# BREEDING FOR YELLOW VEIN MOSAIC VIRUS (YVMV) RESISTANCE IN OKRA

## [*Abelmoschus esculentus* (L.) Moench]


***by***

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**(2018-12-001)**


**THESIS**

**Submitted in partial fulfilment of the requirement for the degree of**

*Master of Science in Horticulture*

**(VEGETABLE SCIENCE)**

**Faculty of Agriculture**

**Kerala Agricultural University**



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**COLLEGE OF HORTICULTURE**

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**VELLANIKKARA, THRISSUR – 680 656**

**KERALA, INDIA**


**2020**

# DECLARATION

I, hereby declare that this thesis entitled **"Breeding for Yellow Vein Mosaic Virus (YVMV) resistance in okra [*Abelmoschus esculentus* (L.) Moench]"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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# CERTIFICATE

Certified that this thesis entitled **"Breeding for Yellow Vein Mosaic Virus (YVMV) resistance in okra [*Abelmoschus esculentus* (L.) Moench]"** is a bonafide record of research work done independently by **Ms. Alphy Mathew (2018-12-001)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to her.

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# ACKNOWLEDGEMENT

*First and foremost, I owe my heartfelt gratitude towards the* ***Almighty God*** *for all the blessing showered upon me to complete the thesis work successfully ahead of all the odds I faced.*

*My words cannot express the deep sense of immeasurable gratitude and undoubtful indebtedness to* ***Dr. T. Pradeepkumar,*** *Professor and Head, Department of Vegetable Science, chairman of my advisory committee. With great respect and devotion, I wish to place my heartfelt thanks to him for the inspiring guidance, untiring interest, unstinted co- operation, esteemed advice, constructive criticism, valuable suggestion and immense help rendered by him during the investigation and preparation of the thesis. I am genuinely indebted to him for the constant encouragement and affectionate advice rendered throughout the academic programme.*

*I would like to express my extreme indebtedness and obligation to* ***Dr. Anita Cherian K.,*** *Professor and Head, Department of Plant Pathology, College of Horticulture, Vellanikkara, member of my advisory committee for her meticulous help, unwavering encouragement, timely support and critical evaluation.*

*I am ever grateful to* ***Dr. Minimol J. S.,*** *Associate Professor, Department of Plant Breeding and Genetics, Cocoa Research Centre, Vellanikkara for her valuable help and guidance rendered throughout the period of the research work.*

*I express my heartiest gratitude to* ***Dr. Sangeeta Kutty M.****, Assistant Professor, Department of Vegetable Science, College of Horticulture, Vellanikkara, member of my advisory committee for her relentless support and valuable suggestions throughout the course of study.*

*I wish to extend my heartfelt thanks to my beloved teachers* ***Dr. P. Indira, Dr. P. Anitha, Dr. Dicto Jose*** *and* ***Dr. Ashwini A.*** *of Department of Vegetable Science for their encouragement, valuable help, and friendly suggestions rendered during the course of study.*

*I am thankful to the research associates of Department of Vegetable Science especially* ***Geethu chechi, Veni chechi*** *and* ***Varun chettan*** *for their whole hearted cooperation and timely assistance. I also cordially acknowledge the assistance extended by all the field and office staff for timely and sincere help, especially* ***Pradeep chettan, Shali chechi*** *and all.*

*I duly acknowledge the encouragement and timely persuasions and precious suggestions by my dear classmate,* ***Nidhin Raj.*** *I thank my dear friends* ***Anjukrishna V. U., Harithalekshmi V., Aswathi K. P., Arya P. J., Darshana, Neethu R. S., Alfiya A. R., Harya Krishna, Riya*** *and* ***Ashwini S.*** *for their affection and innumerable help and support.*

*I have infinite pleasure to express whole hearted thanks to my dear seniors* ***Archana chechi, Minnu chechi, Anju chechi, Athulya chechi, Anita chechi, Shilpa chechi, Remzeena chechi*** *and* ***Divya chechi*** *for their encouragement, moral support and timely assistance.*

*Special word of thanks to my juniors* ***Arya K. S., Arya S., and Anu Latha Robi*** *for their prompt help and co- operation during the entire period of study.*

*I express my deep sense of gratitude to* ***Kerala Agricultural University*** *for the financial support offered during the study period.*

*I take this opportunity to extend my gratitude to* ***Dr. A. T. Francis,*** *Librarian of the KAU central library.*

*I am in dearth of words to express my love towards* ***my beloved parents and siblings*** *for their boundless affection, moral support, deep concern, prayers and personal sacrifices, without which this endeavour would never have become a reality.*

*It would be impossible to list out all those who have helped me in one way or another, for the completion of my work. I once again express my heartfelt thanks to all those who helped me in completing my work on time. Thanking the Almighty.*

***Alphy Mathew***

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# *Introduction*

# 1. INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) is an economically important vegetable crop grown all over the world. It is known as lady's finger in England, guino-gombo in Spanish, guibero in Portuguese and Bamia in Middle East (Ndunguru and Rajabu, 2004). The common names in India are Bhindi (Hindi), Dhenras (Bengali), Vendai (Tamil), bhindo (Gujarati), Bendekayi (Kannada), Ventaykka (Malayalam), Asra-pattraka (Sanskrit) *etc.*

The genus *Abelmoschus* consists of both cultivated and several wild or semi-wild species of okra. According to the classification followed by IBPGR (1991), the genus consist of *A. esculentus, A. moschatus, A. manihot, A. tuberculatus, A. angulosus, A. tetraphyllus, A. caillei, A. ficulneus* and *A. crinitus*. The most widely cultivated species of okra is *A. esculentus.* Medikus (1787) cited by Sharma (1993) stated that okra was earlier included in the genus *Hibiscus*. Later, it was designated to *Abelmoschus,* which is distinct from the genus *Hibiscus*.

Okra is a cultigen (a plant that has been altered by humans through a process of selective breeding) which belongs to the family Malvaceae. Okra is believed to have originated in Africa (Ethiopia). However, disputes regarding this exist between different authors. The chromosome number (2n) of okra have been variably reported by different authors. However, the most commonly observed somatic chromosome number is 2n=130. Okra is probably an amphidiploid or allotetraploid derived from *Abelmoschus tuberculatus* (2n = 58), a wild species from India, and a species with 2n = 72 chromosomes (possibly *Abelmoschus ficulneus*) (Kumar *et al*., 2013).

Okra is an annual vegetable, popular in India, Turkey, Iran, Western Africa, Yugoslavia, Bangladesh, Afghanistan, Pakistan, Burma, Japan, Malaysia, Brazil, Ghana, Ethiopia, Cyprus and the southern United States. India ranks first in area and production of okra in the world. In India, it is grown in an area of 511 ha with an annual production of 6219 MT. The major okra producing states are Gujarat, West Bengal, Bihar, Madhya Pradesh, Odisha *etc.* (NHB Database, 2018-19).

Okra is a potential multipurpose crop grown in the tropics, subtropics and warm temperate regions of the world. It is mainly grown for its tender fruits. The mature okra

seed is a good source of oil and protein (Karakoltsidis and Constantinides, 1975). Seed oil is rich in unsaturated fatty acids such as linoleic acid, which is essential for human nutrition. The crude fibre obtained from mature fruits and stem is used in paper industry. The mucilage obtained from roots and stems of okra are used for clarification of sugarcane juice (Chavan *et al*., 2007). Okra fruit is a good source of protein, carbohydrates, vitamins, calcium, potassium, enzymes, and minerals. The composition of okra pods per 100 g edible portion is: water 88.6 g, energy 144.00 kJ (36 kcal), protein 2.10 g, carbohydrate 8.20 g, fat 0.20 g, fibre 1.70 g, Ca 84.00 mg, P 90.00 mg, Fe 1.20 mg, β-carotene 185.00 µg, riboflavin 0.08 mg, thiamine 0.04 mg, niacin 0.60 mg, ascorbic acid 47.00 mg *etc*. (Gemede *et al*., 2014).

Okra has perfect flowers and is a self pollinated crop, however insects such as honey bees and bumble bees can effect cross pollination in okra. Cross pollination up to the extent of 4-19 per cent and maximum of 42.2 per cent has been reported in okra (Tripathi *et al*., 2011). The extent of cross-pollination in a particular location depends upon the cultivar, competitive flora, insect population and season.

The production of okra is constrained by the incidence of various pests and diseases. Shoot and fruit borer, leaf folder, jassids, whiteflies, *etc.* are some of the insect pests infesting okra. The important fungal diseases affecting okra are powdery mildew (*Erysiphe cichoracearum*), damping off (*Pythium* sp., *Rhizoctonia* sp.), *Fusarium* wilt (*Fusarium oxysporum* f. sp. vasinfectum), *Cercospora* leaf spot (*Cercospora abelmoschi* and *C. malayensis*) *etc*. However, the incidence of viral disease poses serious constraints to the production and profitability of okra. Okra is susceptible to different plant viruses like Yellow vein mosaic virus, Enation leaf curl virus, Okra yellow crinkle virus, Leaf curl virus *etc*.

Yellow Vein Mosaic Disease (YVMD) is the major constraint in okra cultivation. It is caused by Yellow Vein Mosaic Virus (YVMV), which belongs to the family Geminiviridae and is transmitted by whiteflies. The disease is characterized by homogeneous interwoven network of yellow veins enclosing islands of green tissues. Yield loss due to the disease ranges from 50 to 94 per cent depending upon the stage of crop at which infection occurs (Sastry and Singh, 1974).

The disease affects the quality of fruit and yield adversely. It cannot be controlled by the application of chemicals also, uprooting of infected plants is not practical and economical because of heavy infection rate in the field. Hence, the only pragmatic solution to this problem is to evolve tolerant or resistant varieties. The existing varieties released by KAU are susceptible to YVMD, except 'Susthira' which is not preferred by farmers due to its poor market appeal.

In this background, the present study entitled "Breeding for Yellow Vein Mosaic Virus (YVMV) resistance in okra [*Abelmoschus esculentus* (L.) Moench]" was taken up with the objective of evaluating and identifying resistant varieties/lines of okra against Yellow vein mosaic disease for augmenting effective resistant breeding programme in okra.

# *Review of literature*

# 2. REVIEW OF LITERATURE

Okra is one of the important vegetable crops grown in India and YVMD is the major constraint in its production. Breeding okra cultivars resistant to YVMV appears to be one of the best approaches in disease management. Resistant or tolerant varieties can be developed by transferring resistant genes from cultivated or wild species of okra through interspecific hybridization followed by selection of promising lines. The available literature concerning the research topic 'Breeding for Yellow Vein Mosaic Virus (YVMV) resistance in okra [*Abelmoschus esculentus* (L.) Moench]' is presented under the following headings:

2.1 Yellow Vein Mosaic Disease (YVMD) in okra

2.2 Influence of YVMD on plant growth and yield of okra

2.3 Screening of okra genotypes against Yellow Vein Mosaic Disease (YVMD)

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## 2.1 Yellow Vein Mosaic Disease (YVMD) in okra

Yellow vein mosaic is one of the most dreadful diseases affecting okra. The earliest report of this disease came from Bombay in India (Kulkarni, 1924). The warm tropical climate in India which favours the survival of whiteflies renders okra cultivation more vulnerable to YVMD. Now, this disease has spread across different countries.

The disease is caused by a complex consisting of the monopartite begomovirus, Okra Yellow Vein Mosaic Virus (OYVMV, family: Geminiviridae) and a small

satellite DNA beta component (Jose and Usha, 2003). The cultivation of okra is greatly constrained by this disease as it causes significant reduction in the yield and quality of fruits.

Under field conditions, the infected okra plants exhibits three types of symptoms depending upon the stage at which infection occurs. In the first type, leaves of plants infected very early in the season become complete yellow and later turn brown and dry up. In the second type, infection starts after flowering. Upper leaves and flowering parts show vein clearing symptoms. The number of fruits produced by infected plants will be less, and they became yellow and hard at picking stage. In third type, infection occurs towards the end of the cropping season, few small young shoots appear at the basal portion of the stem, which shows vein clearing. However, in such plants yield was comparable to healthy plants (Venkataravanappa *et al*., 2013).

Venkataravanappa (2008) conducted a survey on begomoviruses associated with okra in India and revealed that the occurrence of YVMD incidence ranged from 23.0 to 67.67 per cent in Karnataka, 45.89 to 56.78 per cent in Andhra Pradesh, 23 to 75.64 per cent in Tamil Nadu, 42.45 to 75.64 per cent in Kerala, 23 to 85.64 per cent in Maharashtra, 24.85 to 65.78 per cent in Haryana, 35.76 to 57 per cent in Uttar Pradesh, 45.45 per cent in Delhi, 67.78 per cent in Chandigarh and 45.89 to 66.78 per cent in Rajasthan.

During the past two decades several resistant varieties have been developed which were giving sustainable high yields in virus prone areas. However, recently, frequent break down of the YVMV resistance have been observed in popular varieties like Parbhani Kranti, Punjab 7, Arka Anamika and Arka Abhay all over the country probably due to appearance of new strains of viruses or due to recombination in virus strain (Sanwal *et al*., 2016).

**2.2 Influence of YVMD on plant growth and yield of okra**

The early attack of this virus can cause total yield loss in okra and late attack reduces the fruit yield by over 25 per cent (Capoor and Varma, 1950). The fruit yield was reduced to 84 and 49 per cent if infected at 50 and 65 days after germination respectively (Sastry and Singh, 1974) and up to 96 per cent if infected at an early stage

(Pun and Doraiswamy, 1999). The extent of losses decrease with delay in infection of pathogens.

Ndunguru and Rajabu (2004) assessed the yield loss due to the disease in the fields with disease incidence between 30 and 89 per cent and noted significant variation in the yield components of diseased and healthy plants. Compared to healthy ones, plant height was reduced by 19.5 per cent, number of fruits by 34.7 per cent and petiole length by 32.1 per cent in diseased plants. However, stem girth was enlarged by 27 per cent in diseased plants.

Chattopadhyay *et al*. (2011) revealed that seed yield in okra was highly influenced by the incidence of YVMD and higher yield was obtained during disease free period, particularly between February and March.

The virus infection causes significant variation in the above ground and below ground components between the diseased and healthy plants. The height of the diseased plant was reduced by 24 per cent, number of fruits by 32 per cent, fruit length by 31 per cent, stem girth by 16 per cent and root length by 50 per cent. Fruit malformation was also observed in diseased plants (Sheikh *et al*., 2013).

According to Khaskheli *et al.* (2017) the diseased plants showed significant reduction in plant height, flowers, fruits, number of harvests and yield. However, the number of leaves showed a significant increase in diseased plants compared to healthy plants.

### 2.3 Screening of okra genotypes against Yellow Vein Mosaic Disease (YVMD)

The availability of a suitable source of resistance within a cultivated species itself or in related wild species is the necessary prerequisite for improving disease resistance. The resistance occurring within cultivated species is more desirable as this can be more easily transferred to an otherwise superior but susceptible variety. Screening of genotypes provides an idea in identification of stable source of resistance for YVMV in okra which can be utilized for development of disease resistant cultivars.

Batra and Singh (2000) screened eight open pollinated okra varieties (Okra No.-6, HOE-202, HOE-301, LORM-1, VRO-3, VRO-4, D-1-87-5 and P-7), six hybrids

(AROH-8, AROH-9, DVR-1, DVR-2, JOH-5 and Parbhani Kranti) and Pusa Sawani (control) against YVMV. The results revealed that Okra No.-6, LORM-1, VRO-3, P-7, DVR-1 and DVR-2 were found free from disease reaction and VRO-4 showed mild reaction.

Rashid *et al*. (2002) evaluated 12 okra germplasm under field conditions and found that the lines OK-292 and OK-285 were resistant to YVMV in both seasons. The lines OK-315, OK-316 and OK-317 were found to be tolerant.

Screening of 941 germplasm accessions of okra for disease resistance revealed that none of the accessions were immune or highly resistant, 43 were moderately resistant, three accessions *viz*., IC 218887, IC 69286 and EC 305619 were resistant and the rest were susceptible (Nizar *et al.*, 2004).

Ali *et al.* (2005) evaluated the resistance of four commercially grown okra varieties of Pakistan (Pahuja, Safal, Subz Pari and Surkh Bhindi) against YVMD. The results revealed that none of the varieties evaluated were found to be immune. Surkh Bhindi showed resistant response to OYVMV with only 3.30 per cent plant infection, Subz Pari and Safal showed moderately resistant response while Pahuja was tolerant.

Singh *et al.* (2007) identified three lines of okra namely, COS-05-25, Arka Anamika and Punjab-7 as a reliable source of resistance against YVMV under subtropical conditions.

Bhattiprolu and Rahman (2008) evaluated 12 okra entries during *kharif* season and found that VRO-4 showed minimum disease incidence followed by P-7, LORM 1 and VRO- 3 respectively while the check Pusa Sawani recorded the maximum PDI.

Mehra *et al.* (2008) evaluated 29 germplasm collection of okra under field conditions. The promising lines which showed resistance under field conditions were tested under protected conditions. Six okra entries (Arka Abhay, Arka Anamika, SOH-150, TC-17, P-7, NOH-147, NOL-101, NOH-15, ZCH-3002 and US-7109) were found totally resistant to YVMV both under field as well as under artificial inoculation conditions.

Prashanth *et al.* (2008) performed an experiment to screen 55 okra genotypes against YVMD. Five genotypes (EC 305647, EC 305633, EC 329424, IC 90273 and IC 90269) were categorised as highly resistant and 13 genotypes (EC 305625, EC 305646, EC 305650, EC 305649, EC 316046, EC 329375, EC 329369, EC 329411, IC 90178, IC 90263, IC 128146, IC 117204 and DVR-3) were categorised as resistant.

Deshmukh *et al.* (2011) conducted field screening during *kharif* and summer seasons of 2004-2007 to identify new resistant sources for YVMD. The promising genotypes were also screened using graft inoculation and vector transmission techniques for confirmation of resistance. The results revealed that NOL-285 was found highly resistant and its performance was consistent.

Venkataravanappa *et al.* (2013) evaluated 20 genotypes of okra under both natural and artificial conditions and found that Nun 1144 and Nun 1145 were moderately resistant. The genotypes M10, Nun 1140, Nun 1142 and Nun 1143 were moderately susceptible to the virus, whereas in other genotypes reaction ranged from susceptible to highly susceptible.

