	2.62	12.21	84.00
8	PusaSawani (SC)	2.06	1.02	3.07	16.21	83.00
9	Arka Anamika (C)	2.83	0.72	3.56	13.67	84.33
10	Arka Abhay (C)	2.64	0.79	3.41	14.20	81.33
	Grand mean	2.76	0.79	3.56	12.11	83.40
	SE (m)±	0.02	0.03	0.04	0.47	0.65
	CD(P=0.05)	0.08	0.10	0.12	1.47	2.04
	CV	1.64	7.10	1.97	7.08	1.42

Fruit crude protein content (%)

The results data on fruit crude protein content showed significant variations among the tested genotypes (Table 4.5), which varied from 7.09 % (2012/OKYVRES-1) to 16.34% (2012/OKYVRES-3). Significantly highest crude protein was recorded in 2012/OKYVRES-3 (16.34%) followed by PusaSawani (16.21%) as compared to rest of genotypes tested. Invariably, the check varieties recorded relatively higher protein content ranging from 12.21 to 16.21%, average of 14.07% as compared to the tested genotypes (7.09 % to 12.79%, average being 9.71%), except the highest value of 16.34% recorded in line, 2012/OKYVRES-3.

4.3 Coefficient of variance (C.V.)

The coefficients of variance with respect to 26 different characters are presented in Table 4.6, which ranged from 1.43% (hardness of fruits) to 84.58% (incidence of YVMV at 30 DAS). The C.V. of present results indicated that the low variability of <5 % for parameters such as hardness of fruits (1.43), reducing sugar (1.64), total sugar (1.98), days to 50% flowering (2.62) and incidence of YVMV at 90 DAS (3.23).

Similarly, moderate variability (CV from 5-10%) observed for parameters like days to first harvesting (5.32), incidence of YVMV 75 DAS (5.83), days to first flowering (6.61), fruit crude protein content (7.08), crop duration (7.09), non-reducing sugar (7.10), nodes plant^{-1} (7.52), plant height (8.33) and fruit girth (9.64).

High variability (CV of > 10%) was observed for fruit length (11.70), fruit dry weight (11.84), fruit yield (q ha^{-1}) (12.28), fruit yield (kg plot^{-1}) (12.28), node at which 1st flower appeared (12.99), fruit weight (13.11), ridges fruit^{-1} (13.17), fruits plant $^{-1}$(13.44), incidence of YVMV at 30,45 & 60 DAS (84.58,13.50 & 15.69) &fruit weight plant^{-1} (14.12).

Table 4.6 Estimation of Coefficient of variance (C.V.) of different parameters in okra

Sl. No	Characters	Range	General mean	CV	GV	PV
1	Plant height at final harvesting stage(cm)	57.28-120.83	98.36	8.33	310.63	377.58
2	Number of nodes plant^{-1}	17.27-22.20	19.76	7.52	2.31	4.51
3	Node at which first flower appeared	4.67-7.17	6.07	12.99	0.32	0.94
4	Days to first flowering	31.33-40.00	36.17	6.61	7.51	13.22
5	Days to 50 % flowering	36.67-42.67	40.70	2.62	2.64	3.78
6	Number of fruits plant^{-1}	4.78-20.75	12.33	13.44	23.87	26.62
7	Fruit length (cm)	9.93-13.89	11.88	11.70	0.78	2.14
8	Fruit girth (cm)	5.55-6.96	6.22	9.64	0.19	0.35
9	Average fruit weight (g)(average 10 fruits /entry)	14.63-23.20	17.12	13.11	4.38	9.42
10	Average fruit weight (g)plant^{-1}	22.25-141.49	61.42	14.12	1003.80	1075.52
11	Number of ridges fruit^{-1}	5.00-7.00	5.20	13.17	0.39	0.42
12	Days to first harvesting	45.00-54.67	47.40	5.32	7.20	13.63
13	Fruit yield kg plot^{-1}	2.16-11.50	6.03	12.28	7.29	7.836
14	Fruit yield qha^{-1}	26.54-141.98	74.38	12.28	1111.48	1194.59
15	Dry weight (g)	7.20-10.80	8.31	11.84	0.80	1.77
16	Crop duration from sowing to last harvesting	74.00-83.00	79.60	7.09	4.78	9.97
17	Crude protein content of fruits	7.09 - 16.34	12.12	7.08	9.60	10.34
18	Reducing sugar	2.06 – 3.54	2.77	1.64	0.20	0.20
19	Non-Reducing sugar	0.33 – 1.21	0.79	7.10	0.09	0.09
20	Total sugar	2.56-4.49	3.55	1.98	0.34	0.35
21	Measuring of hardness	81.33 -84.67	83.40	1.43	0.81	2.22
22	YVMV incidence 30 DAS	0.00-14.26 (0.00-20.81)	7.51 (12.38)	84.58 (60.92)	20.65 (62.89)	48.25 (119.72)
23	YVMV incidence45 DAS	0.00-88.36 (0.00-70.49)	52.35 (44.80)	13.50 (16.35)	1436.61 (729.90)	1487.32 (783.52)
24	YVMV incidence 60 DAS	0.00-98.64 (0.00-86.13)	73.33 (63.06)	15.69 (15.57)	1358.19 (869.74)	1490.38 (966.18)
25	YVMV incidence 75 DAS	0.00-100.00 (0.00-90.02)	79.38 (70.09)	5.83 (9.07)	1456.11 (992.54)	1477.72 (1032.94)
26	YVMV incidence 90 DAS	0.00-100.00 (0.00-90.02)	81.64 (74.37)	3.23 (3.50)	1449.668 (1046.13)	1456.67 (1050.54)

Figures in the parentheses indicate corresponding angular values

4.4 Estimation of genetic parameters

The results on genetic parameters indicated wide variations among the 26 parameters, varied from 0.00% (incidence of YVMV at 30,45,60,75 and 90 DAS) to 100% (incidence of YVMV at 75 and 90 DAS) (Table 4.6). Similarly, the general mean varied widely from minimum of 0.79% with fruit non-reducing sugar to maximum of 98.36 cm in plant height.

The genotypic variance (GV) ranged from 0.09 for fruit non-reducing sugar content to 1456.11 for incidence of YVMV at 75DAS. Similarly, the phenotypic variance (PV) ranged from 0.09 for fruit non reducing sugar to 1490.38 for incidence of YVMV at 60 DAS. In general, all the 26 traits studied exhibited almost parallel values between GV and PV showing lower values in GV than PV.

A perusal of result data (Table 4.7) revealed that the phenotypic coefficient variance (PCV) was higher than genotypic coefficient of variance (GCV) for all the characters, clearly demonstrating the influence of environmental factors for expression of the genotypes of the traits, of course they varied widely in different parameters. The GCV varied from 1.08% (fruit hardness) to 71.87% (incidence of YVMV at 45 DAS). On the other hand, PCV varied from 1.79% (fruit hardness) to 75.74% (incidence of YVMV at 30 DAS). Relatively higher PCV was observed fruits plant^{-1} (41.84%), fruit weight plant^{-1} (53.55%), fruit yield plot^{-1} (kg) (46.46%), fruit yield(q ha^{-1}) (46.47%) as well as incidence of YVMV at 30,45,60,75 and 90 DAS(46.59 to 75.74%). Similarly, moderate value of PCV was recorded for plant height (19.76%), nodes plant^{-1} (10.75%), node at which 1st flower appeared (15.98%), days to 1st flowering (10.06%), fruit length(12.3%), fruit weight (17.92%), ridges fruit^{-1} (12.44%), fruit dry weight (15.99%), fruit reducing sugar (16.13%), non-reducing sugar (38.91%), total sugar(16.58%) and crude protein content (26.54%). The other traits such as days to 50% flowering (4.78%),fruit girth (9.54%), days to first harvest (7.75%), crop duration (3.97%) and hardness of fruits (1.79%) exhibited lower PCV. More are less similar trend was also observed for all the 26 traits for GCV.

Table 4.7 Estimation of genetic parameters, heritability, genetic advance in okra

Sl. No.	Characters	GCV (%)	PCV (%)	h2 (%)	GA	GAM (%)
1	Plant height at final harvesting stage (cm)	17.92	19.76	82.23	32.93	33.49
2	Number of nodes plant^{-1}	7.69	10.75	51.22	2.24	11.34
3	Node at which first flower appeared	9.30	15.98	33.86	0.68	11.14
4	Days to first flowering	7.58	10.06	56.76	4.25	11.76
5	Days to 50 % flowering	4.00	4.78	69.93	2.80	6.88
6	Number of fruits plant^{-1}	39.62	41.84	89.68	9.53	77.29
7	Fruit length (cm)	7.44	12.33	36.40	1.09	9.24
8	Fruit girth (cm)	7.07	9.54	55.04	0.67	10.81
9	Average fruit weight (g)(avg. 10 fruits	12.22	17.92	46.49	2.94	17.16
10	Average fruit weight (g)plant^{-1}	51.73	53.55	93.32	63.05	102.96
11	Number of ridges fruit^{-1}	12.02	12.44	93.49	1.25	23.95
12	Days to first harvesting	5.63	7.75	52.81	4.02	8.43
13	Fruit yield kg plot^{-1}	44.82	46.46	93.07	5.37	89.08
14	Fruit yield ha^{-1}	44.82	46.47	93.05	66.25	89.06
15	Dry weight of average 10 fruits	10.76	15.99	45.24	1.24	14.90
16	Crop duration from sowing to last harvesting	2.75	3.97	47.99	3.12	3.92
17	Crude protein content of fruits	25.57	26.54	92.87	6.15	50.77
18	Reducing sugar	16.05	16.13	98.97	0.91	32.88
19	Non-reducing sugar	38.26	38.91	96.67	0.61	77.50
20	Total sugar	16.46	16.58	98.58	1.20	33.66
21	Measuring of hardness	1.08	1.79	36.33	1.12	1.34
22	YVMV incidence 30 DAS	13.48 (64.08)	75.74 (88.41)	17.79 (52.53)	3.19 (11.84)	42.47 (95.66)
23	YVMV incidence 45 DAS	71.87 (60.31)	73.12 (62.48)	96.59 (93.16)	76.74 (53.72)	145.50 (119.91)
24	YVMV incidence 60 DAS	50.528 (46.77)	52.68 (49.30)	91.13 (90.02)	72.47 (57.64)	98.89 (91.41)
25	YVMV incidence 75 DAS	47.858 (44.95)	48.21 (45.85)	98.54 (96.09)	78.03 (63.62)	97.87 (90.71)
26	YVMV incidence 90 DAS	46.479 (43.38)	46.59 (43.47)	99.51 (99.58)	78.24 (66.48)	95.52 (89.17)

Figures in the parentheses indicate corresponding angular values

The result also indicated that difference between PCV and GCV was relatively higher for incidence of YVMV at 30 DAS (461.87%), node at which 1st flower appeared (72.01%), fruit length(65.73%),fruit hardness (62.73%),fruit dry weight (48.61%), fruit weight (46.64%), crop duration (44.36%) etc. On the other hand, the parameters such as plant height (10.27%), fruits plant^{-1} (5.60%), fruit weight plant^{-1} (3.52%), ridges fruit^{-1} (3.68%), fruit crude protein (3.79%), reducing sugar (0.50%), non-reducing sugar (1.73%) and total sugar (0.73%) showing the minimum difference.