Tiwari *et al*. (2012) screened five okra varieties (Pusa Sawani, Pusa Makhmali, VRO-6, VRO-3, HRB-9-2) against YVMD during rainy season for two years. The results revealed that the variety VRO-6 had high degree of resistance and varieties VRO-3 and HRB-9-2 had moderate resistance towards the disease.

Vijaya and Joshi (2013) screened 11 okra genotypes against YVMV and found that the genotypes VRO-6 and JOL-2K-19 were found to be promising in terms of mild YVMV incidence and maximum fruit yield.

Saurabh *et al.* (2016) evaluated 19 okra varieties during summer and *kharif* season and found that Soumya F1 (OH-4002) and Hybrid No.-10 was moderately resistant, while Hybrid No-8 was resistant to OYVMV.

Solankey *et al*. (2014) carried out screening of 91 okra genotypes during summer and rainy season of 2012 and 2013. The results revealed that, six genotypes (IIHR123, IC 90381, IC 140982, 1C 141065, IIHR1 and Kavya) were highly resistant during both the seasons.

The results of screening experiment conducted by Talaviya *et al.* (2014) revealed that none of the genotypes were found to be completely free or immune, whereas two genotypes (JOL-08-5, AOL-08-2) were highly resistant, while one genotype (JOL-07-12-15) was moderately resistant and seven genotypes (JOL-7-K-3, JOL-07K-13, AOL-05-1, JOL-07-16, JOL-07-K16 and JOL-09-8) were tolerant against YVMV.

Meena *et al.* (2015) evaluated 98 lines of okra and found that the lines OK 292 and OK 285 can be used as resistant source to YVMV. Six lines of okra, *viz*., AO:109, AO:118, AO:133, AO:151, AO:189 were completely free from BYVMV (highly resistant).

Kumar *et al.* (2015) evaluated 30 okra genotypes for yield and YVMD resistance. The genotypes IIHR 129, IIHR 123, IIHR 112, IC 14845B, IC 14600, IIHR 120, IIHR 53 and IIHR 113 were found promising due to their high yield and lower YVMV incidence.

Eighteen okra genotypes were screened for YVMV resistance for two consecutive years during *kharif* season by Kumar and Raju (2017). During both the years VRO-6 and IIVR-11 were found resistant while Pusa Sawani was found highly susceptible.

Kumar and Tayde (2018) screened eight okra genotypes under field conditions and revealed that the genotype VRO-5 showed completely free or immune reaction. The genotypes IC 117216, IC 140934 and Parbhani Kranti (check) were moderately resistant while IC 433695 and IC 140906 were tolerant to YVMV.

Field screening studies for OYVMV resistance were conducted with 25 okra germplasm accessions during summer season of 2015 and 2016. One wild accession IC 344598 and two cultivated accessions *viz.*, PSRJ-12952 and RJR-124 did not show any signs of OYVMV infection throughout the crop period and exhibited immune reaction while, PSRJ-13040 and RJR-193 exhibited a highly susceptible reaction (Manjua *et al*., 2018).

Kumari *et al.* (2018) assessed 20 okra genotypes including four checks Kashi Kranti, Kashi Satdhari, Kashi Lalima and Arka Anamika under open field conditions in rainy season. The lowest percent disease incidence was observed in Kashi Kranti followed by Kashi Satdhari, Kashi Lalima, Kashi Mohini and Punjab-8, respectively at 45 days after sowing.

Screening of 32 okra genotypes were carried out under open field condition in rainy season by Kumari *et al.* (2018). The results revealed that the genotypes IIVR-11, checks- Pusa A-4 and GS-123 were highly resistant and Kashi Kranti, 135-10-1 and EC 169459 were found resistant. Two genotypes IC 69304 and IC 282240 were susceptible and Pusa Sawani exhibited highly susceptible reaction.

Five parents (AE 64, AE 65, AE 66, Kashi Pragati and VRO 106) and 20 hybrids were screened for YVMD by Rynjah *et al.* (2018). The genotypes AE 64, AE 65 and AE 66 were found immune to the disease. Among the hybrids, the cross combinations of AE 64 x AE 65, AE 64 x AE 66, AE 65 x AE 64, AE 65 x AE 66 and AE 66 x AE 64 did not express any disease symptoms.

Jamir *et al.* (2020) screened 565 okra genotypes against YVMV and OLCV and found that only BCO-1 was found resistant against YVMV disease. All the other genotypes including Arka Anamika were found susceptible to YVMV.

Kolakar *et al.* (2018) evaluated 50 okra genotypes under field conditions in Karnataka. The results revealed that four lines were highly resistant (IC 43735, VRO-103, IC 45818 and IC 45980), nine lines were moderately resistant, 13 lines were tolerant, 20 lines were moderately susceptible and four lines were susceptible to the disease.

Karthika and Maheshwari (2019) screened thirty genotypes of bhindi for YVMD resistance during summer season. The results revealed that IC 043750, IC 045792, IC 069304 and IC 282228 were immune to YVMD incidence, while IC 113904, IC 282233, IC 113922, IC 282238, IC 218881 and IC 282243 showed moderately resistant reaction. All the other genotypes were susceptible to the disease.

Sarkar *et al.* (2019) studied variation in the susceptibility of 14 okra genotypes to YVMD under field conditions and observed that 2014/OKYV RES5, 2014/OKYV RES-1, 2014/OKYV RES-3, 2014/OKYV RES-6, 2014/OKYV RES-10, 2014/OKYV RES-9 and 2014/OKYV RES-4 were found highly resistant while VRO-6 and 2014/OKYV RES-7 were highly susceptible to YVMV.

## 2.4 Transmission of Yellow Vein Mosaic Virus (YVMV)

Bhindi yellow vein mosaic virus is not seed borne and sap transmissible. They are also not transmitted by dodders (Capoor and Varma, 1950). Under natural conditions, they are transmitted by whiteflies (*Bemisia tabaci*) in a semi persistent manner. However, graft transmission of this virus is also possible.

### *2.4.1 Whitefly transmission*

Whitefly feeding is required for acquisition and inoculation of this virus, and they are unable or cannot be easily transmitted by other means.

Capoor and Varma (1950) revealed that, a minimum of 10-120 minutes inoculation is needed by the whiteflies and the symptoms will be noted after about 15-20 days. He also revealed that, not only the adult whiteflies but nymphs also have the ability to transmit the virus.

Female whiteflies were six times as efficient as males in transmitting the whitefly-borne Tomato yellow leaf curl virus in Israel. The minimum acquisition and inoculation feeding periods were 15-30 minutes and latent period in the vector was at least 21 hours (Czosnek, 2001).

According to Mehra *et al*. (2008), an inoculation feeding period of 24 h on diseased plants, infection feeding period of 24 h on healthy plants and ten virus-charged whiteflies were needed for the transmission of YVMV.

The minimum number of whiteflies required to induce 100 per cent infection is 10 per plant, although a single whitefly can transmit the virus effectively (Sanwal *et al*., 2016).

Naik *et al*. (2019) revealed that a single whitefly can transmit the virus to an extent of 19.5 per cent with an incubation period of 13.75 days while, fifteen whiteflies can transmit 100 per cent virus within 6.15 days of incubation. Minimum 16 min Acquisition Access Feeding Period (AAFP) is required for whiteflies to become viruliferous resulting in 15.65 per cent transmission while, Inoculation Access Feeding Period (IAFP) of 30 min resulted in 47.25 per cent transmission and IAFP of 3 h or more resulted in 100 per cent disease transmission which lead to the conclusion that as IAFP increased, the incubation period of virus decreased.

### *2.4.2 Graft transmission*

The resistance of okra genotypes to YVMV can be confirmed by graft transmission technique.

Ali *et al*. (2000) tested the transmissibility of YVMV through graft transmission. Two weeks old healthy seedlings of 'IPSA Okra 1' (tolerant) were grafted with the same aged seedlings of 'SL-44' (susceptible) and Parbhani Kranti through tongue approach grafting technique. The results revealed that all susceptible component of graft combination produced disease symptoms however none of the tolerant components produced any symptom which indicated the failure of transmission of YVMV through graft union. From this, it may be concluded that the tolerance in the variety IPSA Okra 1 is genetic and not due to escape.

Samarjeewa and Rathnayaka (2004) conducted graft transmission studies in three wild (*A. angulosus, A. ficulneus* and *A. moschatus*) and five cultivated species (MI-5, MI-7, Haritha, Parbhani Kranti and Pusa Sawani) of *Abelmoschus*. Infected plants of the cultivar Athupaha was used as source of virus and wedge grafting method was adopted. The results revealed that MI-5, MI-7, Parbhani Kranti and Pusa Sawani were highly susceptible and only *A. angulosus* showed complete resistance to YVMV.

Deshmukh *et al*. (2011) conducted graft inoculation studies on 10 different genotypes of okra (NOL-364, NOL-303, NOL-285, NOL-260, NOL-231, NOL-52-1, NOL-145, NOL-2-1, Parbhani Kranti and Pusa Sawani). 21 days old plants of these genotypes were grafted using 2 cm scion obtained from YVMV infected plants and disease symptoms were observed four weeks after grafting.

## 2.5 Influence of environmental factors and season on disease incidence

Environmental factors had great impact on disease incidence and white fly population in okra. The severity of YVMV varies from season to season, year to year and location to location especially in case of genotypes which do not exhibit stable resistance. The varying level of disease severity could be associated to the climatic conditions especially temperature and humidity which directly influences the population of vector. Due to the variations in climatic conditions of different geographic locations the disease incidence also varies.

In South India, the occurrence of YVMD and whitefly is highest in the month of March in contrast to the lesser incidence during cooler months. This may be due to the fact that hot and dry weather conditions favour fast spread of YVMD and multiplication of whiteflies. Cooler weather with high relative humidity and rainfall were detrimental for the multiplication of whitefly and spread of YVMD (Singh, 1990).

Ali *et al.* (2005) revealed that minimum temperature and relative humidity had significant correlation with OYVMV disease severity and whitefly population. The disease incidence increased with the rise in minimum temperature and whitefly population decreased with increase in the relative humidity.

Nath *et al*. (2007) studied the effect of sowing dates on the incidence of YVMV and whitefly population in the plains of West Bengal and observed no disease incidence in crops under six sowing dates from last week of November to first week of February. The lowest whitefly population was recorded in December sown and continued up to April sown crop. Thereafter, the whitefly population increased and was maintained at higher level up to November in two varieties.

The sowing date of crop have remarkable role in the incidence of YVMD and vector population. The crop sown in the month of March, April, May, June and July recorded more whitefly and disease incidence compared to the crop sown in other months (Magar and Nirmal, 2010).

Deshmukh *et al*. (2011) revealed that the incidence of YVMD was more in summer than *kharif* season. The per cent disease during *kharif* ranged from 0 to 58.64 per cent and in summer it varied from 0 to 98.92 per cent.

In Bihar, the mean incidence of YVMD was low in summer season compared to high incidence in rainy season (Solankey *et al*., 2014).

An extensive survey for incidence of YVMV was carried out in four districts of Pakistan. The incidence of disease was in the range of 51 per cent to 88 per cent. Maximum temperature and relative humidity favoured the disease development and increased the white fly population. The maximum disease incidence and whitefly population was recorded at a temperature of $42^0$ C (Mubeen *et al.,* 2017).

The YVMV incidence was initiated in March (30 DAS) and with the age of the crop the incidence increased progressively and reached maximum during the month of May (harvest stage) for all the varieties. The YVMV incidence has resulted in low yields in all the varieties (Sree *et al.,* 2018).

Kumari *et al*. (2018) revealed that the incidence of YVMV was higher during the months of April and May because of high temperature coupled with high rainfall.

**2.6 Genetics and inheritance of YVMD in okra**

Only a few attempts have been made in the past to study the genetics of resistance to YVMV in okra. All the reports are contradictory to each other and there is no definite report for inheritance of resistance to YVMV.

In India, Singh *et al*. (1962) made the first attempt to understand the nature of inheritance of YVMV resistance. They found that two recessive alleles at two loci conferred resistance in intervarietal crosses of okra. Inheritance studies in the crosses between IC-1542 as the resistant parent and Pusa Makhmali, S-91 and S-72 as susceptible parents suggested that two loci are involved and the presence of dominant alleles at both the loci are necessary for causing susceptibility to disease.

Jambhale and Nerkar (1981) crossed *A. manihot* (L.) Medik and *A. manihot* (L.) Medik ssp. manihot, resistant to YVMD with *A. esculentus* cv. 'Pusa Sawani', a susceptible culture. The hybrids obtained were resistant and partially fertile. Segregation pattern for disease reaction in $F_2$, $BC_2$ and subsequent generations of the two crosses revealed that resistance to YVM is controlled by a single dominant gene in each species.

Ali *et al*. (2000) studied the inheritance pattern of tolerance to YVMV in a cultivar of okra, IPSA Okra 1 by crossing it with three susceptible genotypes *viz*., Parbhani Kranti, SL-44 and SL-46. From the segregation pattern for disease reaction in $F_2$ and $BC_1$ generations of the three crosses, it could be understood that the tolerance to YVMV in IPSA Okra 1 is quantitative and dependent on gene dosage with incompletely dominant gene action.

Arora *et al*. (2008) conducted an experiment with segregating generations of two YVMV resistant cultivars (Punjab-8 and Parbhani Kranti) and two susceptible cultivars (Pusa Sawani and Pusa Makhmali). The qualitative analysis for segregation of resistant and susceptible plants in $F_2$ and back cross generations revealed that the genes governing the resistance in the two resistant parents were different. In the crosses involving resistant x susceptible parents, the presence of single dominant gene along with some minor genes controlling YVMV resistance was confirmed. The quantitative analysis of $F_2$ and back cross generations revealed the presence of additive gene effects for three virus related traits.

The inheritance studies by Seth *et al*. (2017) revealed that tolerance to YVMV disease was conditioned by two duplicate dominant genes in Tolerant x Tolerant cross, and by two complementary dominant genes in Tolerant x Susceptible cross.

Senjam *et al*. (2018) revealed that a single dominant gene along with some minor factors governed the disease tolerance trait in tolerant parents (BCO-1 and Lal Bhindi). However, the genes governing disease tolerance in both the tolerant varieties were different and is genotype specific. Duplicate gene action was evident from the cross of these two tolerant varieties and this gave scope for increasing the tolerance level of the hybrid plants when both the tolerant genes are brought together. However, generation mean analysis revealed involvement of both additive and non additive effects in the inheritance of disease tolerance.

Two resistant (HBT-12 and HB-1157) and two susceptible (HBT-49 and HBT-24) lines were crossed in resistant × susceptible manner to obtain four hybrids, their $F_1$, $F_2$ and backcrosses ($BC_1$ and $BC_2$) to reveal the gene action involved in these resistant lines. Qualitative analysis for YVMV resistance through segregation in the $F_2$ and

backcrosses of four cross combinations revealed the involvement of two complementary dominant genes in HBT-12 and a single dominant gene in HB-1157. The involvement of additive gene action in all these crosses was revealed by quantitative analysis performed for days to first disease appearance via generation mean analysis (Bharathkumar *et al*., 2019).

**2.7 Estimation of genetic variability, heritability and genetic advance in okra**

Dhankhar and Dhankhar (2002) recorded high PCV and GCV for number of branches and fruits per plant, fruit yield and plant height, suggesting that selection may be based on these traits. High heritability coupled with high genetic advance was recorded for all characters except days to 50 per cent flowering.

Mehta *et al*. (2006) observed high GCV, heritability and genetic advance as percentage of mean for fruit yield, average fruit weight, plant height and fruit length which might be attributed to additive gene action resulting in their inheritance.

Singh *et al*. (2006) studied the genetic variability, heritability and genetic advance of 15 quantitative characters in 19 diverse okra genotypes. High PCV and GCV were observed for internodal length, number of branches per plant, number of fruits per plant, number of seeds per pod and fruit yield per plant. High heritability coupled with high genetic advance was exhibited by the characters number of seeds per pod, internodal length, number of branches per plant, fruit yield per plant, number of fruits per plant, plant height and 100 seed weight.

Mohapatra *et al*. (2007) reported high PCV and GCV for plant height, primary branches per plant, height to first fruiting, number of fruits per plant, total yield per plant, internodal length, average fruit weight and number of leaves per plant. High heritability coupled with high genetic advance were observed for plant height and total yield per plant.

Magar and Madrap (2009) observed higher GCV and PCV for fruit yield per plant followed by number of fruits per plant, node at which first flower appear, plant height and fruit weight. The estimates of heritability were of high magnitude for fruit

length and total fruit yield per plant indicating major role of genotype with less environmental influence.

Ramanjinappa *et al.* (2011) estimated high PCV and GCV for plant height and number of branches per plant. The characters *viz*., plant height, number of branches per plant, number of nodes per plant, internodal length, number of fruits per plant, number of seeds per fruit, harvest index and total yield per plant exhibited high heritability along with high genetic advance.

Genetic variability studies on 100 genotypes of okra by Reddy *et al*. (2012) revealed high magnitude of genetic variability and high degree of transmission of majority of the growth, earliness and yield associated traits. High heritability coupled with high expected genetic advance was estimated for the characters like plant height, number of branches per plant, internodal length, days to fifty per cent flowering, first flowering node, first fruiting node, fruit length, fruit weight, total number of fruits per plant, number of marketable fruits per plant, total yield per plant, marketable yield per plant and yellow vein mosaic disease infestation on fruits and plants.

High values of PCV and GCV were observed for the characters *viz.*, number of primary branches and number of fruits per plant which indicated the presence of substantial variability for these characters. High value of heritability coupled with high genetic advance were recorded for the characters *viz.*, leaf axil bearing first fruit, plant height, duration, yield per plant, number of fruits per plant, number of primary branches, fruit weight and fruit length (Duggi *et al*., 2013).

Koundinya *et al.* (2013) revealed that high heritability coupled with high genetic advance as per cent of mean was observed for the characters like plant height, internodal length, fruits per plant, test weight and fruit yield per plant.

Kumar *et al.* (2015) evaluated genetic parameters of 14 traits in okra and found that the magnitude of PCV was higher than that of GCV for all the traits. High value of PCV and GCV were observed for number of branches, number of fruits per plant, fruit yield per plant, per cent disease incidence (PDI) and coefficient of infection (CI). High heritability coupled with high genetic advance as percentage of mean were observed for plant height, number of branches per plant and number of fruits per plant.

Phanikrishna *et al*. (2015) revealed that high heritability coupled with high genetic advance as per cent mean were observed for plant height, internodal length, number of nodes on main stem, first fruiting node, number of ridges, number of pickings, fruit and shoot borer infestation on plants, yellow vein mosaic virus infestation on plants and fruit yield per plant. High heritability along with moderate genetic advance as per cent mean were observed for days to first flowering, days to 50 per cent flowering, fruit width and average fruit weight.

**2.8 Correlation and Path coefficient analysis in okra**

Dhankhar and Dhankhar (2002) observed that fruit yield and number of fruits per plant was significantly and positively correlated with the number of fruits and branches per plant and plant height, but negatively correlated with days to 50 per cent flowering.

Mehta *et al*. (2006) revealed that fruit yield was significant and positively correlated with fruit length and average fruit weight. Path coefficient analysis revealed that fruit girth had the maximum direct effect followed by fruit length towards fruit yield. Thus, fruit yield in okra can be enhanced by selecting for higher fruit length, fruit girth and average fruit weight at the same time.

Total fruit yield per plant had significant and positive correlation with number of fruits per plant, fruit weight and plant height. Path coefficient analysis revealed that number of fruits per plant had maximum direct contribution towards total yield followed by fruit weight, plant height and days to first flowering (Magar and Madrap, 2009).

The results of correlation and path coefficient analysis done by Vijayakumar (2009) revealed that the characters *viz*., average fruit weight, number of ridges per fruit and number of fruits per plant had positive association and direct positive effect on yield per plant.

Duggi (2012) and Kishor (2012) conducted correlation analysis in okra and revealed that number of fruits per plant, average fruit weight and fruit girth had positive association with yield per plant.

The correlation and path coefficient analysis conducted by Reddy *et al*. (2013) revealed that fruit weight, total number of fruits per plant and number of marketable fruits per plant not only had positively significant association and high direct effect on marketable pod yield per plant.

Balai *et al*. (2014) revealed positive association of plant height, fruit length, average fruit weight and number of seeds per fruit with fruit yield per plant.

Kumar *et al*. (2015) revealed that plant height, number of fruits per plant, average fruit weight and days to first flowering had positive correlation with yield per plant while coefficient of infection of YVMV had negative correlation with yield.

The results of correlation analysis conducted by Hareesha (2016) revealed positive association of number of fruits per plant, average fruit weight, number of ridges per fruit, fruit width, fruit length and days to first flowering with yield per plant while, first fruiting node and coefficient of infection of YVMV had negative correlation with yield.

Kumar and Reddy (2016) revealed that total number of fruits per plant and yield per plant had positively significant correlation and high direct effect on marketable pod yield per plant. He also observed that genotypic correlation coefficient of plant height, number of branches per plant, internodal length, fruit length, fruit weight and number of marketable fruits per plant with marketable yield per plant was significantly positive, but their direct effect on marketable yield per plant was negative or negligible suggesting that the indirect casual factors have to be considered simultaneously for selection.

Prasath *et al*. (2017) conducted correlation and path coefficient analysis of fruit yield and yield attributes in okra and found that plant height, number of fruits per plant, internodal length, last harvest, fruit length, fruit girth, fruit weight, number of fruits per plant, number of seeds per fruit, 100 seed weight, number of pickings and iodine content had significant and positive correlation with fruit yield per plant. The results of path coefficient analysis using genotypic correlation coefficient revealed that internodal length, days to 50 per cent flowering, days to last harvest, fruit girth, number of fruits per plant and number of seeds per fruit showed positive direct effect on fruit yield.

Singh *et al.* (2017) disclosed that number of fruits per plant, first fruit producing node and average fruit weight not only had positively significant association with fruit yield but also positive direct effect on yield. He also revealed that fruit width had the highest positive direct effect on fruit yield.

Mahalik (2018) revealed that plant height, average fruit weight and number of fruits per plant had positive association with fruit yield. Path coefficient analysis revealed that number of fruits per plant, fruit length, number of branches, average fruit weight and internodal length had direct positive effect on yield per plant.

# *Materials and methods*

# 3. MATERIALS AND METHODS

The present study entitled 'Breeding for Yellow Vein Mosaic Virus (YVMV) resistance in okra [*Abelmoschus esculentus* (L.) Moench] was carried out at Department of Vegetable Science, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur, during the period of 2018- 2020.

## 3.1. EXPERIMENTAL MATERIAL

The materials used for the study comprised of 34 genotypes of okra (Plate 1). The details of the genotypes are given below.

**Table 1. List of genotypes used for the study**

| Sl. No | Accession No. | Source | Sl. No | Accession No. | Source |
|---|---|---|---|---|---|
| 1 | EC 305635 | NBPGR, Akola | 18 | IC 13995 | NBPGR, Akola |
| 2 | EC 305637 | NBPGR, Akola | 19 | IC 14018 | NBPGR, Akola |
| 3 | EC 305638 | NBPGR, Akola | 20 | IC 14026 | NBPGR, Akola |
| 4 | EC 305639 | NBPGR, Akola | 21 | IC 14096 | NBPGR, Akola |
| 5 | EC 305640 | NBPGR, Akola | 22 | IC 14600 | NBPGR, Akola |
| 6 | EC 305642 | NBPGR, Akola | 23 | IC 14845 | NBPGR, Akola |
| 7 | EC 305643 | NBPGR, Akola | 24 | IC 14909 | NBPGR, Akola |
| 8 | EC 305645 | NBPGR, Akola | 25 | IC 15027 | NBPGR, Akola |
| 9 | EC 305646 | NBPGR, Akola | 26 | IC 15036 | NBPGR, Akola |
| 10 | EC 305647 | NBPGR, Akola | 27 | IC 15435 | NBPGR, Akola |
| 11 | EC 305649 | NBPGR, Akola | 28 | IC 15438 | NBPGR, Akola |
| 12 | EC 305650 | NBPGR, Akola | 29 | IC 15537 | NBPGR, Akola |
| 13 | EC 305651 | NBPGR, Akola | 30 | IC 15540 | NBPGR, Akola |
| 14 | EC 305673 | NBPGR, Akola | 31 | Aruna | KAU, Vellanikkara |
| 15 | EC 305674 | NBPGR, Akola | 32 | Arka Anamika | KAU, Vellanikkara |
| 16 | IC 13664 | NBPGR, Akola | 33 | Salkeerthi | KAU, Vellanikkara |
| 17 | IC 13917 | NBPGR, Akola | 34 | Susthira | KAU, Vellanikkara |

## 3.2. EXPERIMENTAL SITE

Screening of okra genotypes under field and protected conditions were carried out at Department of Vegetable Science, College of Horticulture, Vellanikkara (Plate2).

## 3.3. EXPERIMENTAL DESIGN

The genotypes were evaluated following randomized block design with two replications. Each replication had six plants per genotype.

## 3.4. CULTURAL PRACTICES

The field was prepared to a fine tilth and ridges were made 60cm apart. Each entry was sown in a single row at a spacing of 60 x 45 cm in furrows. Earthing up and weeding was done as and when required during the crop growth period to support the plant stand. The crop was irrigated daily. The application of fertilizers were done as per the recommendation given in package of practices (KAU, 2016).

## 3.5. OBSERVATIONS RECORDED

The genotypes were described based on NBPGR Minimal Descriptor for Characterization and Evaluation of Agri-Horticultural Crops (2001). Two plants per genotype were selected in each replication. The selected plants were tagged and the following observations were recorded.

### 3.5.1. Qualitative characters

#### *3.5.1.1. Plant characters*

a. Plant growth habit : Erect
Medium
Procumbent

b. Branching habit : Branched or unbranched

Plant characters like plant growth habit and branching habit were recorded at completion of vegetative stage.