The result of heritability (broad sense) indicated wide variations which varied from 33.86% for node at which 1st flower appeared to maximum 99.51%for incidence of YVMV at 90 DAS. High heritability of above 60% were observed in traits like days to 50% flowering (69.93%), plant height (82.23%), fruits plant^{-1} (89.68%),incidence of YVMV at 60 DAS (91.13%),fruit crude protein (92.87%),fruit yield qha^{-1} (93.05%),fruit yield (kg plot)$^{-1}$ (93.07%), fruit weight plant^{-1} (93.32%), ridges fruit^{-1} (93.49%), incidence of YVMV at 45 DAS (96.59%), fruit non-reducing sugar (96.67%),incidence of YVMV at 75 DAS (98.54%), total sugar (98.58%), fruit reducing sugar (98.97%),as well as incidence of YVMV at 90DAS (99.51%). Similarly, rest of the other traits recorded moderate values of heritability of above 30% ranging from 33.86% to node at which 1st flower appeared to 56.76% for days to 1st flowering except incidence of YVMV at 30 DAS with least heritability of only 17.79%.

The genetic advance (GA) varied from 0.61(fruit non-reducing sugar) to 78.24 (incidence of YVMV at 90 DAS). High GA was observed for incidence of YVMV at 60 DAS to 90 DAS (72.47 to 78.24), fruit plant^{-1} (63.05) and fruit yield (qha^{-1}) (66.25) as well as plant height (32.93). The other traits exhibits relatively lower GA of above 1.0, ranging from 1.09 (fruit length) to 9.53 (fruits plant^{-1}). The lowest GA was observed for both non-reducing (0.61) and reducing sugar (0.91) and fruit girth (0.67).

The predicted GA expressed as % of population mean ranged from 1.34% (fruit hardness) to 145.50% (incidence of YVMV at 45 DAS). High expected GAM (%) by selection above 60% was observed in the traits for incidence of YVMV at 45,60,75,and 90 DAS (95.52 to 145.50%), fruit non reducing sugar (77.50%), fruits

plant^{-1} (77.29%), fruit yield (qha^{-1}) (89.06%), fruit yield(kg plot^{-1}) (89.08), and fruit weight plant^{-1} (102.96%). Other traits exhibited moderate GAM (%) were ridges fruit^{-1} (23.95%), fruit reducing sugar (32.88%), plant height (33.49%) and fruit total sugar (33.66%), incidence of YVMV at 30 DAS (42.47%), and fruit crude protein (50.77%).

4.5 Phenotypic correlation

Results on phenotypic correlation (Table 4.8) revealed that the plant height was positively and significantly correlated with 1st flowering node (0.645), days to 1st flowering (0.645). On the contrary, it was negatively and significantly correlated with fruit weight (-0.496), fruit weight plant^{-1} (-0.555), ridges fruit^{-1} (-0.714), days to 1st harvesting (-0.402), fruit dry weight (-0.457). Similarly, nodes plant^{-1} was positively and significantly correlated with fruit weight plant^{-1} (0.380), ridges fruit^{-1} (0.429), and days to 1st harvesting (0.471). Negatively significant correlation with fruit non-reducing, reducing and total sugar (-0.430, -0.385 and -0.540, respectively).

First flowering node was negative & significantly correlated with fruit weight (-0.402), fruit weight plant^{-1}(-0.533), ridges fruit^{-1} (-0.456), fruit yield (-0.364 kg plot^{-1} and -0.364 qha^{-1}) & dry weight (-0.405). Similarly, days to 1st flowering was positively and significantly correlated with days to 50 % flowering (0.851), fruit length (0.439), ridges fruit^{-1} (0.392), fruit dry weight (0.406). The negatively significant association with non-reducing sugar (-0.445), incidence of YVMV 30 and 45 DAS (-0.382 and -0.577). Days to 50 % flowering was positively and significantly correlated with fruit length (0.366), ridges fruit^{-1} (0.378), and fruit dry weight (0.411). The negatively significant association with non reducing sugar (-0.566), incidence of YVMV 30, 45 and 60 DAS (-0.409,-0.572 and -0.378), respectively.

Fruits plant^{-1} was positively and significantly correlated with fruit length (0.565), fruit weight (0.558), fruit weight plant^{-1}(0.866), ridges fruit^{-1} (0.557), fruit yield (0.943 for kg plot^{-1} and 0.943 for qha^{-1}), crop duration (0.376) & fruit dry weight (0.533). The negatively significant association was recorded with non-reducing sugar (-0.466), fruit crude protein (-0.584), incidence of YVMV 30 & 45 DAS (-0.486 and -0.426).

Fruit length was positively and significantly correlated with fruit weight (0.651),fruit weight plant^{-1} (0.632),ridges fruit^{-1} (0.455), fruit yield (0.602 for kg plot^{-1} and 0.602 qha^{-1}), days to 1st harvesting (0.399), crop duration (0.485), reducing sugar (0.361), fruit dry weight (0.650) and incidence of YVMV 75 DAS (0.402). The negatively significant association with non-reducing sugar (0.397), fruit crude protein (-0.621), incidence of YVMV 30, 45 & 60 DAS (0.569,-0.577 and -0.431), respectively. The fruit girth negatively significant association with incidence of YVMV 60, 75 and DAS (-0.373, -0.426 and 0.477).

Fruit weight was positively and significantly correlated with fruit weight plant^{-1} (0.731), ridges fruit^{-1} (0.728), fruit yield kg plot^{-1} (0.604), fruit yield qha^{-1} (0.604), days to 1st harvesting (0.482)& fruit dry weight (0.687). The negatively significant correlation with fruit crude protein (-0.599), incidence of YVMV 30 & 45 DAS (-0.486 and -0.440). Similarly, fruit weight plant^{-1} was positively and significantly correlated with ridges fruit^{-1} (0.847), fruit yield kg plot^{-1} (0.905), fruit yield qha^{-1} (0.905), crop duration (0.376) & fruit dry weight (0.533). The negatively significant correlation with non-reducing sugar (-0.466), fruit crude protein (-0.584) &incidence of YVMV 30 & 45 DAS (-0.486 and -0.426).

Ridges fruit^{-1} was positively and significantly correlated with fruit yield (kg plot^{-1}) (0.676), fruit yield (qha^{-1}) (0.677), days to 1st harvesting (0.613), fruit dry weight (0.681). The negatively significant correlation with fruit crude protein (-0.369) and incidence of YVMV 30 DAS (-0.399).

Fruit yield (kg plot^{-1}) was positively and significantly correlated with fruit yield (qha^{-1}) (1.000), days to 1st harvesting (0.392), fruit dry weight (0.584). The negatively significant correlation with non-reducing sugar (-0.428), fruit crude protein (-0.662), incidence of YVMV 30 & 45 DAS (-0.531 & -0.490). Similarly, fruit yield (qha^{-1}) was positively and significantly correlated with days to 1st harvesting (0.392), fruit dry weight (0.585). The negatively significant correlation with fruit non-reducing sugar (-0.427), fruit crude protein (-0.661) and incidence of YVMV 30 & 45 DAS (-0.530 and -0.490).

Table 4.8. Phenotypic correlation co-efficient between all pairs of 26 quantitative characters in okra germplasm

Characters		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26
1	rp	1.000	-0.093	0.645**	0.645**	-0.006	-0.198	-0.123	0.045	-0.496**	-0.555**	-0.714**	-0.333	-0.334	-0.402*	0.253	-0.053	-0.017	-0.033	-0.457**	0.280	-0.254	0.112	0.022	-0.175	-0.135	-0.188
2	rp		1.000	-0.025	0.254	0.245	0.310	0.278	-0.242	0.127	0.380*	0.429*	0.259	0.259	0.471**	0.285	-0.430*	-0.385*	-0.540**	0.078	0.070	0.317	-0.046	-0.063	0.163	0.236	0.353
3	rp			1.000	0.168	0.226	-0.337	-0.168	-0.004	-0.402*	-0.533**	-0.456*	-0.364*	-0.364*	-0.121	0.192	-0.165	-0.034	-0.099	-0.405*	0.114	-0.356	0.030	-0.064	-0.196	-0.156	-0.185
4	rp				1.000	0.851*	0.075	0.439*	0.175	0.357	0.200	0.392*	0.086	0.086	0.357	0.125	-0.445*	0.063	-0.187	0.406*	-0.183	-0.036	-0.382*	-0.577**	-0.348	-0.236	-0.154
5	rp					1.000	0.091	0.366*	0.154	0.358	0.173	0.378*	0.133	0.133	0.332	0.178	-0.566**	-0.082	-0.353	0.411*	-0.143	0.028	-0.409*	-0.572*	-0.378*	-0.273	-0.217
6	rp						1.000	0.565**	0.107	0.558**	0.866**	0.557**	0.943**	0.943**	0.249	0.376*	-0.466**	0.220	-0.073	0.533**	-0.584**	0.321	-0.486**	-0.426*	-0.271	-0.281	-0.189
7	rp							1.000	-0.065	0.651**	0.632**	0.455*	0.602**	0.602**	0.399*	0.485**	-0.397*	0.361*	0.069	0.650**	-0.621**	0.073	-0.569**	-0.577**	-0.431*	0.402*	-0.302
8	rp								1.000	0.226	0.003	-0.063	-0.007	-0.007	-0.245	-0.091	-0.097	-0.041	-0.084	0.183	-0.085	-0.055	-0.097	-0.237	-0.373*	-0.426*	-0.477**
9	rp									1.000	0.731**	0.728**	0.604**	0.604**	0.482**	0.266	-0.338	0.187	-0.032	0.687**	-0.599**	0.112	-0.486**	-0.440*	-0.177	-0.172	-0.051
10	rp										1.000	0.847**	0.905**	0.905**	0.249	0.376*	-0.466**	0.220	-0.073	0.533**	-0.584**	0.304	-0.486**	-0.426*	-0.271	-0.281	-0.189
11	rp											1.000	0.676**	0.677	0.613**	0.012	-0.270	0.010	-0.129	0.681**	-0.369*	0.284	-0.399*	0.342	-0.010	0.022	0.164
12	rp												1.000	1.000**	0.392*	0.353	-0.428*	0.301	0.009	0.584**	-0.662**	0.309	-0.531**	-0.490**	0.297	-0.315	-0.208
13	rp													1.000	0.392*	0.352	-0.427*	0.301	0.009	0.585**	-0.661**	0.309	-0.530**	-0.490**	0.297	-0.315	-0.208
14	rp														1.000	0.308	-0.202	0.135	0.004	0.216	-0.275	-0.055	-0.291	-0.433*	-0.025	-0.053	-0.004
15	rp															1.000	-0.317	0.361*	0.109	0.097	-0.474**	-0.104	-0.436*	-0.452*	-0.343	-0.313	-0.219
16	rp																1.000	0.138	0.643**	-0.300	0.297	-0.301	0.445*	0.403*	0.307	0.239	0.177
17	rp																	1.000	0.844**	0.243	-0.760**	-0.218	-0.448*	-0.593**	-0.661**	0.690**	-0.659**
18	rp																		1.000	0.028	-0.423*	-0.327	-0.116	-0.249	-0.346	-0.403*	-0.413*
19	rp																			1.000	-0.561**	0.139	-0.436*	-0.452*	-0.373*	-0.313	-0.219
20	rp																				1.000	0.086	0.678**	0.701**	0.695**	0.725**	0.660**
21	rp																					1.000	-0.098	0.036	0.158	0.218	0.262
22	rp																						1.000	0.757**	0.645**	0.661**	0.573**
23	rp																							1.000	0.856**	0.825**	0.749**
24	rp																								1.000	0.968**	0.912**
25	rp																									1.000	0.972**
26	rp																										1.000

*** and ** indicate significant at 5 and 1 per cent probability level, respectively.**

1. Plant Height at Final harvesting 2. First Flowering Node 3.First flowering node 4. Days to first flowering 5.Days to 50% Flowering 6. Number of fruits per plant
7. Fruit length 8. Fruit girth 9. Average fruit weight (g) (average 10 fruits /entry) 10. Average fruit weight (g)/plant 11. Number of ridges/fruit
12. Fruit yield kg/plot 13. Fruit yield q/ha 14. Days to first harvesting 15. Crop duration from sowing to last harvesting 16. Non-reducing sugar
17. Reducing sugar 18. Total sugar 19. Dry weight of average 10 fruits 20. Crude protein content of fruits 21. Hardness of fruits 22. Incidence of YVMV 30 DAS (ASIN)
23. Incidence of YVMV 45 DAS (ASIN) 24. Incidence of YVMV 60 DAS (ASIN) 25. Incidence of YVMV 75 DAS (ASIN) 26. Incidence of YVMV 90 DAS. (ASIN)

Days to 1st harvesting was negatively significant correlation with incidence of YVMV 45 DAS (-0.433). Crop duration was positively and significantly correlated with fruit reducing sugar (0.361). The negatively significant correlation with fruit crude protein (-0.474), incidence of YVMV 30 & 45 DAS (-0.436 & -0.452). Non-reducing sugar was positively and significantly correlated with total sugar (0.643), incidence of YVMV 30 & 45 DAS (0.445 & 0.403). Reducing sugar was positively and significantly correlated with total sugar (0.844), incidence of YVMV 75 DAS (0.690). The negatively significant correlation with fruit crude protein (-0.760), incidence of YVMV 30, 45, 60 & 90 DAS (-0.448,-0.593,-0.661 &-0.659), respectively. Total sugar of fruits was negatively significant correlation with fruit crude protein (-0.423) and incidence of YVMV 75 & 90 DAS (-0.403 & -0.413). Dry weight of was negatively significantly correlated with fruit crude protein of fruits (-0.561) and incidence of YVMV 30, 45 and 60 DAS (-0.436,-0.452 and -0.373).

Fruit crude protein was positively and significantly correlated with incidence of YVMV 30, 45, 60, 75 & 90 DAS (0.678, 0701, 0.695, 0.725 & 0.660) respectively.

Incidence of YVMV 30 DAS was positively and significantly correlated with incidence of YVMV 45, 60, 75 & 90 DAS (0.757, 0.645, 0.661 & 0.573) respectively. Similarly, incidence of YVMV 45 DAS was positively and significantly correlated with 60, 75 & 90 DAS (0.856, 0.825 & 0.749), respectively. Incidence of YVMV 60 DAS was positively and significantly correlated with 75 & 90 DAS (0.968 & 0.912). Incidence of YVMV 75 DAS was positively and significantly correlated with 90 DAS (0.972).

4.6 Path co-efficient analysis

In order to find out the cause and effect relationship on yield per plant, path co-efficient analysis was carried out with 17 quantitative characters. The correlations of fruit yield with other characters were partitioned into components of direct and indirect effects that would reflect on the nature of these associations and the relative importance of the components in determining the fruit yield. The phenotypic correlation co-efficient was used in path analysis and the results are presented in Table 4.9.

The results on Phenotypic path analysis revealed that incidence of YVMV at 60 DAS has the highest positive direct effect (0.886) fruit yield (kg plot^{-1}) followed by fruits plant^{-1}(0.723). Positive direct effect were also observed for incidence YVMV at 90 DAS(0.387), fruit weight plant^{-1} (0.279), incidence of YVMV at 30 & 45 DAS(0.087, 0.086) , days to 50 % flowering(0.067), fruit crude protein (0.032) and plant height (0.016.). Rest of character showed negative direct effect being highest in incidence of YVMV at 75 DAS (-0.986), followed by fruit girth (-0.286), crop duration (-0.210), fruit reducing sugar (-0.052), nodes plant^{-1} (-0.034), fruit non-reducing sugar (-0.023) and fruit length (-0.013).

Incidence of YVMV at 60 DAS had the highest positive direct effect (0.886) on the fruit yield (kg/plot^{-1}). The resulted by positive indirect effect *via* crop duration (0.073), incidence of YVMV at 30 &90 DAS(0.052 & 0.352) , fruit crude protein (0.024) , reducing sugar (0.035), fruit length(0.006), fruit girth(0.095). The indirect effect of incidence of YVMV at 60 DAS was observed *via* plant height (-0.003), days to 50 % flowering (-0.026), fruits plant^{-1} (-0.397), fruit weight (g) plant^{-1} (-0.349), nodes plant^{-1}(-0.004), incidence of YVMV at 45 & 75DAS (-0.099 & -0.861) and non reducing sugar (-0.079).

Incidence of YVMV at 75 DAS (-0.986) showed the highest negative direct effect. The indirect effect of plant height (-0.017), days to 50 % flowering(-0.019), fruits plant^{-1}(-0.212), fruit weight plant^{-1}(-0.061), nodes plant^{-1}(-0.006), incidence of YVMV at 45 DAS(-0.079) and non-reducing sugar (-0.041) were negative direct while rest of characters like crop duration (0.086), incidence of YVMV at 30,60 and 90 DAS (0.043), (0.250) & (0.376), fruit crude protein (0.205), reducing sugar(0.036), fruit length (0.005), fruit girth (0.105) were found positive indirect effect.

Plant height showing positive direct effect (0.016) exhibited. Indirect positive effect *via* days to 50 % flowering (0.004), nodes plant^{-1} (0.005), incidence of YVMV at 30 & 75DAS (0.009 & 0.205), fruit crude protein (0.001), reducing sugar (0.009), non-reducing sugar (0.002) and fruit length (0.002). The characters like fruits plant^{-1} (-0.144), fruit weight plant^{-1} (-0.155), crop duration (-0.043), incidence of YVMV at 45, 60 & 90 DAS (-0.004,-0.155 &-0.076) and fruit girth (-0.009), the indirect negative effect.

Days to 50 % flowering showing positive direct effect (0.067) exhibited. Indirect positive effect *via* fruits plant^{-1}(0.066), fruit weight plant^{-1}(0.049), incidence of YVMV at 45& 75 DAS (0.049 & 0.413), reducing sugar (0.004), non-reducing sugar (0.015). Rest of the characters like plant height (-0.001), nodes plant^{-1}(-0.004), crop duration (-0.021), incidence of YVMV at 30, 60&90 DAS (-0.033, -0.335 & -0.085), fruit crude protein (-0.005), fruit length (-0.005) and fruit girth (-0.041) was indirect negative effect.

Fruits plant^{-1} showing positive direct effect (0.723). Indirect positive effect *via* days to 50 % flowering (0.006), fruit weight plant^{-1}(0.245), incidence of YVMV at 45 & 75 DAS (0.037 & 0.424) and non-reducing sugar (0.013). Rest of the characters like plant height (-0.006), nodes plant$^{\backslash 1}$ (-0.011), crop duration (-0.048), incidence of YVMV at 30, 60 & 90 DAS (-0.039, 0.241 & -0.079), fruit crude protein (-0.020), reducing sugar (-0.012), fruit length (-0.007), fruit girth (-0.042) effect was indirect negatively.

Fruit weight plant^{-1} showing positive direct effect (0.279). Indirect positive effect *via* days to 50 % flowering (0.013), fruits plant^{-1} (0.628), incidence of YVMV at 45 & 75DAS (0.039 & 0.259) and non-reducing sugar (0.009). Similarly plant height (-0.009), nodes plant^{-1}(-0.013), crop duration (-0.032), incidence of YVMV at 30, 60 & 90 DAS (-0.039, -0.158 & -0.021), fruit crude protein (-0.021), reducing sugar (-0.010), fruit length (-0.008), fruit girth (-0.011) effect was on indirect negatively.

Incidence of YVMV at 30 DAS showing positive direct effect (0.087),which was mainly contributed by indirect positive *via* plant height (0.018), crop duration (0.117), incidence of YVMV at 60 & 90 DAS(0.513& 0.224), fruit crude protein (0.023), reducing sugar(0.023), fruit length (0.007) & fruit girth (0.019). Rest of the characters like days to 50 % flowering (-0.027), fruits plant^{-1}(-0.352), fruit weight plant^{-1}(-0.124), nodes plant^{-1}(-0.009), incidence of YVMV at 45 & 75DAS (-0.068 & -0.986), non-reducing sugar (-0.014) effect in indirect negatively.