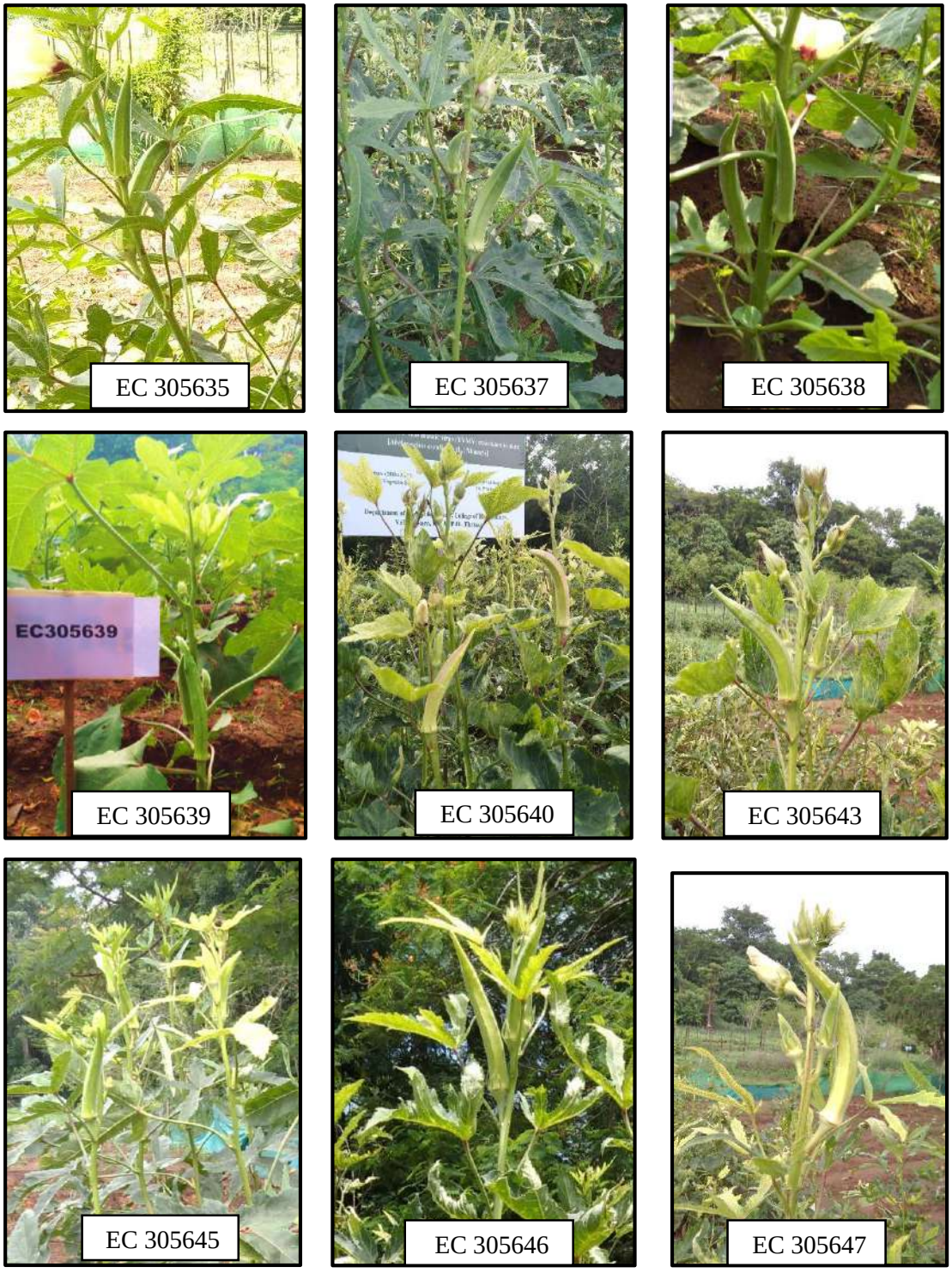



**Plate 1. Genotypes of okra used in the study**

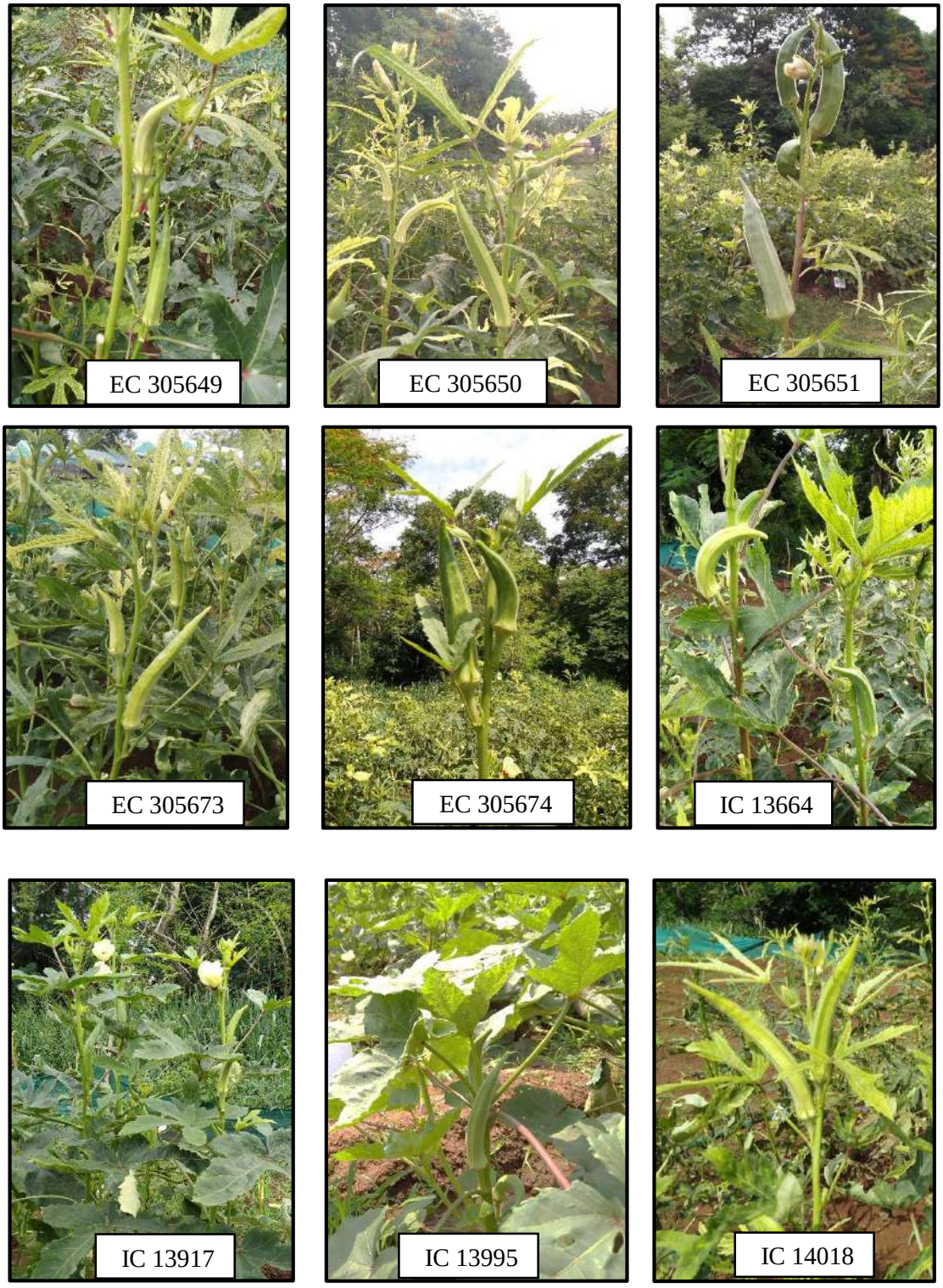



**Plate 1. Genotypes of okra used in the study (Contd.)**

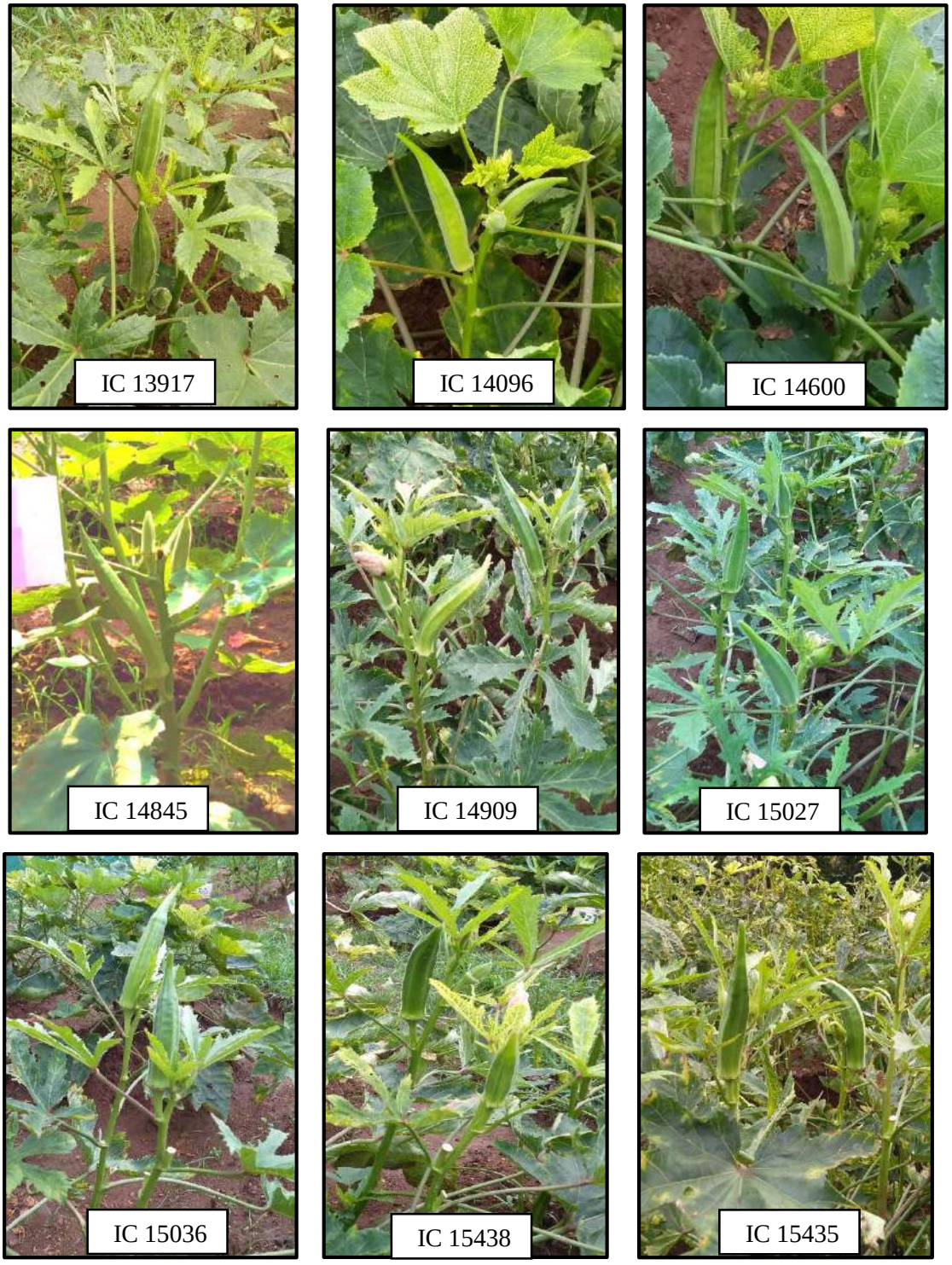



**Plate 1. Genotypes of okra used in the study (Contd.)**

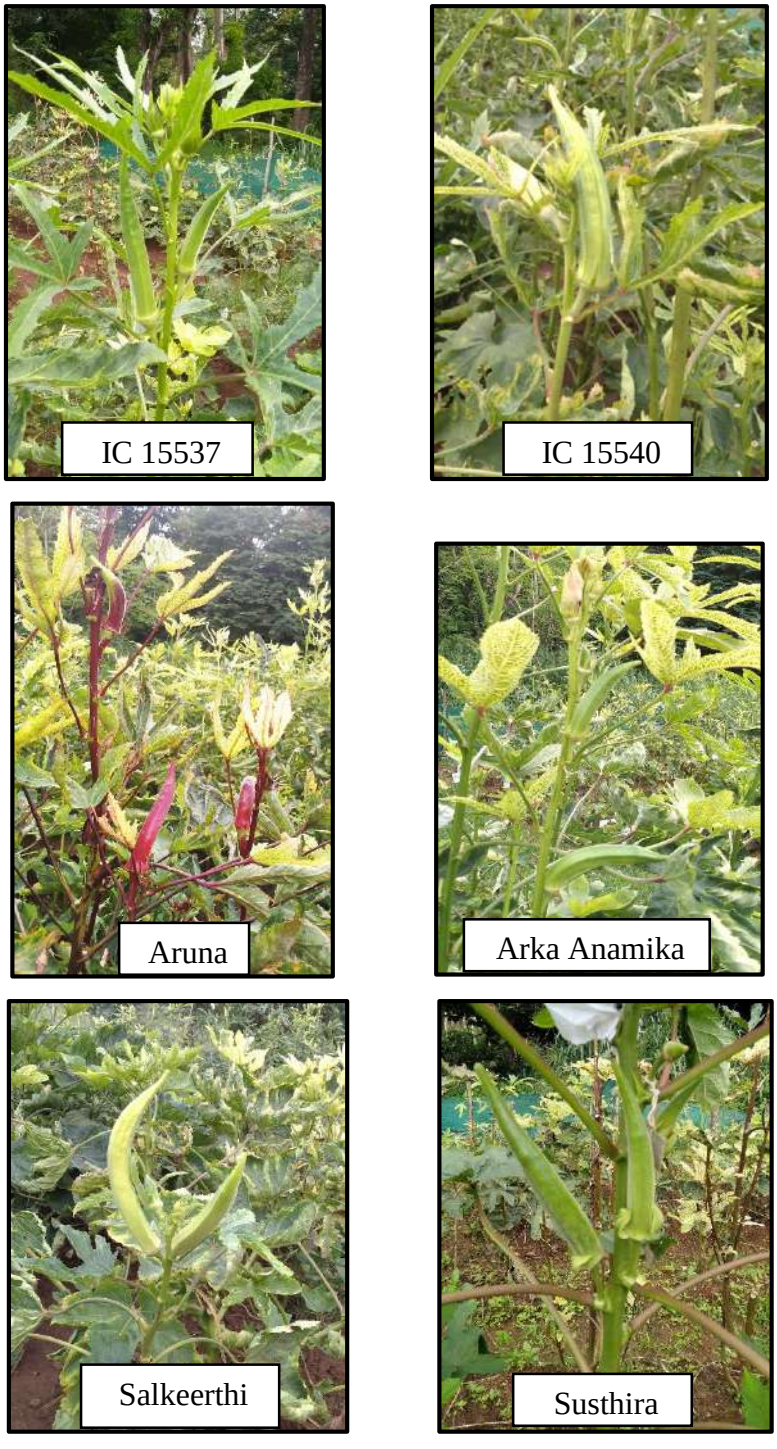



**Plate 1. Genotypes of okra used in the study (Contd.)**

**Plate 2. General view of experimental field**

### *3.5.1.2. Leaf characters*

a. Leaf lobing : Deeply lobed or narrowly lobed

b. Colour of leaf base : Green/ green with red tinge/ red with green tinge

c. Colour of leaf vein : Light green/green/red

Leaf characters like leaf lobing, colour of leaf base and colour of leaf vein were recorded from seventh leaf of each selected plant.

### *3.5.1.3. Flower characters*

a. Flower colour : Yellow/ golden yellow

b. Flower size : Small/ medium/ large

c. Nature of corolla : Red throat/ purple throat

Flower characters such as flower colour, flower size and nature of corolla were noted at the time of anthesis.

### *3.5.1.4. Fruit characters*

a. Immature fruit colour : Yellowish green
Green
Dark green
Red
Dark red

b. Mature fruit colour : Yellowish green
Green
Dark green
Red
Dark red

c. Fruit pubescence : Downy
Slightly rough
Prickly

d. Surface between ridges : Flat

Concave

Convex

Fruit characters such as fruit colour and fruit pubescence were recorded at the time of harvest.

### 3.5.2. Quantitative characters

***1) Plant height (cm)***

The height of the plants were recorded from the base to the tip at the time of last harvest.

***2) Internodal length (cm)***

The length of the internode between the sixth and seventh internode were recorded at the time of last harvest.

***3) Petiole length (cm)***

The length of the petiole of seventh leaf of selected plants were recorded.

***4) Days to first flowering***

The date of opening of first flower on each selected plant was recorded and the number of days from sowing to first flower opening was calculated.

***5) Days to first harvest***

The date of first harvest was noted and the number of days from sowing to first harvest was calculated.

***6) First fruiting node***

The node at which first fruit developed was recorded on each selected plant.

***7) Length of fruit (cm)***

The length of three fruits were recorded after harvest and the mean value was calculated.

***8) Girth of fruit (cm)***

The girth of three fruits were recorded from the middle of the fruit after harvest and the mean value was calculated.

***9) Number of ridges per fruit***

The number of ridges per fruit of three fruits were counted and the mean value was calculated.

***10) Number of seeds per fruit***

The number of seeds per fruit of two fruits from each treatment was counted and the mean value was calculated.

***11) Number of primary branches***

The number of primary branches per plant was recorded at the time of final harvest.

***12) Average fruit weight (g)***

The weight of three fruits were recorded after harvest and the mean value was calculated.

***13) Number of fruits per plant***

The total number of fruits in each plant was recorded and the same was expressed in numbers.

***14) Number of harvest***

The total number of harvest in each treatment was recorded and the same was expressed in numbers.

***15) Crop duration (days)***

The duration of the crop from sowing to last harvest was recorded separately.

***16) Yield per plant (kg)***

The green fruit weight per plant of all pickings were recorded and the total was calculated.

***17) 100 seed weight (g)***

The 100 seed weight of all the treatments were recorded separately.

***18) Incidence of pest and diseases***

The incidence of other pest and diseases were noted down during the field screening.

## 3.6. SCREENING OF YELLOW VEIN MOSAIC DISEASE (YVMD) UNDER FIELD CONDITIONS

The genotypes were evaluated for Yellow Vein Mosaic Disease (YVMD) resistance under natural conditions. Disease incidence was recorded starting from one week after germination by counting the number of plants infected with YVMD at periodical interval up to last harvest. The disease severity was assessed using a standard score chart (Banerjee and Kalloo, 1987) using the 0- 4 scale as mentioned in Table 2. Scoring for YVMD was done in each observational plant based on characteristic symptoms on leaves, fruit and stem.

**Table 2. Scale for scoring of YVMD**

| YVMV symptoms | Severity grade |
|---|---|
| Symptoms absent | 0 |
| Mild symptoms (< 25% leaves) | 1 |
| 26-50% leaves | 2 |
| 51-75% leaves | 3 |
| Severe disease symptoms above 75% leaves | 4 |

The percent disease incidence (PDI) and percent disease severity (PDS) was calculated using the formula:

$$PDI = \frac{\text{Number of infected plants}}{\text{Total numberof plants observed}} \times 100$$

$$PDS = \frac{\text{Sum of all numerical ratings}}{\text{Total number of plants observed}} \times \frac{100}{\text{Maximum disease grade}}$$

Based on PDI and PDS, coefficient of infection was calculated as per the procedure reported by Dater and Mayee (1981).

$$\text{Coefficient of infection (CI)} = \frac{\text{PDI x PDS}}{100}$$

Based on the values of CI, the genotypes were classified into the following categories.

| CI | Category |
|---|---|
| 0-4 | Highly resistant (HR) |
| 4.1-9 | Resistant (R) |
| 9.1-19 | Moderately resistant (MR) |
| 19.1-39 | Moderately susceptible (MS) |
| 39.1-69 | Susceptible (S) |
| 69.1-100 | Highly susceptible (HS) |

### 3.6.1. Days to first symptom appearance

The number of days taken for the appearance of initial symptoms were noted for each treatment and the same was expressed in numbers.

### 3.6.2 Whitefly count

The whitefly count was recorded by counting the number of whiteflies from two randomly selected plants in each treatment and replication at 60 and 90 days after sowing.

## 3.7. ARTIFICIAL INOCULATION OF YELLOW VEIN MOSAIC VIRUS

The genotypes showing resistance under field conditions were selected and their resistance confirmed by whitefly mediated artificial inoculation of virus.

### 3.7.1. Rearing of whiteflies

Cages for rearing whiteflies were designed with metal frame covered using muslin cloth having a small opening at the front side covered with a polythene sheet for the collection and release of whiteflies (Plate 3a). Whiteflies (*Bemisia tabaci*) were collected from brinjal plants of Department of Vegetable Science. The collected whiteflies were reared on brinjal plants raised in polythene bags as brinjal is a preferred host for the multiplication of whiteflies. Old plants were replaced by young plants at weekly intervals for the maintenance of the culture.

### 3.7.2. Source of inoculum

Okra plants showing characteristic symptoms of YVMD were collected from the field of Krishi Vigyan Kendra, Thrissur. These plants were planted in polythene bags and kept in insect proof cages (Plate 3b).

### 3.7.3. Test plants

Okra seedlings were raised in polythene bags kept in insect proof cages. 10-12 days old seedlings were used for inoculation (Plate 3c).

### 3.7.4. Cages for inoculation of OYVMV

Small insect proof cages were made using plastic bottles with a small opening at one side for the release of viruliferous whiteflies. Only one okra seedling was kept per cage (Plate 3d).

### 3.7.5. Acquisition and inoculation access period

Whiteflies were collected from the rearing cages using a glass test tube and released to the cages with diseased plant. After 24 h of acquisition access period, the viruliferous whiteflies were released to healthy okra seedlings kept in inoculation cages

**a) Cages for rearing whiteflies**

**b) Cages for acquisition of virus**

**c) Seedlings for artificial inoculation**

**d) Inoculation cages**

**Plate 3. Requirements for artificial inoculation of YVMV**

at the rate of 15 whiteflies per seedling. After 24 h of inoculation access period, seedlings were removed from these cages and sprayed with insecticide. The plants were then kept for symptom development under insect proof conditions.

### 3.7.6. Incubation period of virus

Incubation period refers to the time elapsed between exposure to a virus or any pathogenic organism and when symptoms and signs are first apparent. The number of days taken for the expression of symptoms on inoculated plants were recorded.

### 3.7.7. Percent transmission

The percent transmission of virus was calculated by dividing the number of plants infected by the total number of plants inoculated with YVMV.

## 3.8. ORGANOLEPTIC TEST

The genotypes were subjected to organoleptic test using a nine point hedonic scale (Jellinek, 1985). The organoleptic qualities of fresh fruits were evaluated by a panel of 15 judges. The fresh fruits were evaluated for their colour, appearance, flavour, taste, texture and overall acceptability.

| | |
|---|---|
| Like extremely | 9 |
| Like very much | 8 |
| Like moderately | 7 |
| Like slightly | 6 |
| Neither like or dislike | 5 |
| Dislike slightly | 4 |
| Dislike moderately | 3 |
| Dislike very much | 2 |
| Dislike extremely | 1 |

## 3.9. ESTIMATION OF GENETIC PARAMETERS

### 3.9.1. Phenotypic and genotypic variance

The variance components were calculated using formula suggested by Burton (1952).

a. Phenotypic variance (Vp) = Vg + Ve

Where, (Vg) = Genotypic variance

(Ve) = Environmental variance

b. Genotypic variance (Vg) = (MSST – MSSE)/n

Where, MSST = Mean sum of squares of treatments

MSSE = Mean sum of squares due to error

n = Number of replications

c. Environmental variance (Ve) = VE

Where, VE = Mean sum of squares due to error

### 3.9.2. Phenotypic and genotypic coefficient of variation (%)

The phenotypic and genotypic coefficients of variation were estimated by the formula given by Burton and Devane (1953).

0-10 % : Low

10-20 % : Moderate

20 % and above : High

a. Phenotypic coefficient of variation (PCV) = ($\sqrt{Vp}$/ x ×100)

Where, Vp = phenotypic variance

x = Mean of the character under study

b. Genotypic coefficient of variation (GCV) = ($\sqrt{Vg}$/ x ×100)

Where, Vg = genotypic variance

x = Mean of the character under study

### 3.9.3. Heritability (%)

Heritability in the broad sense was estimated by the formula suggested by Burton and Devane (1953)

$$\text{Heritability, } H^2 = (Vg/Vp) \times 100$$

Where, Vg = Genotypic variance

Vp = Phenotypic variance

Heritability estimates were classified into low, moderate and high by following Hanson *et al.* (1956).

| | |
|---|---|
| 0-30% | : Low |
| 30-60% | : Moderate |
| 60% and above | : High |

### 3.9.4. Genetic advance (GA)

It was calculated by using the formula given by Johnson *et al*. (1955) at five percent selection intensity.

$$GA = k \times H^2 \times \sqrt{Vp}$$

Where, $H^2$ = Heritability

Vp = Phenotypic variance

k = Selection differential (2.063)

### 3.9.5. Genetic advance as percentage of mean (GAM) (%)

$$GAM = GA/\bar{x} \times 100$$

Where, GA = Genetic advance

$\bar{x}$ = mean of character under study

The range of genetic advance as per cent of mean were classified by following Johnson *et al*. (1955).

Less than 10% : Low

Between 10 – 20% : Moderate

Greater than 20% : High

## 3.10. CORRELATION STUDIES

The degree of association between different characters and their contribution to the yield of fruits were found out using correlation and path coefficient analysis. Phenotypic and genotypic correlation coefficients were worked out using the respective variances and covariances of the characters. The phenotypic and genotypic correlation coefficients between different characters were calculated in all possible combinations according to the formula given by Johnson *et al.* (1955).

a. Phenotypic correlation coefficient between two characters

$$rp_{xy} = COVp_{xy} / Vp_x Vp_y$$

Where, $COVp_{xy}$ = Phenotypic covariance between characters x and y

$Vp_x$ = Phenotypic variance of character x

$Vp_y$= Phenotypic variance of character y

b. Genotypic correlation coefficient between two characters

$$rg_{xy} = COVg_{xy} / Vg_x Vg_y$$

Where. $COVg_{xy}$ = Genotypic covariance between characters x and y

$Vg_x$ = Genotypic variance of character x

$Vg_y$ = Genotypic variance of character y

## 3.11. PATH COEFFICIENT ANALYSIS

Path coefficient analysis is a form of regression analysis that is used to examine the relationships between a dependent variable and two or more independent variables. It was carried out as suggested by Dewey and Lu (1959) by partitioning the correlation

coefficients into direct and indirect effects. Based on the scales of Lenka and Misra (1973), the direct and indirect effects were ranked as given below:

| | |
|---|---|
| Negligible | : 0.00 to 0.09 |
| Low | : 0.10 to 0.19 |
| Moderate | : 0.20 to 0.29 |
| High | : 0.30 to 0.99 |
| Very high | : > 1.00 |

### 3.12. LOGISTIC REGRESSION ANALYSIS

Logistic regression model (Logic model) is statistical model which in its basic form uses a logistic function to model a binary dependent variable. It is a uni/multivariate technique that is used to estimate the probability that a character is present by predicting a binary dependent outcome from a set of explanatory variables and it is used for model binary response data. This model can be used for making a classifier by choosing a cut off value and classifying inputs with probability greater than the cut off as one class and below the cut off as another class. Here the genotypes are grouped into two high yielders and low yielders and scored binary.

### 3.13 STATISTICAL ANALYSIS

The data was analyzed statistically by using and WASP 2.0, Online Package softwares developed by ICAR- Central Coastal Agricultural Research Institute, Goa and OPSTAT.

# Results

# 4. RESULTS

The present investigation entitled “Breeding for Yellow Vein Mosaic Virus (YVMV) resistance in okra [*Abelmoschus esculentus* (L.) Moench] was taken up with the objective of evaluating and identifying resistant varieties/lines of okra against Yellow vein mosaic virus for augmenting effective resistant breeding programme in okra. The results obtained from the various experiments are furnished below under following heads.

4.1 Estimation of qualitative characters of okra genotypes

4.2 Estimation of quantitative characters of okra genotypes

4.3 Organoleptic evaluation of okra genotypes

4.4 Estimation of disease parameters during field screening

4.5 Estimation of disease parameters under protected conditions

4.6 Estimation of genetic parameters

4.7 Correlation and Path Coefficient analysis

## 4.1 ESTIMATION OF QUALITATIVE CHARACTERS OF OKRA GENOTYPES

Thirty four genotypes of okra were evaluated and described based on NBPGR Minimal Descriptor for Characterization and Evaluation of Agri-Horticultural Crops (2001). The plant, leaf, flower and fruit characters were recorded and the results are presented in Table 3 and 4.

### 4.1.1 Plant characters

All the accessions used for the study exhibited erect growth habit and the plants were branched.

### 4.1.2 Leaf characters

Almost all the accessions had deeply lobed leaves except EC 305640, EC 305642, EC 305643, IC 14096, IC 14600 and Susthira (Plate 4a).

The colour of the leaf base was red for Aruna. The genotypes EC 305638, EC 305640, EC 305642, EC 305643, EC 305645, EC 305646, EC 305649, EC 305650, EC 305651, IC 13664, IC 13917, IC 14026, IC 14909, IC 15036, IC 15435, IC 15438 and Susthira had green with red tinge leaf base. All the other genotypes had green colour leaf base (Plate 4b).