Incidence of YVMV at 45 DAS showing positive direct effect (0.086),which was mainly contributed by indirect positive *via* plant height (0.004), crop duration (0.092), incidence of YVMV at 30 & 60 DAS(0.061& 0.758), fruit crude protein

(0.024), reducing sugar(0.031), fruit length (0.008) & fruit girth (0.058). Rest of the characters like days to 50 % flowering (-0.039), fruits plant^{-1} (-0.309), fruit weight plant^{-1} (-0.124), nodes plant^{-1} (-0.002), incidence of YVMV at 75 & 90 DAS (-0.982 & -0.113) and non-reducing sugar (-0.043) effect was indirect negatively.

Incidence of YVMV at 90 DAS (0.387) showed the highest positive direct effect. The indirect positive effect of crop duration (0.079), incidence of YVMV at 30 & 60 DAS (0.047&0.501), fruit crude protein (0.024), reducing sugar (0.034), fruit length (0.003) & fruit girth (0.121). Similarly, plant height (-0.006), days to 50 % flowering (-0.029), fruits plant^{-1}(-0.242), fruit weight plant^{-1} (-0.056), nodes plant^{-1} (-0.006), incidence of YVMV at 45& 75 DAS (-0.081& -0.951) and non-reducing sugar (-0.041) were indirect negatively.

Crude protein (0.032) showed the positive direct effect. The indirect positive effect of plant height (0.005), nodes plant^{-1}(0.002), crop duration (0.065), incidence of YVMV at 30, 60 & 90DAS (0.54, 0.512 & 0.254), reducing sugar (0.039), fruit length (0.008) & fruit girth (0.019). Rest of the characters like days to 50 % flowering (-0.009), fruits plant^{-1}(-0.427), fruit weight plant (-0.188), incidence of YVMV at 45 & 75 DAS (-0.078 & -0.915), non-reducing sugar (-0.035) were indirect negatively.

Nodes plant^{-1} (-0.034) showed the negative direct effect. The indirect negative effect of plant height (-0.012), incidence of YVMV at 45 & 75 DAS (-0.005 & -0.133), fruit crude protein (-0.002), fruit length (-0.004)& fruit girth (-0.043)).Rest of the characters like days to 50 % flowering(0.007), fruits plant^{-1}(0.235), fruit weight plant^{-1} (0.103), crop duration (0.017), incidence of YVMV at 30 ,60 & 90 DAS(0.018,0.091& 0.043), reducing sugar(0.013) & non-reducing sugar(0.008) were indirect and positive.

Crop duration showed the negative direct effect (-0.210). The indirect negative effect of incidence of YVMV at 30, 60 & 90 DAS (-0.046,-0.321 & -0.155), fruit crude protein (-0.012), reducing sugar (-0.014) & fruit length(-0.005). Similarly, plant height (0.007),days to 50 % flowering(0.009), fruits plant^{-1}(0.175), fruit weight plant^{-1} (0.047), nodes plant^{-1}(0.006), incidence of YVMV at 45 & 75 DAS(0.037 &0.645), non-reducing sugar(0.005) and fruit girth(0.058) were positive indirect effect.

Fruit reducing sugar fruits showed the negative direct effect (-0.052). The indirect negative effect of plant height (-0.003), days to 50 % flowering (-0.007), crop duration (-0.052), incidence of YVMV at 30, 60 & 90 DAS (-0.035, -0.586 & -0.254), fruit crude protein (-0.026), non-reducing sugar (-0.004), fruit length (-0.005). Similarly fruits plant^{-1} (0.169), fruit weight plant^{-1} (0.052), nodes plant^{-1}(0.0019), incidence of YVMV at 45& 75 DAS (0.081 & 0.993) & fruit girth (0.011) were positive indirect effect.

Fruit non-reducing sugar showed negative direct effect (-0.023). The indirect negative effect of *via* plant height (-0.008), days to 50 % flowering (-0.038), fruits plant $^{-1}$(-0.338), fruit weight plant^{-1} (-0.096), incidence of YVMV at 45& 75 DAS (-0.035 & -0.036) and reducing sugar (-0.007). Similarly, nodes plant^{-1} (0.007), crop duration (0.047), incidence of YVMV at 30, 60 & 90 DAS (0.036, 0.272 & 0.074), fruit crude protein (0.012), fruit length (0.005) and fruit girth (0.025) were positive indirect effect.

Fruit length showed the negative direct effect (-0.013). The indirect negative effect of *via* plant height (-0.002), nodes plant^{-1}(-0.012), crop duration (-0.071), incidence of YVMV at 30, 60 & 90 DAS (-0.045, -0.382& -0.177), fruit crude protein (-0.021) and reducing sugar (-0.019). Similarly, days to 50 % flowering (0.025), fruitsplant^{-1}(0.409), fruit weight plant^{-1}(0.177), incidence of YVMV at 45 & 75 DAS (0.049 & 0.605), non-reducing sugar (0.011) and fruit girth (0.008) were positive indirect effect.

Fruit girth showed the negative direct effect (-0.286). The indirect negative effect of *via* of nodes plant^{-1}(-0.005), incidence of YVMV at 30, 60 & 90 DAS (-0.007, -0.297& -0.167), fruit crude protein (-0.004). Plant height (0.006), days to 50 % flowering(0.009), fruits plant^{-1}(0.106), fruit weight plant^{-1} (0.010), crop duration (0.041), incidence of YVMV at 45 & 75 DAS (0.017 & 0.552), reducing sugar(0.002), non-reducing sugar(0.003) and fruit length(0.005) were negative and indirect.

Table 4.9. Estimate of direct (diagonal) and indirect effect of component characters on yield (kg plot^{-1}) in okra germplasm

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1	**0.016**	0.004	-0.144	-0.155	0.005	-0.043	0.009	-0.004	-0.155	0.205	-0.076	0.001	0.009	0.002	0.002	-0.009	-0.333
2	-0.001	**0.067**	0.066	0.049	-0.004	-0.021	-0.033	0.049	-0.335	0.413	-0.085	-0.005	0.004	0.015	-0.005	-0.041	0.133
3	-0.006	0.006	**0.723**	0.245	-0.011	-0.048	-0.039	0.037	-0.241	0.424	-0.079	-0.02	-0.012	0.013	-0.007	-0.042	0.943
4	-0.009	0.013	0.628	**0.279**	-0.013	-0.032	-0.039	0.039	-0.158	0.259	-0.021	-0.021	-0.01	0.009	-0.008	-0.011	0.905
5	-0.012	0.007	0.235	0.103	**-0.034**	0.017	0.018	-0.005	0.091	-0.133	0.043	-0.002	0.013	0.008	-0.004	-0.043	0.302
6	0.007	0.009	0.175	0.047	0.006	**-0.21**	-0.046	0.037	-0.321	0.645	-0.155	-0.012	-0.014	0.005	-0.005	0.058	0.226
7	0.018	-0.027	-0.352	-0.124	-0.009	0.117	**0.087**	-0.068	0.531	-0.986	0.224	0.023	0.023	-0.014	0.007	0.019	-0.531
8	0.004	-0.039	-0.309	-0.124	-0.002	0.092	0.061	**0.086**	0.758	-0.982	-0.113	0.024	0.031	-0.043	0.008	0.058	-0.49
9	-0.003	-0.026	-0.397	-0.349	-0.004	0.073	0.052	-0.099	**0.886**	-0.861	0.352	0.024	0.035	-0.079	0.006	0.095	-0.295
10	-0.017	-0.019	-0.212	-0.061	-0.006	0.086	0.043	-0.079	0.25	**-0.986**	0.376	0.205	0.036	-0.041	0.005	0.105	-0.315
11	-0.006	-0.029	-0.242	-0.056	-0.006	0.079	0.047	-0.081	0.501	-0.951	**0.387**	0.024	0.034	-0.041	0.003	0.121	-0.216
12	0.005	-0.009	-0.427	-0.188	0.002	0.065	0.054	-0.078	0.512	-0.915	0.254	**0.032**	0.039	-0.035	0.008	0.019	-0.662
13	-0.003	-0.007	0.169	0.052	0.019	-0.052	-0.035	0.081	-0.586	0.993	-0.254	-0.026	**-0.052**	-0.004	-0.005	0.011	0.301
14	-0.008	-0.038	-0.338	-0.096	0.007	0.047	0.036	-0.035	0.272	-0.361	0.074	0.012	-0.007	**-0.023**	0.005	0.025	-0.428
15	-0.002	0.025	0.409	0.177	-0.012	-0.071	-0.045	0.049	-0.382	0.605	-0.117	-0.021	-0.019	0.011	**-0.013**	0.008	0.602
16	0.006	0.009	0.106	0.01	-0.005	0.041	-0.007	0.017	-0.297	0.552	-0.167	-0.004	0.002	0.003	0.005	**-0.286**	-0.015

Residual effect = 0.139

1. plant height at final harvesting stage 2. days to 50%flowering 3. fruits plant^{-1} 4. Avg. fruit wt plt^{-1} 5. Nodes plant^{-1} 6. crop sowing to harvesting 7. YVMV incidence 30 DAS 8. YVMV incidence 45 DAS 9. YVMV incidence 60 DAS 10. YVMV incidence 75 DAS 11. YVMV incidence 90 DAS 12. crude protein 13. reducing sugar 14. non reducing sugar 15. fruit length 16. fruit girth 17.fruit yield kg plot^{-1}

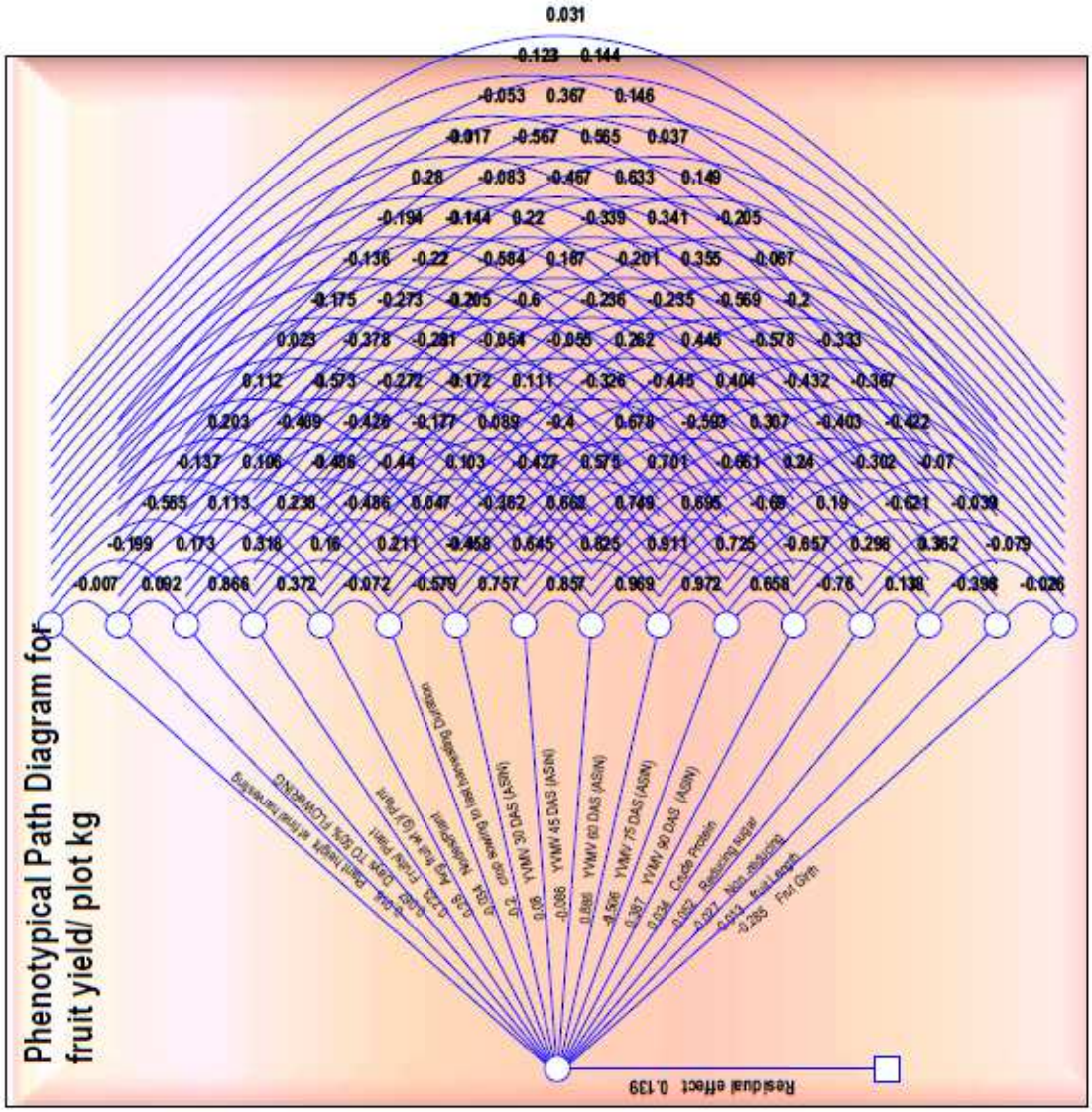

Fig. 4.7 Phenotypical path diagram for fruit yield (kg/plot)

4.7 Genetic divergence

A perusal Table 4.10 showed that genotypes of okra could be grouped into 4 clusters on the basis of intra and inter cluster distance. The first cluster comprise of 7 genotypes, *viz;* 2012/OKYVRES-1, 2012/OKYVRES-4, 2012/OKYVRES-6 along with all check varieties Kashi Pragati, Pusa Sawani, Arka Anamika and Arka Abhay while cluster II (2012/OKYVRES-5), III (2012/OKYVRES-3) and IV (2012/OKYVRES-2) consisted of one genotypes each.

Table 4.10 Clustering pattern of 10 okra genotypes

Cluster No/	Number of genotype (s)	Name of the genotypes
I	07	2012/OKYVRES-1, 2012/OKYVRES-4, 2012/OKYVRES-6, Kashi Pragati, Pusa Sawani, Arka Anamika and Arka Abhay
II	01	2012/OKVYRES-5
III	01	2012/OKVYRES-3
IV	01	2012/OKVYRES - 2

Intra and inter-cluster distances

The results on average intra and inter cluster distance presented in Table 4.11 revealed that among the two multivariate Cluster, Cluster II had the minimum intra-cluster distance (D^2 = 0.00) whereas maximum intra-cluster distance (D^2 = 777.24) was observed in Cluster I. The average inter-cluster distance revealed that the most divergent clusters were Cluster II and IV (D^2 = 9582.65), followed by Cluster II and III (D^2 = 8741.88) and Cluster I and II (D^2 = 6683.23).

Table 4.11 Intra (Diagonal) and Inter cluster average (D^2) corresponding D ($\sqrt{D^2}$) Values (in parenthesis) among groups (Euclidean^2: cluster distance: ward)

Cluster	I	II	III	IV
I	777.24(27.88)	6683.23(81.75)	3575.80(59.80)	3776.23(61.42)
II		0.00(0.00)	8741.88(93.50)	9582.65(97.89)
III			91.58(9.58)	849.66(29.15)
IV				516.74(22.73)

Characteristics features of four clusters

The cluster means of 25 characters for groups of okra genotypes are presented in Table 4.12 indicated that Cluster I consisting of 7 okra genotypes having highest reducing & total sugar content (3.29 & 3.91%) with minimum days taken for 1st flowering (37.50), fruit hardness (82.83 mm) and lowest incidence of YVMV at 30, 45, 60, 75 and 90 DAS (0.00, 4.67, 9.62, 11.58 & 14.60, respectively). For rest of the characters moderate expressions were observed. Similarly, Cluster II having one genotype showed the maximum values for node plant^{-1} (22.20), ridges fruit^{-1} (7.00), fruits plant^{-1} (20.75), fruit weight plant^{-1} (141.59g), fruit weight (23.20g), fruit length (13.88 cm), fruit yield (11.50 kg plot^{-1}) and dry weight of fruits (10.80g) with minimum value for node at which 1st flower appeared (4.66) and incidence of YVMV at 30 DAS (0.00%). Rest characters have moderate expressions.

Table 4.12. Mean of 25 characters in different clusters of okra genotypes

Sl. no	Cluster / Characters	I	II	III	IV
1	Plant height at final harvesting(cm)	107.62	57.27	89.57	120.83
2	Number of nodes plant^{-1}	18.53	22.20	17.26	19.60
3	First flowering node	6.49	4.66	5.91	6.70
4	Days to first flowering	37.50	40.00	37.66	38.00
5	Days to 50% flowering	41.50	42.66	41.00	41.33
6	Number of Fruits plant^{-1}	15.13	20.75	4.78	20.23
7	Fruit length (cm)	12.73	13.88	9.93	12.72
8	Fruit girth (cm)	6.81	6.07	6.85	6.96
9	Avg. fruit weight (10 fruits entry^{-1})	17.95	23.20	16.20	17.23
10	Average fruit weight (g)plant^{-1}	66.53	141.59	22.25	77.69
11	Number of ridges fruit^{-1}	5.00	7.00	5.00	5.00
12	Fruit yield plot^{-1} (kg)	7.48	11.50	2.15	9.46
13	Days to first harvesting	47.50	54.67	45.00	46.33
14	Crop duration (days)	83.00	80.00	74.00	83.00
15	Non -reducing Sugars (%)	0.62	0.55	1.02	0.33
16	Reducing Sugars (%)	3.29	2.78	2.46	3.03
17	Total Sugars (%)	3.91	3.33	3.48	3.36
18	Dry weight of average 10 fruits (g)	8.80	10.80	7.900	8.43
19	Crude protein content of fruits (%)	8.21	8.75	16.34	9.34
20	Fruit hardness (mm)	82.83	84.67	84.00	84.00
21	YVMV incidence 30 DAS (ASIN)	0.00	0.00	20.81	0.00
22	YVMV incidence 45 DAS (ASIN)	4.67	17.02	64.73	9.34
23	YVMV incidence 60 DAS (ASIN)	9.62	65.74	83.39	19.24
24	YVMV incidence 75 DAS (ASIN)	11.58	74.16	90.02	23.16
25	YVMV incidence 90 DAS (ASIN)	14.60	90.02	90.02	26.82

The Cluster-III with one genotype showed maximum value for non-reducing sugar content (1.02%) and crude protein (16.34%) with minimum values for days to 50% flowering (41.00), days to 1st harvest (45.00) and crop duration (74.00 days). The rest of the characters have moderate expression. However, the genotype showed relatively higher incidence of YVMV at different stages of crop growth stage.

The Cluster-IV with one genotype showed maximum value for plant height (120.83 cm) & fruit girth (6.96cm) with minimum incidence of YVMV at 30 DAS (0.00%). The rest of the characters have moderate expression.

DISCUSSION

The present investigation entitled, "**Screening of okra (*Abelmoschus esculentus* L. Moench) germplasm against Okra Yellow Vein Mosaic Virus under field condition**" was conducted under All India Coordinated Research Project on Vegetable crops of Orissa University of Agriculture and Technology, Bhubaneswar, Odisha, India during summer season of 2015. The primary objective of the study was to screen out suitable genotype(s) resistance / tolerance against YVMV along with the genetical variability for improvement of the okra.

In this chapter, a brief discussion has been made relating to observations recorded on various aspects of investigation and interpretation of significant findings. The interpretation in terms of causes and effects relationship were also highlighted simultaneously along with earlier established scientific views of available both national and international research works.

5.1 Vegetative growth and flowering parameters

The vegetative growth parameters i.e., plant height at the time of final harvest and nodes plant^{-1} showed significant variations among the tested genotypes. Significantly tallest plant was recorded in genotype 2012/OKYVRES-2 (120.83cm) while nodes plant^{-1} in 2012/OKYVRES-5 (22.20). However, both the check varieties, Arka Anamika and Arka Abhay showed better vegetative growth and were *statistically at par* with respect to highest values. However, 2012/OKYVRES-5 (57.27cm) and 2012/OKYVRES-3 (17.26) recorded significantly lowest values for plant height and nodes plant^{-1}, respectively. The better performance of Arka Anamika was also reported by Bora *et al*. (1992) and Sangar (1997).

In okra, it is also desirable to produce the flowers at lower nodes with early flowering habit for better yield and profit under commercial scale. The result indicated that the genotype, 2012/OKYVRES-5(4.66) recorded lowest node for appearance of 1st flower and was *statistically at par* with 2012/OKYVRES-3(5.91), 2012/OKYVRES-4(5.19) and 2012/OKYVRES-6(5.76) suggesting the better performance of evaluated genotypes over the check varieties. Days to 1st flowering with 2012/OKYVRES-6 (31.33 days), 2012/OKYVRES-4 (32.33) followed by check variety Pusa Sawani (32.66). Similar trend was also observed for days to 50 % flowering. The results suggesting the performance of early type in the evaluated genotypes which can be utilized in further crop improvement programmes.