The colour of leaf vein was green for six genotypes (EC 305637, EC 305638, EC 305642, EC 305646, EC 305651 and EC 305674), red for Aruna and light green for all the other genotypes.

### 4.1.3 Flower characters

The flower colour was yellow for all the genotypes and they also had purple throat at the base of corolla. Flower size was medium for all the genotypes except IC 14096, IC 14600, Aruna and Susthira (Plate 5).

### 4.1.4 Fruit characters

The immature fruit colour was yellowish green for 12 genotypes (EC 305635, EC 305637, EC 305638, EC 305639, EC 305640, EC 305642, EC 305643, EC 305645, EC 305647, IC 14096, IC 14600 and Salkeerthi) and red for Aruna. All the other genotypes had green coloured fruits. The immature fruit colour changed from green to yellowish green in seven genotypes (EC 305650, EC 305673, IC 13917, IC 13995, IC 14018, IC 14845 and IC 15537) whereas no change in colour was noticed in other genotypes (Plate 6a).

The fruit surface was slightly rough in six genotypes (EC 305635, EC 305642, EC 305647, IC 13664, IC 15435 and IC 15438) while it was downy for all the other genotypes.

The surface between ridges of fruits were concave for seven genotypes (IC 13664, IC 13917, IC 14026, IC 14909, IC 15027, IC 15036 and IC 15438) while it was flat for all the other genotypes (Plate 6b).

**Table 3. Plant and leaf characters of okra genotypes**

| Sl. No | Treatments | Plant characters | | Leaf characters | | |
|---|---|---|---|---|---|---|
| | | Growth habit | Branching habit | Leaf lobbing | Colour of leaf base | Colour of leaf vein |
| 1 | EC 305635 | Erect | Branched | Deeply lobed | Green | Light green |
| 2 | EC 305637 | Erect | Branched | Deeply lobed | Green | Green |
| 3 | EC 305638 | Erect | Branched | Deeply lobed | Green with red tinge | Green |
| 4 | EC 305639 | Erect | Branched | Deeply lobed | Green | Light green |
| 5 | EC 305640 | Erect | Branched | Narrowly lobed | Green with red tinge | Light green |
| 6 | EC 305642 | Erect | Branched | Narrowly lobed | Green with red tinge | Green |
| 7 | EC 305643 | Erect | Branched | Narrowly lobed | Green with red tinge | Light green |
| 8 | EC 305645 | Erect | Branched | Deeply lobed | Green with red tinge | Light green |
| 9 | EC 305646 | Erect | Branched | Deeply lobed | Green with red tinge | Green |
| 10 | EC 305647 | Erect | Branched | Deeply lobed | Green | Light green |
| 11 | EC 305649 | Erect | Branched | Deeply lobed | Green with red tinge | Light green |
| 12 | EC 305650 | Erect | Branched | Deeply lobed | Green with red tinge | Light green |
| 13 | EC 305651 | Erect | Branched | Deeply lobed | Green with red tinge | Green |
| 14 | EC 305673 | Erect | Branched | Deeply lobed | Green | Light green |
| 15 | EC 305674 | Erect | Branched | Deeply lobed | Green | Green |
| 16 | IC 13664 | Erect | Branched | Deeply lobed | Green with red tinge | Light green |
| 17 | IC 13917 | Erect | Branched | Deeply lobed | Green with red tinge | Light green |

**Table 3. Plant and leaf characters of okra genotypes (Contd.)**

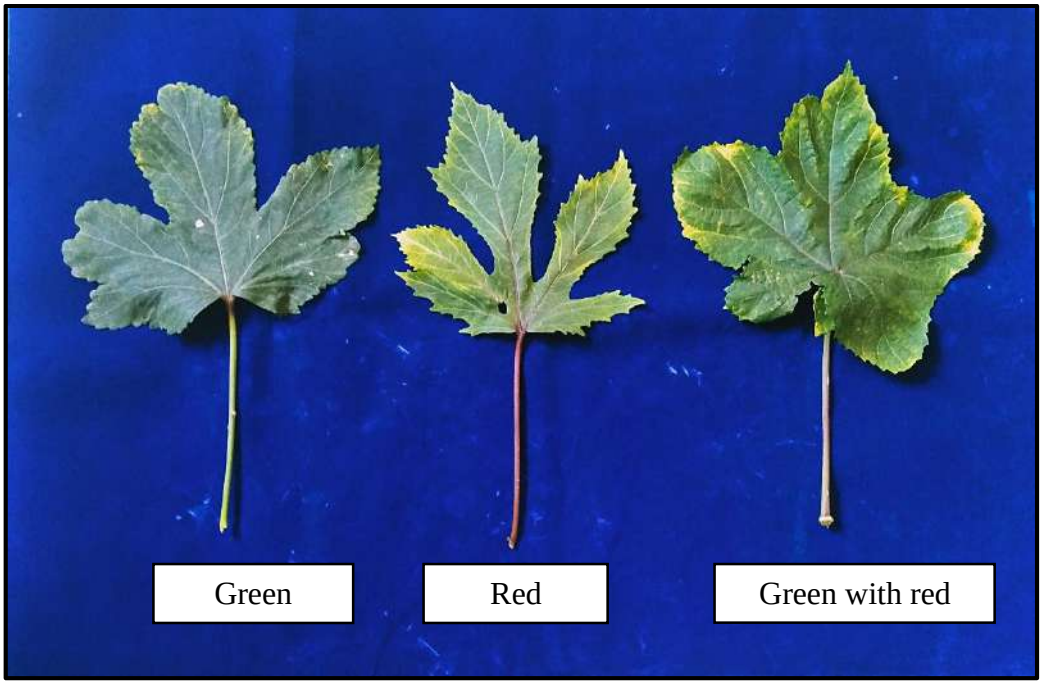
| Sl. No | Treatments | Plant characters | | Leaf characters | | |
|---|---|---|---|---|---|---|
| | | Growth habit | Branching habit | Leaf lobbing | Colour of leaf base | Colour of leaf vein |
| 18 | IC 13995 | Erect | Branched | Deeply lobed | Green | Light green |
| 19 | IC 14018 | Erect | Branched | Deeply lobed | Green | Light green |
| 20 | IC 14026 | Erect | Branched | Deeply lobed | Green with red tinge | Light green |
| 21 | IC 14096 | Erect | Branched | Narrowly lobed | Green | Light green |
| 22 | IC 14600 | Erect | Branched | Narrowly lobed | Green | Light green |
| 23 | IC 14845 | Erect | Branched | Deeply lobed | Green | Light green |
| 24 | IC 14909 | Erect | Branched | Deeply lobed | Green with red tinge | Light green |
| 25 | IC 15027 | Erect | Branched | Deeply lobed | Green | Light green |
| 26 | IC 15036 | Erect | Branched | Deeply lobed | Green with red tinge | Light green |
| 27 | IC 15435 | Erect | Branched | Deeply lobed | Green with red tinge | Light green |
| 28 | IC 15438 | Erect | Branched | Deeply lobed | Green | Light green |
| 29 | IC 15537 | Erect | Branched | Deeply lobed | Green with red tinge | Light green |
| 30 | IC 15540 | Erect | Branched | Deeply lobed | Green | Light green |
| 31 | Aruna | Erect | Branched | Deeply lobed | Red | Red |
| 32 | Arka Anamika | Erect | Branched | Deeply lobed | Green | Light green |
| 33 | Salkeerthi | Erect | Branched | Deeply lobed | Green | Light green |
| 34 | Susthira | Erect | Branched | Narrowly lobed | Green with red tinge | Light green |

**Table 4: Flower and fruit characters of okra genotypes**

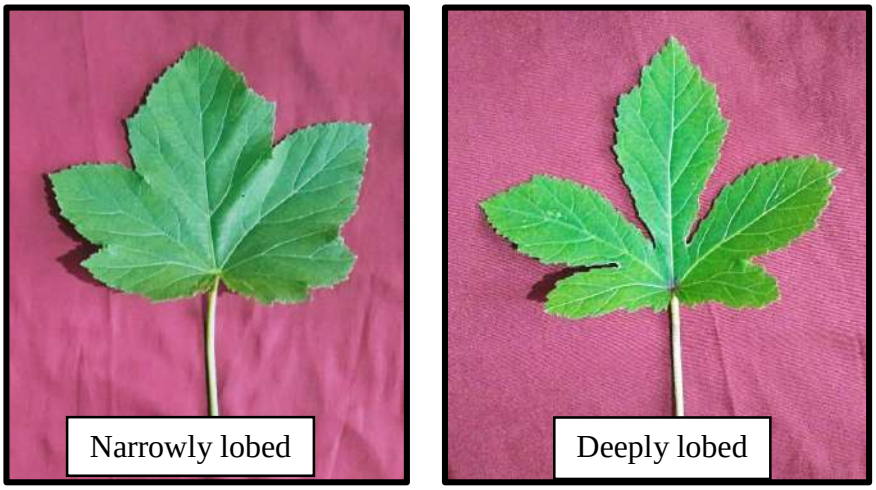
| Sl. No | Treatments | Flower characters | | | Fruit characters | | | |
|---|---|---|---|---|---|---|---|---|
| | | Colour | Size | Nature of corolla | Immature fruit colour | Mature fruit colour | Fruit pubescence | Surface between ridges |
| 1 | EC 305635 | Yellow | Medium | Purple throat | Yellowish green | Yellowish green | Slightly rough | Flat |
| 2 | EC 305637 | Yellow | Medium | Purple throat | Yellowish green | Yellowish green | Downy | Flat |
| 3 | EC 305638 | Yellow | Medium | Purple throat | Yellowish green | Yellowish green | Downy | Flat |
| 4 | EC 305639 | Yellow | Medium | Purple throat | Yellowish green | Yellowish green | Downy | Flat |
| 5 | EC 305640 | Yellow | Medium | Purple throat | Yellowish green | Yellowish green | Downy | Flat |
| 6 | EC 305642 | Yellow | Medium | Purple throat | Yellowish green | Yellowish green | Slightly rough | Flat |
| 7 | EC 305643 | Yellow | Medium | Purple throat | Yellowish green | Yellowish green | Downy | Flat |
| 8 | EC 305645 | Yellow | Medium | Purple throat | Yellowish green | Yellowish green | Downy | Flat |
| 9 | EC 305646 | Yellow | Medium | Purple throat | Green | Green | Downy | Flat |
| 10 | EC 305647 | Yellow | Medium | Purple throat | Yellowish green | Yellowish green | Slightly rough | Flat |
| 11 | EC 305649 | Yellow | Medium | Purple throat | Green | Green | Downy | Flat |
| 12 | EC 305650 | Yellow | Medium | Purple throat | Green | Yellowish green | Downy | Flat |
| 13 | EC 305651 | Yellow | Medium | Purple throat | Green | Green | Downy | Flat |
| 14 | EC 305673 | Yellow | Medium | Purple throat | Green | Yellowish green | Downy | Flat |
| 15 | EC 305674 | Yellow | Medium | Purple throat | Green | Green | Downy | Flat |
| 16 | IC 13664 | Yellow | Medium | Purple throat | Green | Green | Slightly rough | Concave |
| 17 | IC 13917 | Yellow | Medium | Purple throat | Green | Yellowish green | Downy | Concave |
| 18 | IC 13995 | Yellow | Medium | Purple throat | Green | Yellowish green | Downy | Flat |

**Table 4. Flower and fruit characters of okra genotypes (Contd.)**

| Sl. No | Treatments | Flower characters | | | Fruit characters | | | |
|---|---|---|---|---|---|---|---|---|
| | | Colour | Size | Nature of corolla | Immature fruit colour | Mature fruit colour | Fruit pubescence | Surface between ridges |
| 19 | IC 14018 | Yellow | Medium | Purple throat | Green | Yellowish green | Downy | Flat |
| 20 | IC 14026 | Yellow | Medium | Purple throat | Green | Green | Downy | Concave |
| 21 | IC 14096 | Yellow | Large | Purple throat | Yellowish green | Yellowish green | Downy | Flat |
| 22 | IC 14600 | Yellow | Large | Purple throat | Yellowish green | Yellowish green | Downy | Flat |
| 23 | IC 14845 | Yellow | Medium | Purple throat | Green | Yellowish green | Downy | Flat |
| 24 | IC 14909 | Yellow | Medium | Purple throat | Green | Green | Downy | Concave |
| 25 | IC 15027 | Yellow | Medium | Purple throat | Green | Green | Downy | Concave |
| 26 | IC 15036 | Yellow | Medium | Purple throat | Green | Green | Downy | Concave |
| 27 | IC 15435 | Yellow | Medium | Purple throat | Green | Green | Slightly rough | Flat |
| 28 | IC 15438 | Yellow | Medium | Purple throat | Green | Green | Slightly rough | Concave |
| 29 | IC 15537 | Yellow | Medium | Purple throat | Green | Yellowish green | Downy | Flat |
| 30 | IC 15540 | Yellow | Medium | Purple throat | Green | Green | Downy | Flat |
| 31 | Aruna | Yellow | Large | Purple throat | Red | Red | Downy | Flat |
| 32 | Arka Anamika | Yellow | Medium | Purple throat | Green | Green | Downy | Flat |
| 33 | Salkeerthi | Yellow | Medium | Purple throat | Yellowish green | Yellowish green | Downy | Flat |
| 34 | Susthira | Yellow | Large | Purple throat | Green | Green | Downy | Flat |




**a) Variation in colour of leaf base of okra genotypes**




**b) Variation in leaf lobing of okra genotypes**

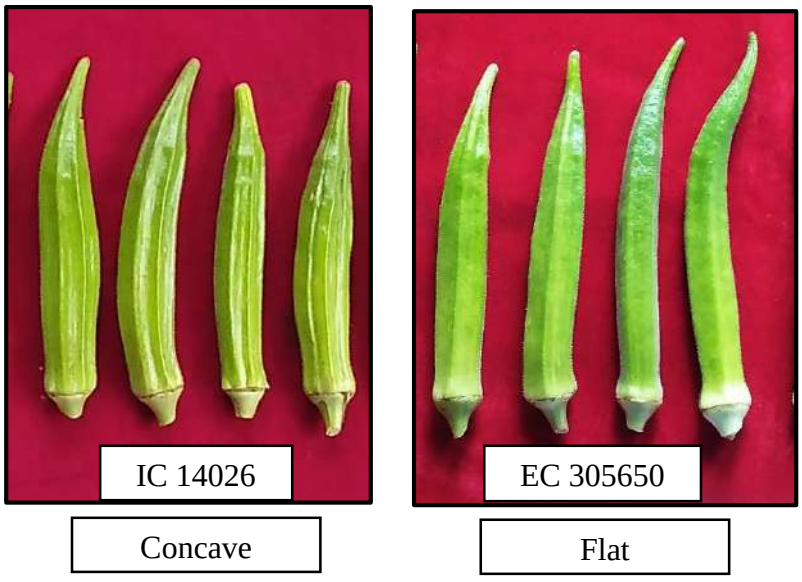
**Plate 4. Leaf characters of okra genotypes**


**a) Variation in flower size of okra genotypes**

**b) Purple throat at the base of corolla**

**Plate 5. Flower characters of okra genotypes**


**a) Variation in fruit colour of okra genotypes**




**b) Variation in surface between ridges of okra fruits**

**Plate 6. Fruit characters of okra genotypes**

## 4.2 ESTIMATION OF QUANTITATIVE CHARACTERS OF OKRA GENOTYPES

The mean values of various quantitative characters were estimated and the results are presented in Table 5.

### 4.2.1 Plant height (cm)

The character plant height ranged from 72.5 cm (Salkeerthi) to 218.25 cm (EC 305649), which itself indicated significant variation among the genotypes. The highest value for plant height was observed in EC 305649 (218.25 cm) followed by Aruna (191.75 cm) and EC 305650 (182.75 cm) while the lowest in Salkeerthi (72.5 cm).

### 4.2.2 Internodal length (cm)

The internodal length varied from 3.25 cm (IC 14026) to 7.55 cm (EC 305645). The highest internodal distance was recorded in EC 305645 (7.55 cm). This was on par with the genotypes *viz*., EC 305639 (6.75), EC 305649 (7.13) and Aruna (7.00). The lowest value was recorded in IC 14026 (3.25 cm) which was on par with EC 305642 (4.08), EC 305673 (3.80), IC 14096 (3.58), IC 14600 (4.00), IC 14909 (3.63), IC 15027 (4.15), IC 15036 (4.00), IC 15435 (3.70), IC 15438 (4.15) and IC 15537 (4.25).

### 4.2.3 Petiole length (cm)

Petiole length varied significantly between the different genotypes and it ranged from 23.32 cm (IC 13995) to 37.86 cm (IC 13917). The highest petiole length was recorded in IC 13917 (37.86 cm). This was on par with the genotypes *viz.*, EC 305642 (36.53 cm), EC 305637 (36.00 cm), IC 15540 (35.21) and Arka Anamika (34.48). The lowest value was recorded in IC 13995 (23.32 cm) which was on par with EC 305643 (26.18), EC 305646 (27.13), EC 305673 (25.92), IC 13995 (23.32), 1C 14600 (25.75) and IC 14845 (26.73).

### 4.2.4 Days to first flowering

Days to first flowering ranged from 36.17 (EC 305643) to 52.75 (Susthira) days. Earliest flowering was recorded in EC 305643 (36.17) which was on par with the

genotypes *viz*., EC 305651 (37.25), EC 305650 (37.83), EC 305635 (38.00), EC 305638 (38.17) and EC 305639 (38.03). Susthira (52.75) took maximum days for flowering and required significantly more days than other genotypes for flowering.

### 4.2.5 Days to first harvest

Significant variations were recorded for days taken to first harvest among the tested genotypes and it ranged from 43.67 (EC 305651) to 65.00 (IC 14096) days. Significantly minimum days was recorded in the genotype EC 305651 (43.67). This was on par with the genotypes *viz.*, EC 305650 (44.67), EC 305635 (44.83), EC 305637 (45.33), EC 305638 (45.75), EC 305639 (45.00), EC 305646 (46.33), EC 305649 (45.50), IC 13995 (46.00) and IC 14018 (46.00). On the other hand, the genotype IC 14096 (65.00) recorded maximum time of 65 days.