5.2 Fruit yield and yield attributing parameters

In okra, the major fruit yield attributing parameters includes fruits plant^{-1}, length, girth, ridges & weight of fruits, days taken to 1st harvesting and crop duration for fruiting etc. The present study invariably showed that, the genotype, 2012/OKYVRES-5 recorded significantly highest values for fruits plant^{-1} (20.75), fruit length (13.88cm), fruit weight(23.20g), fruit weight plant^{-1}(141.59g), ridges fruit^{-1}(7.00), fruit dry weight (10.80g) and fruit yield(11.50kg plot^{-1} and 141.98qha^{-1}) suggesting the superiority of the genotypes than the rest of the genotypes including the checks. However, *statistical parity* were observed with 2012/OKYVRES-1, 2012/OKYVRES-2, 2012/OKYVRES-6 including check varieties, i.e. Kashi Pragathi and Arka Anamika for fruit length, while Arka Abhay for both fruit length & weight. Significantly highest fruit yield recorded in 2012/OKYVRES-5, might be due to highest nodes plant^{-1} with lowest node of 1st flowering, highest values for fruits plant^{-1}, fruit length, weight, weight plant^{-1} and dry weight as observed in the present investigation. Among the check varieties, Kashi Pragati (VRO-6) recorded high fruit yield than other genotypes. Similar the results corroborate the findings of Vijay and Joshi (2013) under Akola condition.

Days taken for 1st harvesting and final harvesting, the genotype 2012/OKYVRES-3 recorded minimum time of 45 and 74 days, respectively as compared to the other tested genotypes. Thus, the genotype can be taken as a source of earliness for future crop improvement programme.

5.3 Reaction of genotypes to YVMV

All the 10 genotypes of the present study were cultivated under natural conditions without any plant protection measures to screen out the suitable resistant and/or tolerant genotype (s). The results clearly indicated significant variations among the genotypes at 30,45,60,75 and 90 DAS of crop growth under field conditions. Among the genotypes evaluated, 2012/OKYVRES-1 showed significant resistant to YVMV incidence (0.00%) at all stages of crop growth than rest of the genotypes. However, *statistical parity* were observed with 2012/OKYVRES-2(0.00%), 2012/OKYVRES-5(0.00%) & check variety, Arka Anamika (5.23%) at 30 DAS. At 45 DAS, both 2012/OKYVRES-1 and 2012/OKYVRES-2 showing significant tolerance to YVMV as compared to the other genotypes. Similar report of tolerance of Arka Anamika was also identified by Chandra (1997), Mathew *et al.* (1993), Deo *et al.* (2000), Tripathy *et al*. (2008) and Nataraj *et al.* (2013).

The results also indicated that the standard susceptible check, Pusa Sawani and check Arka Abhay showed susceptibility to YVMV at 30 DAS under Bhubaneswar condition. The susceptible check, Pusa Sawani showed the susceptibility to YVMV at every stages of crop growth and reached maximum of 100% at 75 DAS. At 45 DAS, 2012/OKYVRES-3, 2012/OKYVRES-4 and Kashi Pragathi showed susceptibility to YVMV and was *statistically at par* with Pusa Sawani. As the days progressed, at 60 DAS, the tolerant genotypes of the present study 2012/OKYVRES-5 and Arka Abhay showed significantly high YVMV infestation along with other genotypes at 45 DAS. However, 75 DAS of crop growth stage both the 2012/OKYVRES-5 and Arka Anamika showed significantly better tolerance to YVMV as compared to susceptible check, Pusa Sawani. The significant tolerance of Arka Anamika have been reported in different parts of India, *viz;* Madhya Pradesh (Sangar, 1997), West Bengal (Tripathy *et al*.,2008) , Assam (Bora *et al*.,1992), Varanasi (Deo *et al* .,2000) etc.

At 90 DAS, all the genotypes showed 100% incidence of YVMV except 2012/OKYVRES-1 (0.00%), 2012/OKYVRES- 2(20.3%), 2012/OKYVRES-4(96.1%). Thus the result clearly indicated that the genotype, 2012/OKYVRES-1 and 2012/OKYVRES-2 showed resistance towards YVMV at all the stages of crop growth in okra suggesting the source of resistance for future crop improvement programme.

The result also revealed that at 30 DAS, Arka Abhay showed susceptibility to YVMV while at 45 and 60 DAS, the variety was significantly tolerant to all the susceptibility genotypes including Pusa Sawani. This might be due to tolerant of the plant to whitefly, the vector of YVMV reported by (Baldwin, 2010). Similar reports of tolerance of Arka Abhay have been reported by Debarnath *et al.* (2006); Biswas *et al.* (2008) and Mehra *et al*. (2008).

The result also clearly suggested that in spite of higher incidence of YVMV at 60 DAS onwards (75.53 to 100%), the genotypes 2012/OKYVRES-5, recorded highest fruit yield. This might be due to better vegetative and fruit yield attributing parameters as observed in present study than rest of the genotypes. Further up to 45 DAS the genotypes showed significantly better resistance to YVMV as compared to all genotypes, except 2012/OKYVRES-1 and 2. It has been established that in okra, if the crop was relatively free from incidence of YVMV up to 50-60 DAS, the % of yield loss was not so significant rather in early incidence (Dahal *et al.*, 1992, Pun *et al*., 1999, and Baghat *et al*., 2001).

Okra plants infected 50 and 65 DAS suffer a loss of 84 and 49 %, respectively. The fruit yield loss was up to 94%, if incidence was within 20 DAS while 49% within 45 DAS clearly confirmed in the findings of the present study (Ali *et al.*, 2005).

The overall green fruit yield was relatively lower under Bhubaneswar condition. This might be due to cultivation of okra genotypes under natural unprotected conditions without any plant protection measures, severe incidence of YVMV and overall the general yield potential of summer okra was lesser than the rainy season crop. Similar report has been reported by Tripathy *et al*. (2008). Bhagabti and Goswami (1992) also recorded severe incidence of YVMV in okra in May sown crop.

5.4 Fruit quality parameters

Invariably, the genotype 2012/OKYVRES-6 and 2012/OKYVRES-1 recorded better fruit quality in terms of high sugar content (reducing, non-reducing and total) with lower hardness. However, significantly highest crude protein was recorded by 2012/OKYVRES-3 (16.34%), followed by Pusa Sawani (16.21%). In all the cases, the superior genotype, 2012/OKYVRES-5 recorded moderate values for different fruit quality. The result also indicated that reduced reducing sugar with increased non-reducing, total sugar, in YVMV susceptible genotypes with higher fruit crude protein content than resistant or tolerant genotypes. A similar report has been reported by Sharma *et al*. (1995) in okra.

5.5 Genetic variability

The most economic trait in okra is the green fruit yield, the resultant of many vegetative growth, flowering and fruit yield attributing parameters under both biotic and abiotic stress situations. Since selection is basically depend on the phenotypic observations, their reflection on genotypic may not hold good until & unless observations on the quantitative traits are subjected and interpreted accordingly. Hence, the genetic variability parameters such as range, mean, CV, GV, PV, GCV, PCV, heritability, GA and GAM(%) for 26 different traits in okra has been calculated to draw a valid conclusion from the present investigation.

The result on analysis of variance (Table 4.6) clearly demonstrated the significant variations for all the parameters under study except fruit girth, ridges plant^{-1} and crop duration in okra. The study also suggested that, there is a vast scope for considerably crop improvement in okra through characters such as plant height, nodes plant^{-1}, days to 1st

flowering, days to 50% flowering, fruit weight, fruit weight plant^{-1}, days to 1st harvest, fruits plant^{-1}, incidence of YVMV at different stage of crop growth as well as fruit yield (kg plot^{-1} and qha^{-1}). Similar reports were also reported by Dhankar and Dhankar (2002), Alan and Hosain (2008), Simon *et al.* (2013) and Mishra *et al.* (2015) in okra. Further, coefficient of variations were less than 20% for most of the parameters under study except incidence of YVMV 30 DAS among the genotypes indicating that good precision was maintained in conducting the experiment.

It is an established fact that effective selection can be possible with existing wide variability followed by effective selection of heritable characters (Allard, 1960). Hence there is urgency to study the extent of variability exist among the genotypes and characters having heritable nature, least influenced by the environment. Therefore, estimation of PCV and GCV provides a sound basis to evaluate the variation component with heritable and non-heritable component (Burton and Devance, 1953).

The perusal of result (Table 4.6 and 4.7) indicated wide range of both phenotypic and genotypic variance for all the 26 characters. The difference between PV and GV was minimum for fruits plant^{-1}, fruit weight plant^{-1}, yield (kg plot^{-1} and qha^{-1}), fruit crude protein and sugar content as well as incidence of YVMV at 45, 60, 75 and 90 DAS, indicating the least influence of these characters by environments. Similarly, relatively higher difference was observed for plant height, nodes plant^{-1}, flowering parameters, fruit weight, fruit dry weight, crop duration, fruit hardness and incidence of YVMV at 30 DAS, indicating that major part was attributed through additive interaction instead of dominant and epistatic component. Khan *et al.* (2005) also observed similar trend for various characters which are in conformity to the present findings.

The study also revealed higher values of PCV than GCV for all the parameters suggesting the impact of environmental factors for expression of the characters. However, the difference between GCV and PCV for all characters varied widely. This is in agreement with the findings of Sateesh *et al.* (2011), Gandy and Aziz (2013) and Mishra *et al.* (2015) in okra. The presence of high to moderate GCV for plant height^{-1}, fruits plant^{-1}, fruit weight plant^{-1}, fruit yield (kg plot^{-1} and qha^{-1}), fruit crude protein and sugar content as well as incidence of YVMV at 30,45,60,75 and 90 DAS clearly indicating the presence of wide variability among the tested genotypes, hence selection for these characters may be useful in crop improvement of okra. The present findings corroborate with the findings of

several scientists working on okra (Patra and Ravisankan, 2004; Khan *et al.,* 2005; Singh *et al.,* 2006; Alan and Hossain, 2008; Prakesh and Pitchaimuthu, 2010; Reddy *et al.,* 2012; Shaikh *et al.,* 2013 and Mishra *et al.,* 2015).

In general, GCV does not indicate the amount of heritable variance with the traits. In order to determine the proportion of the total genetic variations, there is urgency in estimation of heritability in broad sense. Higher the heritability of a trait means, least influenced by the environment, there by suggesting better opportunity for selecting a genetically good individual (Randhawa *et al.,* 1975). The result of present study indicated that high heritability of above 60% have been obtained for plant height, days to 50% flowering, fruits plant^{-1}, ridges fruit^{-1}, fruit yield (kg plot^{-1} and qha^{-1}), fruit crude protein and sugar content as well as incidence of YVMV at 45, 60, 75 and 90 DAS, which clearly suggested that these characters might be highly heritable and less influenced by environment. Therefore, selection of genotypes on basis of such parameters would be beneficial in okra improvement programme. Similar result were also reported by several scientists in okra (Dhankar and Dhankar 2002; Kumar *et al.,* 2011; Goswami *et al.,*2012; Kumar *et al.,*2012 and Jagan *et al.,* 2013).