### 4.2.6 First fruiting node

The results on first fruiting node revealed significant variations among the different genotypes and it ranged from 5.00 (EC 305643) to 9.50 (IC 15036, IC 14600). Significantly lowest node of first fruiting was recorded in the genotype EC 305643 (5.00) which was on par with the genotypes *viz*., Susthira (5.94), EC 305635 (6.00), EC 305637 (6.75), EC 305639 (6.50), EC 305640 (6.50), EC 305649 (6.75), EC 305650 (6.90), EC 305674 (6.75), IC 13917 (6.75), IC 15540 (6.50) and IC 14909 (6.30). Highest node of first fruiting was recorded in the genotypes IC 15036 (9.50) and IC 14600 (9.50) which was on par with Arka Anamika (9.25), IC 14096 (9.25), Salkeerthi (8.25), Aruna (8.00), EC 305642 (7.75), EC 305647 (7.75), EC 305651 (7.75), EC 305673 (8.25), IC 13995 (7.75), IC 14026 (7.25), IC 14845 (8.00), IC 15435 (7.65) and IC 15537 (8.50).

### 4.2.7 Length of fruit (cm)

Length of fruit had significant variation among the different genotypes and it ranged from 12.18 cm (IC 15036) to 19.40 cm (Aruna). The highest value was observed in Aruna (19.40 cm) which was on par with the genotypes *viz.*, EC 305643 (19.06 cm), Salkeerthi (17.50 cm), EC 305635 (17.23), EC 305638 (18.34), EC 305646 (17.27) and

**Table 5. Quantitative characters of okra genotypes**

| Sl. No | Treatments | Plant height (cm) | Internodal length (cm) | Petiole length (cm) | Days to first flowering | Days to first harvest | First fruiting Node | Length of fruit (cm) | Girth of fruit (cm) | No. of ridges/fruit |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | EC 305635 | 157.25 | 5.88 | 30.05 | 38.00 | 44.83 | 6.00 | 17.23 | 5.70 | 5.00 |
| 2 | EC 305637 | 159.00 | 5.68 | 36.00 | 39.00 | 45.33 | 6.75 | 16.67 | 5.52 | 5.00 |
| 3 | EC 305638 | 165.50 | 4.50 | 33.39 | 38.17 | 45.75 | 7.25 | 18.34 | 5.95 | 5.00 |
| 4 | EC 305639 | 174.25 | 6.75 | 33.31 | 38.03 | 45.00 | 6.50 | 14.42 | 5.59 | 5.00 |
| 5 | EC 305640 | 146.94 | 4.50 | 32.22 | 40.00 | 48.50 | 6.50 | 16.94 | 5.51 | 5.00 |
| 6 | EC 305642 | 162.00 | 4.08 | 36.53 | 40.17 | 46.50 | 7.75 | 15.79 | 5.41 | 6.00 |
| 7 | EC 305643 | 142.75 | 4.75 | 26.18 | 36.17 | 46.50 | 5.00 | 19.06 | 5.67 | 5.00 |
| 8 | EC 305645 | 182.38 | 7.55 | 29.89 | 40.67 | 46.50 | 7.00 | 16.62 | 5.63 | 5.00 |
| 9 | EC 305646 | 166.25 | 4.45 | 27.13 | 39.58 | 46.33 | 6.50 | 17.27 | 5.38 | 5.00 |
| 10 | EC 305647 | 174.17 | 5.70 | 29.24 | 39.75 | 47.25 | 7.75 | 14.32 | 5.32 | 5.00 |
| 11 | EC 305649 | 218.25 | 7.13 | 28.79 | 38.84 | 45.50 | 6.75 | 16.19 | 5.92 | 5.00 |
| 12 | EC 305650 | 182.75 | 5.75 | 29.39 | 37.83 | 44.67 | 6.90 | 17.48 | 6.72 | 5.00 |
| 13 | EC 305651 | 156.28 | 5.00 | 32.43 | 37.25 | 43.67 | 7.75 | 15.25 | 6.32 | 5.00 |
| 14 | EC 305673 | 163.25 | 3.80 | 25.92 | 41.00 | 47.50 | 8.25 | 15.76 | 5.18 | 5.50 |
| 15 | EC 305674 | 145.00 | 4.75 | 28.57 | 40.17 | 46.50 | 6.75 | 16.08 | 6.24 | 5.00 |
| 16 | IC 13664 | 172.50 | 5.63 | 31.13 | 44.67 | 50.50 | 7.50 | 14.10 | 6.37 | 7.00 |
| 17 | IC 13917 | 158.25 | 5.80 | 37.86 | 43.50 | 48.50 | 6.75 | 13.93 | 6.20 | 6.00 |
| 18 | IC 13995 | 157.75 | 6.00 | 23.32 | 38.92 | 46.00 | 7.75 | 14.60 | 5.66 | 5.00 |
| 19 | IC 14018 | 146.13 | 5.83 | 32.72 | 39.00 | 46.00 | 7.05 | 14.46 | 5.53 | 5.00 |

**Table 5. Quantitative characters of okra genotypes (Contd.)**

| Sl. No | Treatments | Plant height (cm) | Internodal length (cm) | Petiole length (cm) | Days to first flowering | Days to first harvest | First fruiting node | Length of fruit (cm) | Girth of fruit (cm) | No. of ridges/fruit |
|---|---|---|---|---|---|---|---|---|---|---|
| 20 | IC 14026 | 114.50 | 3.25 | 32.45 | 43.25 | 48.50 | 7.25 | 13.32 | 6.47 | 7.00 |
| 21 | IC 14096 | 94.50 | 3.58 | 32.19 | 46.96 | 65.00 | 9.25 | 13.32 | 5.58 | 5.00 |
| 22 | IC 14600 | 80.00 | 4.00 | 25.75 | 47.25 | 55.50 | 9.50 | 14.26 | 5.68 | 5.00 |
| 23 | IC 14845 | 161.75 | 4.58 | 26.73 | 39.33 | 48.00 | 8.00 | 15.03 | 5.52 | 5.00 |
| 24 | IC 14909 | 120.00 | 3.63 | 31.24 | 42.25 | 48.50 | 6.30 | 12.73 | 6.08 | 6.50 |
| 25 | IC 15027 | 148.25 | 4.15 | 33.01 | 46.13 | 54.50 | 7.50 | 13.40 | 5.84 | 5.00 |
| 26 | IC 15036 | 89.25 | 4.00 | 27.54 | 47.00 | 51.50 | 9.50 | 12.18 | 5.75 | 7.50 |
| 27 | IC 15435 | 131.00 | 3.70 | 31.66 | 44.34 | 49.50 | 7.65 | 12.95 | 6.20 | 6.50 |
| 28 | IC 15438 | 121.75 | 4.15 | 32.32 | 43.34 | 48.67 | 7.50 | 13.83 | 6.71 | 7.00 |
| 29 | IC 15537 | 177.50 | 4.25 | 30.42 | 39.00 | 46.92 | 8.50 | 13.07 | 4.94 | 5.00 |
| 30 | IC 15540 | 145.05 | 5.38 | 35.21 | 45.00 | 50.00 | 6.75 | 15.35 | 5.52 | 6.50 |
| 31 | Aruna | 191.75 | 7.00 | 30.75 | 42.17 | 48.50 | 8.00 | 19.40 | 5.57 | 5.00 |
| 32 | Arka Anamika | 181.38 | 5.53 | 34.48 | 44.09 | 50.00 | 9.25 | 16.88 | 5.99 | 5.00 |
| 33 | Salkeerthi | 72.50 | 4.71 | 31.56 | 46.50 | 61.17 | 8.25 | 17.50 | 6.00 | 5.00 |
| 34 | Susthira | 168.49 | 5.63 | 28.49 | 52.75 | 59.73 | 5.94 | 15.06 | 7.79 | 5.50 |
| | Grand mean | 150.83 | 5.03 | 30.82 | 41.76 | 49.19 | 7.40 | 15.37 | 5.86 | 5.43 |
| | C.D (0.05) | 15.55 | 1.04 | 4.06 | 2.58 | 2.76 | 1.91 | 2.37 | 0.52 | 0.65 |
| | SE(m) | 4.40 | 0.36 | 1.40 | 0.89 | 0.96 | 0.66 | 0.73 | 0.18 | 0.32 |
| | C.V (%) | 5.07 | 10.10 | 6.44 | 3.02 | 2.76 | 12.61 | 7.58 | 4.33 | 5.89 |

**Table 5. Quantitative characters of okra genotypes (Contd.)**

| Sl. No | Treatments | No. of seeds/ fruit | 100 seed weight (g) | No. of primary branches | No. of fruits/ plant | Average fruit weight (g) | Yield /plant (kg) | Crop duration (days) | No. of harvest |
|---|---|---|---|---|---|---|---|---|---|
| 1 | EC 305635 | 56.25 | 7.99 | 4.25 | 40.05 | 16.05 | 0.64 | 112.50 | 14.25 |
| 2 | EC 305637 | 56.50 | 5.65 | 3.60 | 30.05 | 13.73 | 0.39 | 114.00 | 12.75 |
| 3 | EC 305638 | 47.25 | 8.05 | 4.00 | 26.50 | 16.60 | 0.46 | 114.00 | 12.75 |
| 4 | EC 305639 | 56.00 | 6.08 | 3.10 | 21.43 | 13.27 | 0.24 | 93.00 | 9.00 |
| 5 | EC 305640 | 33.50 | 8.13 | 3.50 | 24.80 | 11.00 | 0.31 | 112.00 | 13.00 |
| 6 | EC 305642 | 30.50 | 6.12 | 4.72 | 43.75 | 17.02 | 0.71 | 118.00 | 17.25 |
| 7 | EC 305643 | 31.50 | 9.10 | 3.17 | 25.69 | 16.75 | 0.42 | 116.00 | 9.25 |
| 8 | EC 305645 | 68.50 | 6.27 | 2.40 | 22.50 | 12.08 | 0.25 | 112.50 | 9.50 |
| 9 | EC 305646 | 32.50 | 6.83 | 3.91 | 28.64 | 13.21 | 0.46 | 112.50 | 13.50 |
| 10 | EC 305647 | 77.75 | 6.44 | 3.40 | 30.85 | 15.30 | 0.47 | 97.00 | 10.50 |
| 11 | EC 305649 | 51.00 | 6.52 | 2.88 | 30.00 | 14.58 | 0.45 | 112.50 | 12.50 |
| 12 | EC 305650 | 52.00 | 8.16 | 3.33 | 31.62 | 13.73 | 0.50 | 112.50 | 13.50 |
| 13 | EC 305651 | 36.50 | 6.31 | 2.50 | 23.21 | 15.18 | 0.36 | 93.00 | 9.75 |
| 14 | EC 305673 | 60.00 | 6.99 | 3.75 | 40.05 | 15.13 | 0.62 | 112.50 | 12.75 |
| 15 | EC 305674 | 47.50 | 6.37 | 3.33 | 20.75 | 12.75 | 0.28 | 102.00 | 10.25 |
| 16 | IC 13664 | 86.00 | 3.58 | 4.50 | 24.50 | 19.00 | 0.46 | 116.00 | 12.25 |
| 17 | IC 13917 | 40.50 | 7.68 | 4.33 | 29.91 | 19.08 | 0.55 | 114.00 | 13.00 |
| 18 | IC 13995 | 50.00 | 6.66 | 3.33 | 29.78 | 13.75 | 0.39 | 112.50 | 13.25 |
| 19 | IC 14018 | 38.50 | 7.59 | 3.50 | 31.00 | 12.79 | 0.40 | 111.00 | 11.50 |

**Table 5. Quantitative characters of okra genotypes (Contd.)**

| Sl. No | Treatments | No. of seeds/ fruit | 100 seed weight (g) | No. of primary branches | No. of fruits/ plant | Average fruit weight (g) | Yield /plant (kg) | Crop duration (days) | No. of harvest |
|---|---|---|---|---|---|---|---|---|---|
| 20 | IC 14026 | 64.00 | 5.90 | 4.25 | 36.50 | 15.75 | 0.60 | 121.00 | 11.75 |
| 21 | IC 14096 | 25.00 | 7.52 | 5.25 | 16.00 | 15.50 | 0.27 | 116.00 | 6.50 |
| 22 | IC 14600 | 55.50 | 7.00 | 4.77 | 17.00 | 17.12 | 0.34 | 114.50 | 7.00 |
| 23 | IC 14845 | 48.50 | 6.38 | 3.47 | 20.92 | 16.13 | 0.34 | 104.50 | 10.50 |
| 24 | IC 14909 | 49.00 | 3.93 | 3.46 | 36.25 | 18.50 | 0.58 | 105.50 | 11.75 |
| 25 | IC 15027 | 65.25 | 7.02 | 3.60 | 29.05 | 16.63 | 0.50 | 112.50 | 12.75 |
| 26 | IC 15036 | 64.50 | 5.90 | 3.65 | 26.05 | 13.40 | 0.33 | 111.00 | 9.75 |
| 27 | IC 15435 | 43.50 | 7.99 | 3.20 | 35.52 | 17.50 | 0.56 | 114.00 | 12.50 |
| 28 | IC 15438 | 53.50 | 8.46 | 3.20 | 33.46 | 13.69 | 0.48 | 116.00 | 14.25 |
| 29 | IC 15537 | 36.50 | 7.67 | 3.67 | 30.00 | 12.90 | 0.41 | 114.00 | 12.50 |
| 30 | IC 15540 | 68.25 | 7.37 | 3.70 | 36.00 | 13.00 | 0.48 | 116.00 | 13.00 |
| 31 | Aruna | 54.00 | 4.22 | 3.83 | 20.50 | 18.55 | 0.39 | 116.00 | 11.50 |
| 32 | Arka Anamika | 47.00 | 6.89 | 3.79 | 41.36 | 14.88 | 0.63 | 130.50 | 15.25 |
| 33 | Salkeerthi | 43.50 | 6.17 | 5.10 | 10.00 | 15.25 | 0.16 | 88.00 | 9.25 |
| 34 | Susthira | 31.00 | 7.58 | 3.50 | 22.30 | 16.80 | 0.41 | 167.50 | 15.00 |
| | Grand mean | 50.04 | 6.78 | 3.70 | 28.22 | 15.19 | 0.44 | 112.78 | 11.88 |
| | C.D (0.05) | 17.32 | 0.54 | 0.95 | 8.07 | 2.24 | 0.14 | 8.24 | 2.33 |
| | SE(m) | 6.02 | 0.19 | 0.36 | 3.86 | 0.81 | 0.06 | 2.85 | 1.28 |
| | C.V (%) | 17.01 | 3.91 | 12.67 | 14.05 | 7.24 | 15.67 | 3.58 | 9.63 |

EC 305650 (17.48). The lowest value was recorded in IC 15036 (12.18 cm) which was on par with the genotypes *viz.*, IC 15435 (12.95), 1C 14909 (12.73), IC 15537 (13.07), IC 15438 (13.83), IC 15027 (13.40), IC 14600 (14.26), IC 14096 (13.32), IC 14026 (13.32), IC 14018 (14.46), IC 13664 (14.10), EC 305647 (14.32) and EC 305639 (14.42).

### 4.2.8 Girth of fruit (cm)

The girth of fruit ranged from 4.94 cm (IC 15537) to 7.79 cm (Susthira) which indicated significant variations among genotypes. The highest value was observed in Susthira (7.79 cm) followed by EC 305650 (6.72 cm) and IC 15438 (6.71 cm). The lowest value was recorded in IC 15537 (4.94 cm) which was on par with the genotypes *viz.*, EC 305642 (5.41), EC 305646 (5.38), EC 305647 (5.32) and EC 305673 (5.18).

### 4.2.9 Average fruit weight (g)

The average fruit weight of various genotypes varied from 11.00 g (EC 305640) to 19.08 g (IC 13917). The highest average fruit weight was recorded in the genotype IC 13917 (19.08 g). This was on par with the genotypes *viz*., IC 13664 (19.00 g), Aruna (18.55), IC 14909 (18.50), IC 15435 (17.50), IC 14600 (17.12) and IC 14909 (18.50). The lowest average fruit weight was recorded in EC 305640 (11.00 g) which was on par with the genotypes *viz.*, EC 305645 (12.08), EC 305646 (13.21), EC 305674 (12.75), IC 14018 (12.79), IC 15537 (12.90) and IC 15540 (13.00).

### 4.2.10 Yield per plant (kg)

The fruit yield ranged from 0.16 (Salkeerthi) to 0.71 kg (EC 305642) which showed the presence of significant variability among genotypes under study. The maximum fruit yield per plant was obtained from EC305642 (0.71 kg). This was on par with the genotypes *viz*., EC 305635 (0.64 kg), Arka Anamika (0.63 kg), EC 305673 (0.62), IC 14026 (0.60) and IC 14909 (0.58). The minimum fruit yield per plant was obtained from Salkeerthi (0.16 kg) which was on par with EC 305639 (0.24), EC 305645 (0.25), EC 305674 (0.28) and IC 14096 (0.27).

### 4.2.11 Number of fruits per plant

The results on number of fruits per plant revealed significant variations among the different genotypes and it varied from 10.00 (Salkeerthi) to 43.75 (EC 305642). Lower number of fruits per plant was primarily due to heavy infestation of YVMV during the cropping season. The highest number of fruits per plant was recorded in the genotype EC 305642 (43.75). This was on par with the genotypes *viz.*, Arka Anamika (41.36), EC 305635 (40.05), EC 305673 (40.05), IC 14026 (36.50), IC 14909 (36.25) and IC 15540 (36.00). Salkeerthi (11.00) recorded the lowest number of fruits per plant which was on par with IC 14600 (17.00).

### 4.2.12 Number of ridges per fruit

The number of ridges per fruit varied from 5.00 to 7.50 (IC 15036) among the genotypes. The highest number of ridges per fruit was recorded in the genotype IC 15036 (7.50). This was on par with the genotypes *viz.*, IC 13664 (7.00), IC 15438 (7.00) and IC 14026 (7.00). Twenty three genotypes (IC 14018, EC 305650, EC 305651, EC 305674, IC 13995, EC 305635, EC 305638, EC 305649, EC 305647, EC 305637, EC 305639, EC 305640, EC 305643, EC 305646, EC 305645, IC 14096, IC 14600, IC 15537, IC 15027, IC 14845, Arka Anamika, Salkeerthi and Aruna) had five ridges per fruit which was the lowest value recorded.

### 4.2.13 Number of seeds per fruit

The number of seeds per fruit varied significantly among the different genotypes and it ranged from 25.00 (IC 14096) to 86.00 (IC 13664). The highest number of seeds per fruit was recorded in the genotype IC 13664 (86.00) followed by EC 305647 (77.75) and EC 305645 (68.50). The lowest number of seeds per fruit was recorded in the genotype IC 14096 (25.00) which was on par with the genotypes *viz*., EC 305640 (33.50), EC 305642 (30.50), EC 305643 (31.50), EC 305646 (32.50), EC 305651 (36.50), IC 13917 (40.50), IC 14018 (38.50), IC 15537 (36.50) and Susthira (31.00).