Johnson *et al*. (1955) suggested that though heritability estimate provides the basis for selection of phenotypic performance, but heritability estimates coupled with high GA should always be considered simultaneously for obtaining efficient selection of traits in crop improvement programme. In the present study, the traits having high heritability coupled with high GA for plant height, fruit weight plant^{-1}, fruit yield, fruit crude protein and sugar as well as incidence of YVMV at 45, 60, 75 and 90 DAS indicating that these traits are simply inherited characters, even most of them are under polygenic control, but these traits could be improved through simple selection method. Therefore, these traits can be attributed to additive gene action regulating their inheritance and the phenotypic selection for their improvement could be achieved by adopting simple selection method (Panse, 1957). Similar observations have been reported by Patra and Ravisankar (2004), Singh *et al*. (2006), Gangashetty *et al*. (2010) and Mishra *et al*. (2015) in okra. However, some deviations were also observed in different characters studied in the present investigation as observed by other scientists in okra was primarily due to difference in genetic stock subjected to testing along with environmental factors.

Interestingly, the results also indicated that these above characters not only showing relatively high heritability and GAM (%) but also relatively high values of GCV than rest of the characters under study altogether. Thus, the combined effect of three important genetic factors suggested that additive gene action is responsible for expression of these characters. Therefore, direct selection through these characters will be effective for improvement in okra especially to develop a genotype having tolerance and/or resistance to YVMV. Similar reports of high values of three genetic parameters has been reported in okra by Mehta *et al.*(2006) for fruit yield, Sateesh *et al.*(2011) for fruit yield and days to 50% flowering Gendy and Aziz(2013) and Mishra *et al.*(2015) for most of the traits in okra.

5.6 Character association

Like other fruit vegetables, in okra green fruit yield is also governed by several other quantitative characters that are highly dependent on environmental stress including both biotic and abiotic stresses. Therefore, only phenotypic selection of genotypes on the basis of yield may not be a sound proposition for effective selection. Hence, it is also essential to estimate the association among the fruit yield and its components for planning of a successful and effective crop improvement programme. The results on phenotypic correlation (Table No.4.9) clearly suggested that there was a strong inheritance association between the various characters in okra. A strong positive association of character with yield may be attributed to linkage and pleiotropy (Sparque, 1966). In the present study, significant and positive correlation observed for fruit yield (kg plot^{-1}) with fruits plant^{-1}, ridges fruit^{-1}, fruit weight plant^{-1} , fruit length, fruit weight, days to 1st harvest and fruit dry weight . Similar trend was also observed for fruit yield (q ha^{-1}). On the other hand, the fruit yield was significant but negatively correlated with node at which 1st flower appeared, fruit crude protein and non-reducing sugar and incidence of YVMV at 30 and 45 DAS. These results clearly suggested that selection for these component traits simultaneously will effective in improving the fruit yield in okra. In case of other pairs of traits showing either significant negative values or non-significant values of both positive and negative have least importance for effective selection based on these characters. Similar results of significant positive correlation for green fruit yield in okra with fruits plant^{-1}, fruit weight, fruit length by Jaiprakashnarayan and Melge (2004) and Chaukhande *et al.* (2011),fruit length and fruit weight by Mehta (2006) fruits plant^{-1},fruit length by

Singh *et al.*(2007) and Sengupta and Verma (2009). Further, the incidence of YVMV showing the significant and negative correlation with fruit yield in okra clearly suggested that the YVMV incidence was significantly reduced the fruit yield. The interesting results revealed that at 30 to 45 DAS, the incidence of YVMV was significant and negatively correlated with fruit yield than 60, 75 and 90 DAS suggesting that for effective screening of okra genotypes against YVMV, selection should be done at 30 to 45 DAS only. Similar, observations of reduction of YVMV with increase in age of okra seedlings were reported by Pun *et al.* (1999). They reported 100% infection occurred at early stage with one week while the infection % was dropped down to 31.70% when incidence of YVMV at 49 DAS. Similar reports of significant increase in % of YVMV at 35 to 45 DAS were reported by Bhagat *et al.* (2001); Khan *et al.* (2005) and Ali *et al.* (2005).

5.7 Direct and indirect effect of characters

Yield being a complex character resulting from the direct and indirect effects of several traits operating either alone or in combinations. Selection for a trait in one direction may influence another trait by a direct or indirect effect *via* third variable. Hence, in order to study, the direct and indirect effects of various plant characters on okra fruit yield are presented in Table 4.9. The results revealed that fruits plant-^{1}, fruit weight ,incidence of YVMV at 60 and 90 DAS had maximum positive direct effect on fruit yield (kg plot^{-1}) of okra. Further plant height, days to 50% flowering, incidence of YVMV at 30 and 45 DAS and fruit crude protein content also produced positive direct effect of lower magnitude. On contrary, nodes plant^{-1} , crop duration, incidence of YVMV at 75 DAS ,fruit reducing sugar, length and girth of fruits had negative direct effect on fruit yield, highest being incidence of YVMV at 75 DAS (-0.986). The low positive and negative direct effect resulted might be due to cancellation by the respective indirect effects *via* these characters.

The indirect effect of fruits plant^{-1} *via* fruit weight, incidence of YVMV (75 DAS) & days to 50% flowering. Similarly, incidence of YVMV at 60 DAS *via* nodes plant^{-1}, incidence of YVMV (30, 45, 75 and 90 DAS), fruit crude protein and non-reducing sugars, respectively. The present findings are in agreement with Bhalkar *et al.* (2005) who reported that relatively free from YVMV, long fruited types with tall plants having more nodes plant^{-1} and fruits plant^{-1} yielded maximum fruit yield in okra. Similarly, Gangashetty *et al*. (2010) also reported high path coefficient for higher fruit yield with fruits plant^{-1}, fruit weight and plant height.

The results of present study also indicated that fruits plant^{-1}, fruit weight and lower incidence of YVMV up to 60 DAS had considerable direct contribution towards green fruit yield in okra. High indirect effects to these traits are also observed. Thus, during screening of genotypes against YVMV under field conditions in okra, the importance should be given to isolate the superior types at least within 60 DAS to develop the superior types with higher fruit yield potential having resistance &/or tolerance to YVMV.

5.8 Genetic divergence

The multivariate analysis based on Mahalonobis D^2 statistics is a powerful tool for measuring the genetic divergence among the test genotypes (Nair and Gupta, 1976). The results indicated that all the genotypes were grouped into 4 different clusters, comprising seven genotypes including checks in Cluster I while rest 3 clusters consist of single genotype each (Table 4.10).

From the present investigation, cluster II comprising single genotype (2012/OKYVRES-5) and cluster IV having single genotype (2012/OKYVRES-2) sharing highest inter cluster distance .So promising hybrid derivatives can be obtained by crossing parents of these two divergent groups probably because of complementary interaction divergent gene parents.

From the performance study (Table 4.2 to 4.5), it was clearly demonstrated the superiority of 2012/OKYVRES-5 with respect to fruit yield and tolerance to YVMV under field condition which was grouped in cluster -II. Similarly, the best two lines isolated with resistance to YVMV were 2012/OKYVRES-1(Cluster-I) and 2012/OKYVRES-2(Cluster IV). Thus, the development of hybrids by utilizing cluster II and IV not only produce the genotypes having desirable quantitative parameters but also resistance & / or tolerance to YVMV in okra. Similar reports have been reported by Prakash and Pitchaimuthu (2010), Prakash Kerure (2010) and Mishra *et al*. (2015) in okra which is similar to our findings of present investigation.

SUMMARY AND CONCLUSION

The salient findings of the present investigation entitled, **"Screening of Okra *(Abelmoschus esculentus* L. Moench) germplasm against Okra Yellow Vein Mosaic Virus disease under field condition"** are summarized below

- The results on mean sum of square revealed the existence of significance among the tested genotypes for all the characters studied, except the fruit girth, ridges plant^{-1} and crop duration from sowing to last harvesting.
- The genotype, 2012/OKYVRES-2 recorded significantly highest plant height (120.83cm) and was *statistically at par* with Arka Anamika (114.43 cm) and Arka Abhay (115.27 cm).
- The genotype, 2012/OKYVRES-5 recorded significantly highest node plant^{-1}(22.20).
- Significantly lowest node of 1st flowering was recorded in 2012/OKYVRES-5 (4.66) and *statistically at par* with 2012/OKYVRES-3 (5.91), 2012/OKYVRES-4 (5.19) and 2012/OKYVRES-6 (5.76).
- Significantly earliest days to 1st flowering was recorded in 2012/OKYVRES-6 (31.33) closely followed by 2012/OKYVRES-6 (32.33), Kashi Pragathi (35.33) and Pusa Sawani (32.66) where *statistical parity* were observed.
- Significantly earliest days to 50% flowering by genotype, 2012/OKYVRES-6 (36.66).
- Significantly maximum fruits plant^{-1} by 2012/OKYVRES-5 (20.75) and 2012/OKYVRES-2 (20.23).
- Significantly longest fruits was produced by 2012/OKYVRES-5 (13.88 cm) than rest of the genotypes, except 2012/OKYVRES-1, 2012/OKYVRES-2, 2012/OKYVRES-6, Kashi Pragati, Arka Anamika and Arka Abhay (11.68 cm to 12.73 cm) where *statistical parity* were observed.
- Maximum fruit girth (6.96 cm) was recorded in genotype, 2012/OKYVRES-2.
- The genotype, 2012/OKYVRES-5 recorded significantly heaviest fruit of 23.20g.
- Significantly highest fruit weight plant^{-1}(141.59g) was recorded by 2012/OKYVRES-5.
- Significantly minimum days taken for 1st harvesting (45.00) was recorded in genotype, 2012/OKYVRES-3 and 2012/OKYVRES-4 and Pusa Sawani than rest of the genotypes.