### 4.2.14 Number of primary branches

The number of primary branches ranged from 2.40 (EC 305645) to 5.25 (IC 14096). The highest number of primary branches was in the genotype IC 14096 (5.25) which was on par with the genotypes *viz.*, EC 305642 (4.72), IC 13664 (4.50), Salkeerthi (5.10) and IC 14600 (4.77). The lowest value was recorded in EC 305645 (2.40) which was on par with EC 305639 (3.10), EC 305650 (3.33), IC 13995 (3.33), IC 15435 (3.20) and IC 15438 (3.20).

### 4.2.15 Crop duration (days)

The duration of crop varied significantly among the genotypes under study and it varied from 88.00 days (Salkeerthi) to 167.50 days (Susthira). The duration of crop was highest for Susthira (167.5) followed by Arka Anamika (130.50) and IC 14026 (121.00) while lowest for Salkeerthi (88.00). It was on par with the genotypes *viz.*, EC 305639 (93.00) and EC 305651 (93.00).

### 4.2.16 100 seed weight (g)

The 100 seed weight of genotypes ranged from 3.57 (IC 13664) to 9.10 g (EC 305643) which itself indicate significant variations among them. The highest recorded 100 seed weight was in the genotype EC 305643 (9.10 g) followed by IC 15438 (8.46 g) and EC 305650 (8.16) while the lowest in IC 13664 (3.57).

### 4.2.17 Number of harvest

The total number of harvest recorded from the genotypes varied from 6.50 (IC 14096) to 17.25 (EC 305642) which itself indicated significant variations among them. The maximum number of harvest was recorded in the genotype EC 305642 (17.25) which was on par with Arka Anamika (15.25) and Susthira (15.00). The lowest value was recorded in IC 14096 (6.50) which was on par with IC 14600 (7.00).

### 4.2.18 Incidence of pest and diseases

All the genotypes were monitored for the incidence of pests and diseases and the results are presented in Table 6. The insect pests noted in the field were shoot and

fruit borer (*Earias vitella, E. insulana*), leaf roller (*Sylepta derogate*), jassids (*Amrasca biguttula biguttula*) and whiteflies (*Bemisia tabaci*). Very mild to moderate incidence of shoot and fruit borer and leaf roller were noticed in almost all the genotypes except Susthira. The infestation of jassids varied from mild to high among the genotypes. Yellow vein mosaic disease was the major disease noted in the field.

**Table 6. Incidence of pests in okra genotypes**

| Sl. No | Treatments | Shoot and fruit borer | Leaf roller | Jassids |
|---|---|---|---|---|
| 1 | EC 305635 | Mild | Mild | Mild |
| 2 | EC 305637 | Mild | Very mild | Mild |
| 3 | EC 305638 | Mild | Very mild | High |
| 4 | EC 305639 | Mild | Very mild | Very mild |
| 5 | EC 305640 | Mild | Mild | High |
| 6 | EC 305642 | Moderate | Very mild | High |
| 7 | EC 305643 | Mild | Mild | Mild |
| 8 | EC 305645 | Mild | Mild | Mild |
| 9 | EC 305646 | Moderate | Very mild | Mild |
| 10 | EC 305647 | Mild | Very mild | Mild |
| 11 | EC 305649 | Moderate | Mild | Mild |
| 12 | EC 305650 | Moderate | Mild | Moderate |
| 13 | EC 305651 | Mild | Moderate | Moderate |
| 14 | EC 305673 | Very mild | Mild | Mild |
| 15 | EC 305674 | Mild | Mild | Mild |
| 16 | IC 13664 | Mild | Mild | Mild |
| 17 | IC 13917 | Mild | Mild | Mild |
| 18 | IC 13995 | Moderate | Mild | Mild |
| 19 | IC 14018 | Mild | Mild | Mild |
| 20 | IC 14026 | Moderate | Mild | Mild |
| 21 | IC 14096 | Mild | Mild | Moderate |
| 22 | IC 14600 | Moderate | Mild | Mild |
| 23 | IC 14845 | Moderate | Mild | Mild |
| 24 | IC 14909 | Mild | Mild | Mild |
| 25 | IC 15027 | Very mild | Mild | Moderate |
| 26 | IC 15036 | Mild | Mild | Mild |
| 27 | IC 15435 | Mild | Mild | Mild |
| 28 | IC 15438 | Very mild | Mild | Moderate |
| 29 | IC 15537 | Mild | Mild | Moderate |
| 30 | IC 15540 | Very mild | Mild | Mild |
| 31 | Aruna | Mild | Mild | Moderate |
| 32 | Arka Anamika | Very mild | Mild | Mild |
| 33 | Salkeerthi | Mild | Mild | High |
| 34 | Susthira | Absent | Very mild | Moderate |

## 4.3 ESTIMATION OF DISEASE PARAMETERS DURING FIELD SCREENING

### 4.3.1 Symptoms of YVMD under field conditions

The different symptoms of YVMD noticed during field screening were noted down. The initial symptoms noticed in all the susceptible genotypes were yellowing of the veins and veinlets of leaves followed by thickening. Puckering of leaves were also noticed in some genotypes. Complete yellowing of the newly formed leaves and fruits and reduction in the size were also noticed. In case of severe infection**,** plant growth was stunted (Plate 7).

### 4.3.2 Days to first symptom appearance

The days to first symptom appearance showed significant variations among the genotypes. Disease symptoms appeared first in the genotype IC 15027 (49.50) followed by Aruna (51.00) and Arka Anamika (51.00). All the genotypes showed disease symptoms within 67 days except Susthira. Disease symptoms were completely absent in the variety Susthira.

### 4.3.3 Disease incidence in okra genotypes (%)

The disease incidence in okra genotypes was recorded using two parameters *viz.*, percent disease incidence (PDI) and percent disease severity (PDS). PDI and PDS of yellow vein mosaic disease was recorded at 50, 60, 70, 80 and 90 days after sowing and the results are presented in Table 7. Scoring of YVMD was done as per the scale given by Banerjee and Kalloo (1987).

#### *4.3.3.1 PDI and PDS at 50 DAS (%)*

The mean value of PDI and PDS varied from 0.00 to 16.67 per cent and 0.00 to 3.16 per cent respectively among the genotypes. The highest value of PDI recorded was 16.67 (Arka Anamika, IC 15027, EC 305637, EC 305640, EC 305643, IC 13917 and IC 14845). The highest value of PDS was recorded in Arka Anamika (3.16) followed by Aruna (2.21), IC 15027 (2.04) and IC 13917 (2.04).

## Table 7. Performance of okra genotypes against incidence of YVMD

| Sl. No | Treatments | Days to first symptom appearance | 50 DAS | | 60 DAS | | 70 DAS | | 80 DAS | | 90 DAS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | PDI | PDS | PDI | PDS | PDI | PDS | PDI | PDS | PDI | PDS |
| 1 | EC 305635 | 60.50 | 0.00 (1.17) | 0.00 (1.17) | 16.66 (24.09) | 5.70 (13.81) | 66.67 (54.74) | 29.00 (32.58) | 100.00 (88.83) | 37.50 (37.36) | 100.00 (88.83) | 48.67 (44.23) |
| 2 | EC 305637 | 57.50 | 16.67 (24.09) | 1.03 (5.85) | 58.33 (49.87) | 12.75 (20.91) | 83.34 (71.18) | 27.63 (31.71) | 100.00 (88.83) | 49.00 (44.43) | 100.00 (88.83) | 64.30 (53.32) |
| 3 | EC 305638 | 57.50 | 0.00 (1.17) | 0.00 (1.17) | 33.33 (35.26) | 3.38 (10.57) | 66.67 (54.74) | 30.38 (33.44) | 100.00 (88.83) | 40.00 (39.11) | 100.00 (88.83) | 62.28 (52.11) |
| 4 | EC 305639 | 67.00 | 0.00 (1.17) | 0.00 (1.17) | 0.00 (1.17) | 0.00 (1.17) | 50.00 (45.00) | 26.61 (31.04) | 100.00 (88.83) | 46.00 (42.71) | 100.00 (88.83) | 63.33 (52.75) |
| 5 | EC 305640 | 54.00 | 16.67 (24.09) | 1.02 (5.80) | 50.00 (45.00) | 18.20 (25.25) | 83.34 (71.78) | 34.45 (35.90) | 91.67 (77.37) | 52.50 (46.43) | 100.00 (88.33) | 62.50 (52.33) |
| 6 | EC 305642 | 58.50 | 0.00 (1.17) | 0.00 (1.17) | 50.00 (45.00) | 8.04 (16.47) | 91.67 (77.37) | 23.00 (28.66) | 100.00 (88.83) | 32.50 (34.75) | 100.00 (88.83) | 48.02 (43.86) |
| 7 | EC 305643 | 54.50 | 16.67 (24.09) | 1.18 (6.24) | 73.33 (59.32) | 14.61 (22.47) | 87.50 (74.42) | 28.54 (32.28) | 100.00 (88.83) | 45.83 (42.60) | 100.00 (88.83) | 65.50 (54.05) |
| 8 | EC 305645 | 60.00 | 0.00 (1.17) | 0.00 (1.17) | 24.97 (29.98) | 17.02 (24.36) | 55.00 (47.88) | 66.96 (54.95) | 91.67 (77.37) | 68.48 (55.87) | 100.00 (88.33) | 74.27 (59.52) |
| 9 | EC 305646 | 55.50 | 8.33 (16.69) | 1.47 (6.96) | 58.33 (49.86) | 17.77 (24.93) | 79.16 (63.97) | 35.54 (36.60) | 100.00 (88.83) | 44.00 (41.50) | 100.00 (88.83) | 60.48 (51.05) |
| 10 | EC 305647 | 56.50 | 8.33 (16.69) | 1.94 (8.03) | 33.33 (35.26) | 14.70 (22.54) | 75.00 (60.32) | 25.50 (30.24) | 100.00 (88.83) | 43.00 (40.97) | 100.00 (88.83) | 62.00 (51.96) |
| 11 | EC 305649 | 60.50 | 0.00 (1.17) | 0.00 (1.17) | 25.00 (30.00) | 3.99 (11.52) | 70.83 (57.37) | 27.52 (31.60) | 100.00 (88.83) | 36.08 (36.91) | 100.00 (88.33) | 60.97 (51.34) |
| 12 | EC 305650 | 60.00 | 0.00 (1.17) | 0.00 (1.17) | 50.00 (45.00) | 12.30 (20.53) | 89.59 (71.26) | 22.52 (28.30) | 100.00 (88.83) | 39.58 (38.98) | 100.00 (88.83) | 61.89 (51.89) |
| 13 | EC 305651 | 55.50 | 0.00 (1.17) | 0.00 (1.17) | 50.00 (45.00) | 19.98 (26.55) | 85.00 (72.81) | 41.82 (40.29) | 100.00 (88.83) | 60.83 (51.30) | 100.00 (88.83) | 75.00 (60.11) |

**Table 7. Performance of okra genotypes against incidence of YVMD (Contd.)**

| Sl. No | Treatments | Days to first symptom appearance | 50 DAS | | 60 DAS | | 70 DAS | | 80 DAS | | 90 DAS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | PDI | PDS | PDI | PDS | PDI | PDS | PDI | PDS | PDI | PDS |
| 14 | EC 305673 | 59.50 | 0.00 (1.17) | 0.00 (1.17) | 50.00 (45.00) | 11.30 (19.64) | 83.34 (71.78) | 25.00 (30.00) | 100.00 (88.83) | 40.63 (39.49) | 100.00 (88.83) | 49.38 (44.64) |
| 15 | EC 305674 | 58.50 | 0.00 (1.17) | 0.00 (1.17) | 50.00 (45.00) | 22.00 (27.97) | 83.34 (66.61) | 43.96 (41.52) | 100.00 (88.83) | 52.92 (46.69) | 100.00 (88.83) | 75.00 (60.07) |
| 16 | IC 13664 | 57.00 | 0.00 (1.17) | 0.00 (1.17) | 33.33 (35.26) | 17.25 (24.54) | 79.17 (63.98) | 30.95 (33.79) | 100.00 (88.83) | 46.41 (42.94) | 100.00 (88.83) | 62.00 (51.94) |
| 17 | IC 13917 | 54.50 | 16.67 (24.09) | 2.04 (8.20) | 50.00 (45.00) | 15.50 (23.18) | 86.67 (68.73) | 37.12 (37.53) | 100.00 (88.83) | 49.75 (44.85) | 100.00 (88.83) | 55.67 (48.27) |
| 18 | IC 13995 | 58.50 | 0.00 (1.17) | 0.00 (1.17) | 41.67 (40.13) | 12.25 (20.49) | 75.00 (60.32) | 39.63 (38.92) | 100.00 (88.83) | 49.42 (44.66) | 100.00 (88.83) | 72.70 (58.51) |
| 19 | IC 14018 | 56.50 | 8.34 (16.70) | 1.93 (7.98) | 41.67 (40.13) | 9.50 (17.95) | 75.00 (60.32) | 28.60 (32.27) | 100.00 (88.83) | 47.52 (43.58) | 100.00 (88.83) | 63.33 (52.75) |
| 20 | IC 14026 | 61.50 | 0.00 (1.17) | 0.00 (1.17) | 16.66 (24.09) | 1.80 (7.71) | 58.33 (50.58) | 16.88 (24.22) | 75.00 (66.92) | 32.50 (34.62) | 100.00 (88.83) | 44.06 (41.59) |
| 21 | IC 14096 | 61.50 | 0.00 (1.17) | 0.00 (1.17) | 33.33 (35.26) | 15.00 (22.79) | 75.00 (60.32) | 27.90 (31.84) | 100.00 (88.83) | 35.50 (36.57) | 100.00 (88.83) | 60.83 (51.26) |
| 22 | IC 14600 | 62.00 | 0.00 (1.17) | 0.00 (1.17) | 33.33 (35.26) | 12.50 (20.70) | 58.34 (49.87) | 27.25 (31.27) | 100.00 (88.83) | 40.83 (39.72) | 100.00 (88.83) | 52.28 (46.31) |
| 23 | IC 14845 | 56.00 | 16.67 (24.09) | 2.01 (8.15) | 75.00 (60.32) | 40.70 (22.54) | 87.50 (74.42) | 48.00 (43.81) | 100.00 (88.33) | 61.50 (51.65) | 100.00 (88.83) | 70.00 (56.79) |
| 24 | IC 14909 | 59.00 | 0.00 (1.17) | 0.00 (1.17) | 16.69 (24.10) | 1.06 (5.90) | 62.50 (52.27) | 25.00 (29.98) | 100.00 (88.83) | 43.75 (41.40) | 100.00 (88.83) | 55.19 (48.00) |
| 25 | IC 15027 | 49.50 | 16.67 (24.09) | 2.04 (8.20) | 33.33 (35.26) | 18.75 (25.66) | 75.00 (60.00) | 34.08 (35.72) | 100.00 (88.83) | 45.42 (42.28) | 100.00 (88.83) | 60.58 (51.12) |
| 26 | IC 15036 | 59.50 | 0.00 (1.17) | 0.00 (1.17) | 16.67 (24.10) | 10.23 (18.65) | 50.00 (45.00) | 39.00 (38.64) | 100.00 (88.83) | 51.62 (45.93) | 100.00 (88.33) | 57.84 (49.51) |

**Table 7. Performance of okra genotypes against incidence of YVMD (Contd.)**

| Sl. No | Treatments | Days to first symptom appearance | 50 DAS | | 60 DAS | | 70 DAS | | 80 DAS | | 90 DAS | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | PDI | PDS | PDI | PDS | PDI | PDS | PDI | PDS | PDI | PDS |
| 27 | IC 15435 | 59.00 | 0.00 (1.17) | 0.00 (1.17) | 16.67 (24.10) | 6.65 (14.96) | 62.50 (52.27) | 31.12 (33.86) | 91.67 (77.37) | 45.84 (42.60) | 100.00 (88.83) | 57.69 (49.43) |
| 28 | IC 15438 | 55.00 | 0.00 (1.17) | 0.00 (1.17) | 41.67 (40.13) | 16.75 (24.16) | 79.17 (63.98) | 39.07 (38.65) | 100.00 (88.83) | 55.11 (47.95) | 100.00 (88.83) | 61.78 (51.83) |
| 29 | IC 15537 | 57.00 | 0.00 (1.17) | 0.00 (1.17) | 20.80 (27.02) | 7.89 (16.24) | 62.50 (52.27) | 32.29 (34.56) | 100.00 (88.83) | 45.83 (42.61) | 100.00 (88.83) | 66.67 (54.77) |
| 30 | IC 15540 | 59.00 | 0.00 (1.17) | 0.00 (1.17) | 25.00 (29.68) | 4.43 (12.14) | 66.67 (54.74) | 22.42 (28.24) | 91.67 (77.37) | 46.67 (43.02) | 100.00 (88.83) | 64.58 (53.49) |
| 31 | Aruna | 51.00 | 15.61 (23.26) | 2.21 (8.54) | 44.99 (42.11) | 12.25 (20.49) | 81.67 (64.67) | 37.29 (37.62) | 100.00 (88.83) | 55.28 (48.05) | 100.00 (88.83) | 68.66 (55.99) |
| 32 | Arka Anamika | 51.00 | 16.67 (24.09) | 3.16 (10.23) | 87.50 (74.42) | 20.67 (27.04) | 100.00 (88.83) | 41.42 (40.05) | 100.00 (88.83) | 49.72 (44.82) | 100.00 (88.83) | 56.89 (48.97) |
| 33 | Salkeerthi | 54.50 | 0.00 (1.17) | 0.00 (1.17) | 58.33 (49.87) | 23.00 (28.65) | 85.00 (72.81) | 56.07 (48.48) | 100.00 (88.83) | 80.00 (63.61) | 100.00 (88.83) | 100.00 (88.83) |
| 34 | Susthira | 0.00 | 0.00 (1.17) | 0.00 (1.17) | 0.00 (1.17) | 0.00 (1.17) | 0.00 (1.17) | 0.00 (1.17) | 0.00 (1.17) | 0.00 (1.17) | 0.00 (1.17) | 0.00 (1.17) |
| | Mean | 55.81 | 4.62 | 0.59 | 38.53 | 11.82 | 72.66 | 32.43 | 95.34 | 46.22 | 97.06 | 60.71 |
| | C.D (0.05) | 12.61 | 1.64 | 0.13 | 14.64 | 1.36 | 28.61 | 10.59 | 15.04 | 13.60 | NS | 8.19 |
| | C.V (%) | 7.93 | 17.48 | 10.64 | 18.67 | 5.64 | 19.35 | 16.05 | 7.75 | 14.46 | NS | 6.63 |

The values within parenthesis indicates angular transformation values

DAS – Days after sowing

PDS – Percent disease severity

PDI- Percent disease incidence

**a) Yellowing of veins and veinlets**

**b) Puckering of leaves**

**c) Reduced leaf size**

**d) Thickening of veins**

**e) White colour fruits with reduced size**

**Plate 7. Symptoms of YVMD noticed during field screening**

At 50 days after sowing, disease symptoms appeared in 11 genotypes of okra [Arka Anamika (16.67), EC 305640 (16.67), EC 305637 (16.67), EC 305643 (16.67), IC 14018 (8.34), Aruna (15.61), IC 14845 (16.67), EC 305646 (8.33), EC 305647 (8.33), IC 13917 (16.67) and IC 15027 (16.67)] whereas no disease incidence was recorded in the other genotypes.