- The genotype, 2012/OKYVRES-3 recorded the lowest days for final harvesting (74.00).
- Maximum ridges plant^{-1} was observed in genotype, 2012/OKYVRES-5 (7.00).
- Significantly highest fruit dry weight was recorded by 2012/OKYVRES-5 (10.80g), closely followed by 2012/OKYVRES-1 (9.17g) than rest of the genotypes.
- The genotype, 2012/OKYVRES-5 recorded significantly highest green fruit yield, i.e. 11.50 kg plot^{-1} and 141.98 q ha^{-1} than rest of the genotypes. The next best genotype was 2012/OKYVRES-2 with fruit yield of 9.46 kg plot^{-1} and 116.79 q ha^{-1} , respectively.
- The genotype, 2012/OKYVRES-1 recorded significantly lowest incidence of YVMV (0.00%) at all stages of crop growth.
- At 30 DAS, significantly lowest incidence of YVMV (0.00%) was observed in genotype 2012/OKYVRES-1, 2012/OKYVRES-2, and 2012/OKYVRES-5 than other genotypes except Arka Anamika (5.23%) which was *statistically at par*.
- At 30 DAS significantly maximum YVMV incidence was recorded Arka Abhay, followed by Pusa Sawani, 2012/OKYVRES-3, 2012/OKYVRES-6 and Kashi Pragati (8.26 to 14.26%).
- At 45 DAS of crop growth, both 2012/OKYVRES-1 and 2012/OKYVRES-2 recorded significantly lowest incidence of YVMV (0.00 to 3.98%) than rest of the genotypes.
- Significantly maximum incidence of 88.36% was observed in Kashi Pragati than other genotypes. However, *statistical parity* were observed with 2012/OKYVRES-3, 2012/OKYVRES-4, 2012/OKYVRES-6 and Pusa Sawani (79.98 to 87.66%) at 45 DAS.
- At 60 DAS of crop growth, significantly lowest incidence of YVMV was observed in genotype, 2012/OKYVRES-1 than rest of the genotypes. The next better genotypes significantly tolerant to YVMV, except 2012/OKYVRES-1 were 2012/OKYVRES-2, 2012/OKYVRES-5 and Arka Anamika.
- The susceptible check variety, Pusa Sawani recorded significantly highest incidence of 98.64% and was *statistical at par* with 2012/OKYVRES-3, 2012/OKYVRES-4, 2012/OKYVRES-6, Kashi Pragati and Arka Abhay (94.41 to 97.94%) at 60 DAS.
- At 75 DAS, only 2012/OKYVRES-1 recorded significantly lowest incidence of YVMV (0.00%) than other genotypes. The nest best genotype was 2012/OKYVRES-2 (15.58%).

- The susceptible check variety, Pusa Sawani and 2012/OKYVRES-3 recorded significantly highest incidence of 100.00 % and was *statistical at par* with 2012/OKYVRES-4, 2012/OKYVRES-6, Kashi Pragati and Arka Abhay (98.72 to 99.29 %) at 75 DAS .
- At 90 DAS of crop growth stage, only the genotypes, 2012/OKYVRES-1 showed significantly lowest incidence of YVMV (0.00%) than rest other genotypes. The next best genotypes was 2012/OKYVRES-2 with only 20.30% incidence. All other genotypes were affected by YVMV significantly from 96.10 to 100.00%.
- Significantly highest fruit reducing sugar (3.54%) was observed in 2012/OKYVRES-1.
- Significantly maximum non-reducing and total sugar content of fruit was observed in genotype, 2012/OKYVRES-6 than other genotypes.
- Significantly highest fruit crude protein was recorded in genotype, 2012/OKYVRES-3 (16.34%) followed by Pusa Sawani (16.21%) than rest of the genotypes.
- Arka Abhay recorded significantly lowest fruit hardness (81.33mm) and was *statistically at par* with 2012/OKYVRES-1, 2012/OKYVRES-6 and Pusa Sawani.
- Genetic variability studies indicated wide range of variations for all the characters revealed through statistics of mean, range and coefficient of variation.
- High variability (CV of > 10%) was observed for fruit length (11.70), fruit dry weight (11.84), fruit yield (q ha^{-1}) (12.28), fruit yield (kg $plot^{-1}$) (12.28), node at which 1^{st} flower appeared (12.99), fruit weight (13.11), ridges $fruit^{-1}$ (13.17), fruits $plant^{-1}$ (13.44), incidence of YVMV at 30,45 & 60 DAS (84.58,13.50 & 15.69) and fruit weight $plant^{-1}$ (14.12).
- The PCV was higher than GCV for all the characters under study.
- Relatively higher PCV was observed fruits $plant^{-1}$ (41.84%), fruit weight $plant^{-1}$ (53.55%), fruit yield $plot^{-1}$ (kg) (46.46%), fruit yield(q ha^{-1}) (46.47%), as well as incidence of YVMV at 30,45,60,75 and 90 DAS(46.59 to 75.74%). The parameters such as plant height (10.27%), fruits $plant^{-1}$ (5.60%), fruit weight $plant^{-1}$ (3.52%), ridges $fruit^{-1}$ (3.68%), fruit crude protein (3.79%), reducing sugar (0.50%), non-reducing sugar (1.73%) and total sugar (0.73%) showing the minimum difference between GCV and PCV
- High heritability (> 60%) were observed in traits like days to 50% flowering (69.93%), plant height (82.83%), fruits $plant^{-1}$ (89.68%), fruit crude protein (92.87%),fruit yield qha^{-1} (93.05%),fruit yield (kg $plot)^{-1}$ (93.07%), fruit weight $plant^{-1}$ (93.32%), ridges $fruit^{-1}$ (93.49%), fruit non-reducing sugar (96.67%),fruit

reducing sugar (98.97%),as well as incidence of incidence of YVMV at 45,60,75 and 90DAS (96.59%,91.13%,98.54% and 99.51%, respectively).

- ❖ High GA was observed for incidence of YVMV at 45 to 90 DAS (72.47 to 78.24), fruit plant^{-1} (63.05), fruit yield (qha^{-1}) (66.25) and plant height (32.93).
- ❖ High expected GAM by selection (> 60%) was observed for incidence of YVMV at 45,60,75,and 90 DAS (95.52 to 145.50%), fruit non reducing sugar (77.50%), fruits plant^{-1} (77.29%), fruit yield(kg plot^{-1}) (89.08), and fruit weight plant^{-1}(102.96%).
- ❖ Relatively higher values were observed for GCV, heritability and predicted GA together for traits like fruit weight plant-^{1} , fruit yield (qha^{-1}), incidence of YVMV at 45, 60,75,90 DAS.
- ❖ Significant and positive correlation were observed for fruit yield (kg plot^{-1}) with fruits plant^{-1} (0.943),ridges fruit^{-1}(0.676), fruit weight plant^{-1} (0.905), fruit length(0.602), fruit weight(0.604), days to 1st harvest(0.392), and fruit dry weight(0.584).
- ❖ The fruit yield (kg plot^{-1}) was significant but negatively correlated with node at which first flower appeared (-0.364), fruit crude protein (-0.662), and non-reducing sugar content (-0.428), as well as incidence of YVMV at 30 and 45 DAS (-0.531 and -0.490).
- ❖ Fruits plant-^{1}(0.723), fruit weight (0.279), incidence of YVMV at 60 (0.886) and 90 DAS (0.387) had maximum positive direct effect on fruit yield (kg plot^{-1}) of okra.
- ❖ Nodes plant^{-1} (-0.034), crop duration (-0.210), incidence of YVMV at 75 DAS (-0.986), length (-0.013), and girth (-0.286) of fruits had negative direct effect.
- ❖ The cluster-I comprise of 7 genotypes, *viz;* 2012/OKYVRES-1, 2012/OKYVRES-4, 2012/OKYVRES-6, Kashi Pragati, Pusa Sawani, Arka Anamika and Arka Abhay while cluster II (2012/OKYVRES-5), III (2012/OKYVRES-3) and IV (2012/OKYVRES-2) consisted of one genotypes each.
- ❖ Cluster II had the minimum intra-cluster distance (D^2 = 0.00) whereas maximum intra-cluster distance (D^2 = 777.24) was observed in Cluster I.
- ❖ The most divergent clusters were Cluster II and IV (D^2 = 9582.65), followed by Cluster II and III (D^2 = 8741.88) and Cluster I and II (D^2= 6683.23).
- ❖ Cluster II having one genotype showed the maximum values for node plant^{-1} (22.20), ridges fruit^{-1} (7.00), fruits plant^{-1} (20.75), fruit weight plant^{-1} (141.59g), fruit weight (23.20g), fruit length (13.88 cm), fruit yield (11.50 kg plot^{-1}) and dry weight of fruits (10.80g) with minimum value for node at which 1st flower appeared (4.66) and incidence of YVMV at 30 DAS (0.00%).

CONCLUSION

The salient results of the present investigation entitled, **"Screening of Okra *(Abelmoschus esculentus* (L.) Moench) germplasm against Okra Yellow Vein Mosaic Virus disease under field condition"** have shown significantly positive effect on screening of better genotypes for growth and fruit yield with resistance &/or tolerance to YVMV. The following conclusions were made from the present study.

- The genotype, 2012/OKYVRES-1was identified as most resistant line with 0.00% incidence of YVMV disease at all the stages of crop growth in okra.
- Similarly, the genotype, 2012/OKYVRES-5 was identified as most superior genotype with significantly highest fruit yield attributing parameters and fruit yield (11.50kg plot^{-1} and 141.98qha^{-1}) having moderately better fruit quality. The genotypes also showed tolerance to incidence of YVMV up to 45 to 60 DAS.
- The next best genotype identified was 2012/OKYVRES-2 with better vegetative growth, fruit yield and yield attributes parameters along with resistance to YVMV (0.00 to 20.30% of incidence at 30 to 90 DAS) under field conditions.
- Direct selection through traits like fruit weight plant-^{1,} fruit yield (qha^{-1}), incidence of YVMV at 45, 60, 75 and 90 DAS will be effective for improvement in okra especially to develop a genotype having tolerance and/or resistance to YVMV.
- Fruits plant^{-1}, fruit length, fruit weight, fruit weight plant^{-1}, fruit dry weight and days to 1st harvest, being positive and significantly correlated, hence will be consider for improvements in okra. Further, as incidence of YVMV at 30 and 45 DAS are significant and negatively correlated, hence, due emphasis should be given to isolate the genotypes infected by YVMV within 45 DAS for disease resistance breeding.
- Besides direct selection for fruit yield indirect selection through fruits plant^{-1}, fruit weight and incidence of YVMV at 60 and 90 DAS should be considered for further improvement in fruit yield of okra with tolerance to YVMV.
- Being most divergent Cluster-II (2012/OKYVRES-5) and IV (2012/OKYVRES-2), hence expected hybridization between these two genotypes might result in highly heterotic hybrid and thus, produced wide spectrum variation in segregating generation. Incidence of YVMV is contributing maximum towards divergence suggested that special attention should given to this character while designing crop improvement programme in okra.

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