#### *4.3.3.2 PDI and PDS at 60 DAS (%)*

The mean value of PDI and PDS varied from 0.00 to 87.50 and 0.00 to 23.00 per cent respectively among the genotypes. Disease symptoms were noted in all the genotypes except Susthira and EC 305639. Maximum PDI was recorded in Arka Anamika (87.50) followed by IC 14845 (75.00) and EC 305643 (73.33). Highest value of PDS was recorded in the genotype Salkeerthi (23.00) followed by EC 305674 (22.00) and Arka Anamika (20.67). The lowest value of PDI and PDS was recorded in EC 305639 (0.00) and Susthira (0.00).

#### *4.3.3.3 PDI and PDS at 70 DAS (%)*

The mean value of PDI and PDS ranged from 0.00 to 100.00 and 0.00 to 66.96 per cent respectively among the genotypes. Maximum PDI was recorded in Arka Anamika (100.00) followed by EC 305642 (91.67) and EC 305650 (89.59). The highest value of PDS was recorded in the genotype EC 305645 (66.96) followed by Salkeerthi (56.07) and IC 14845 (48.00). The lowest value of PDI and PDS was recorded in Susthira (0.00).

#### *4.3.3.4 PDI and PDS at 80 DAS (%)*

The mean value of PDI ranged from 0.00 to 100.00 per cent among the genotypes. Out of 34 genotypes, 28 genotypes showed 100 per cent disease incidence whereas other genotypes showed more than 75 per cent disease incidence except Susthira. PDS varied from 0.00 to 80.00 among the genotypes. The highest value of PDS was recorded in Salkeerthi (80.00) followed by EC 305645 (68.48) and IC 14845 (61.50). The lowest value of PDI and PDS was recorded in Susthira (0.00).

#### *4.3.3.5 PDI and PDS at 90 DAS (%)*

The mean value of PDI and PDS varied from 0.00 to 100.00 per cent among the genotypes. All the genotypes except Susthira had PDI value of 100. The highest value of PDS was recorded in Salkeerthi (100.00) followed by EC 305651 (75.00), EC 305674 (75.00) and EC 305645 (74.27). The lowest value of PDI and PDS was recorded in Susthira (0.00).

### 4.3.4 Coefficient of Infection (CI) of YVMD (%)

The coefficient of infection of YVMD was calculated using the values of PDI and PDS and the results are presented in Table 8. Variation in disease reaction of okra genotypes are shown in Plate 8.

#### *4.3.4.1 Coefficient of infection at 50 DAS (%)*

The mean value of CI varied from 0.00 to 1.52 per cent among the genotypes at 50 DAS. The highest value was recorded in Arka Anamika (1.52) followed by IC 14845 (0.63) and EC 305640 (0.50). At 50 DAS, disease symptoms appeared only in 11 genotypes whereas all other genotypes had zero value per cent coefficient of infection.

#### *4.3.4.2 Coefficient of infection at 60 DAS (%)*

The mean value of CI varied from 0.00 to 18.00 per cent among the genotypes at 60 DAS. The highest value was recorded in Arka Anamika (18.00) followed by EC 305640 (13.28) and EC 305643 (12.39). CI was zero in two genotypes namely, EC 305639 and Susthira.

#### *4.3.4.3 Coefficient of infection at 70 DAS (%)*

The mean value of CI varied from 0.00 to 47.38 per cent among the genotypes at 70 DAS. The highest value was recorded in Salkeerthi (47.38) followed by Arka Anamika (41.78) and IC 14845 (40.38). The lowest value was recorded in Susthira (0.00).

## Table 8. Coefficient of infection of YVMD (%) at different intervals

| Sl. No | Treatments | 50 DAS | 60 DAS | 70 DAS | 80 DAS | 90 DAS | Disease reaction |
|---|---|---|---|---|---|---|---|
| 1 | EC 305635 | 0.00 | 1.06 | 19.31 | 37.50 | 48.67 | Susceptible |
| 2 | EC 305637 | 0.39 | 9.30 | 24.00 | 49.00 | 64.30 | Susceptible |
| 3 | EC 305638 | 0.00 | 1.63 | 20.67 | 40.00 | 62.28 | Susceptible |
| 4 | EC 305639 | 0.00 | 0.00 | 13.31 | 46.00 | 63.33 | Susceptible |
| 5 | EC 305640 | 0.50 | 13.28 | 27.97 | 48.00 | 62.50 | Susceptible |
| 6 | EC 305642 | 0.00 | 3.91 | 18.61 | 32.50 | 48.02 | Susceptible |
| 7 | EC 305643 | 0.26 | 12.39 | 29.99 | 45.83 | 65.50 | Susceptible |
| 8 | EC 305645 | 0.00 | 9.00 | 36.65 | 62.53 | 74.27 | Highly susceptible |
| 9 | EC 305646 | 0.04 | 5.73 | 28.12 | 44.00 | 60.48 | Susceptible |
| 10 | EC 305647 | 0.04 | 2.29 | 18.75 | 43.00 | 62.00 | Susceptible |
| 11 | EC 305649 | 0.00 | 1.20 | 19.36 | 36.08 | 60.97 | Susceptible |
| 12 | EC 305650 | 0.00 | 6.78 | 20.13 | 39.58 | 61.89 | Susceptible |
| 13 | EC 305651 | 0.00 | 5.85 | 34.04 | 60.83 | 75.00 | Highly susceptible |
| 14 | EC 305673 | 0.00 | 4.70 | 22.75 | 40.63 | 49.38 | Susceptible |
| 15 | EC 305674 | 0.00 | 7.47 | 36.96 | 52.92 | 75.00 | Highly susceptible |
| 16 | IC 13664 | 0.00 | 5.31 | 31.87 | 46.41 | 62.00 | Susceptible |
| 17 | IC 13917 | 0.04 | 6.67 | 32.15 | 49.75 | 55.67 | Susceptible |
| 18 | IC 13995 | 0.00 | 3.47 | 29.02 | 49.42 | 72.70 | Highly susceptible |
| 19 | IC 14018 | 0.39 | 3.28 | 21.09 | 47.52 | 63.33 | Susceptible |
| 20 | IC 14026 | 0.00 | 0.20 | 8.60 | 22.50 | 44.06 | Susceptible |
| 21 | IC 14096 | 0.00 | 2.93 | 20.64 | 35.50 | 60.83 | Susceptible |
| 22 | IC 14600 | 0.00 | 2.20 | 19.50 | 40.83 | 52.28 | Susceptible |
| 23 | IC 14845 | 0.63 | 8.64 | 40.38 | 61.50 | 72.50 | Highly susceptible |
| 24 | IC 14909 | 0.00 | 0.87 | 15.71 | 43.75 | 55.19 | Susceptible |
| 25 | IC 15027 | 0.04 | 5.96 | 25.56 | 45.42 | 60.58 | Susceptible |
| 26 | IC 15036 | 0.00 | 1.89 | 22.64 | 51.62 | 57.84 | Susceptible |
| 27 | IC 15435 | 0.00 | 1.30 | 17.62 | 42.36 | 57.69 | Susceptible |
| 28 | IC 15438 | 0.00 | 7.76 | 33.14 | 55.11 | 61.78 | Susceptible |
| 29 | IC 15537 | 0.00 | 1.47 | 16.93 | 45.83 | 66.67 | Susceptible |
| 30 | IC 15540 | 0.00 | 1.13 | 17.41 | 41.67 | 64.58 | Susceptible |
| 31 | Aruna | 0.17 | 6.67 | 30.49 | 55.28 | 68.66 | Susceptible |
| 32 | Arka Anamika | 1.52 | 18.00 | 41.78 | 49.72 | 56.89 | Susceptible |
| 33 | Salkeerthi | 0.00 | 12.25 | 47.38 | 80.00 | 100.00 | Highly susceptible |
| 34 | Susthira | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | Highly resistant |
|  | Mean | 0.08 | 5.49 | 24.34 | 45.37 | 60.79 |  |

(DAS- Days after sowing)

#### *4.3.4.4 Coefficient of infection at 80 DAS (%)*

The mean value of CI varied from 0.00 to 80.00 per cent among the genotypes at 80 DAS. The highest value was recorded in Salkeerthi (80.00) followed by EC 305645 (62.53) and IC 14845 (61.50). The lowest value was recorded in Susthira (0.00).

#### *4.3.4.5 Coefficient of infection at 90 DAS (%)*

The mean value of CI varied from 0.00 to 100.00 per cent among the genotypes at 90 DAS. The highest value was recorded in Salkeerthi (100.00) followed by EC 305651 (75.00), EC 305674 (75.00) and EC 305645 (74.27). The lowest value was recorded in Susthira (0.00).

Based on the values of CI, the genotypes were classified as highly resistant, susceptible and highly susceptible. Out of 34 genotypes, six genotypes (EC 305645, EC 305651, EC 305674, IC 13995, IC 14845 and Arka Anamika) had CI in the range 69.1-100 (Highly susceptible), 27 genotypes had CI in the range 39.1-69 (Susceptible) and Susthira had CI=0 (Highly resistant) (Plate 9).

### 4.3.5 Average whitefly count in okra genotypes

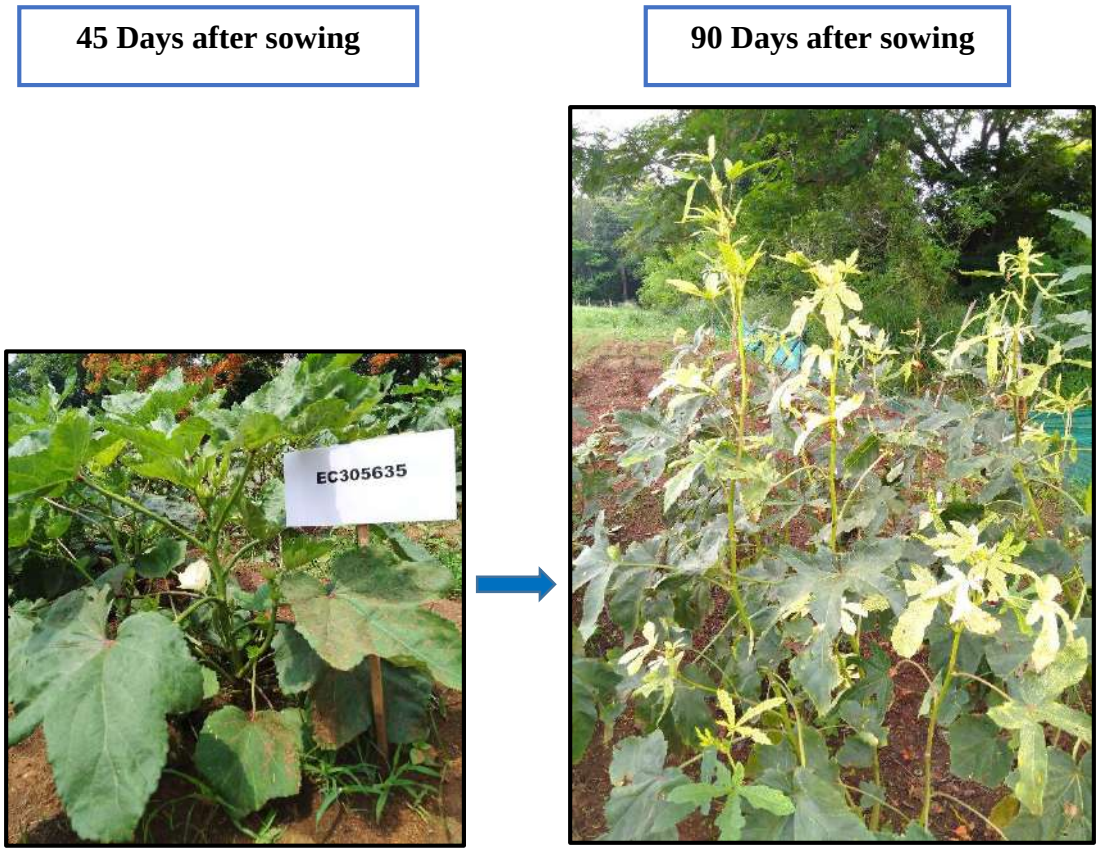
The whitefly count of different genotypes of okra were taken by counting the number of whiteflies on leaves during early morning hours. The observations were taken at 60 and 90 days after sowing and the results are presented in Table 9.

#### *4.3.5.1 Whitefly count at 60 days after sowing*

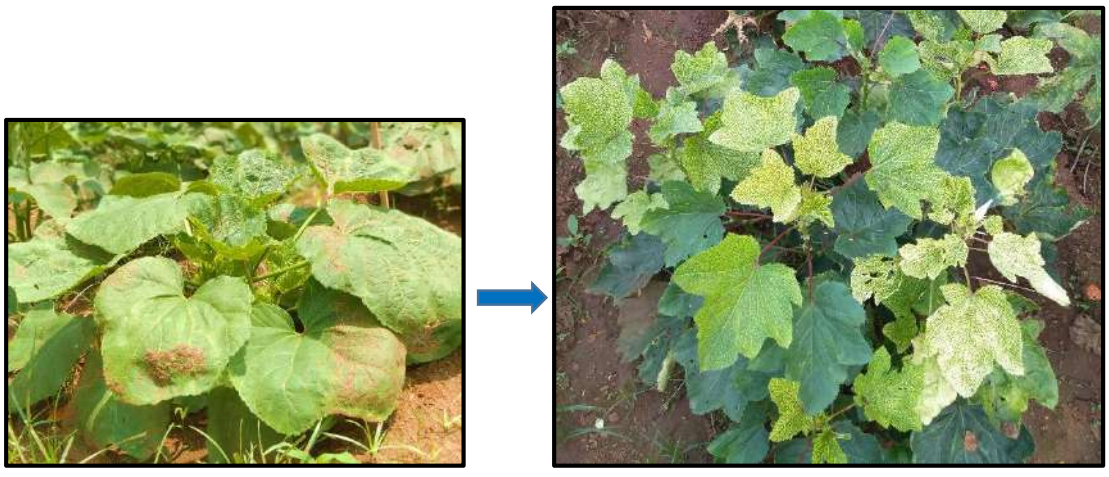
The mean value of whitefly count ranged from 0.25 to 5.00 among the genotypes. The highest whitefly count was recorded in Arka Anamika (5.00) followed by Salkeerthi (4.75) and IC 15540 (4.75). The lowest whitefly count of 0.25 was recorded in the genotypes EC 305646, EC 305674, IC 14018 and IC 15537.

#### *4.3.5.2 Whitefly count at 90 days after sowing*

The mean value of whitefly count ranged from 1.75 (EC 305673) to 8.25 (Salkeerthi) among the genotypes. The highest whitefly count was recorded in Salkeerthi (8.25) followed by Arka Anamika (6.5) and IC 15540 (5.75) while the lowest value was recorded in the genotype EC 305673 (1.75).




**a) EC 305635**

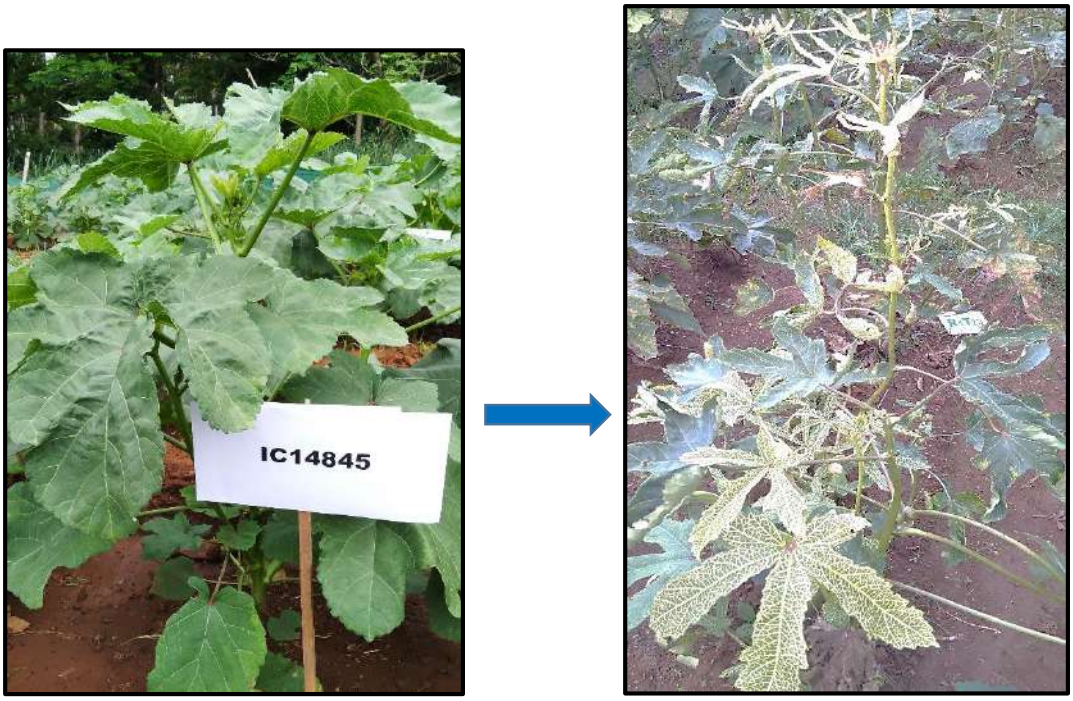


**b) IC 14600**

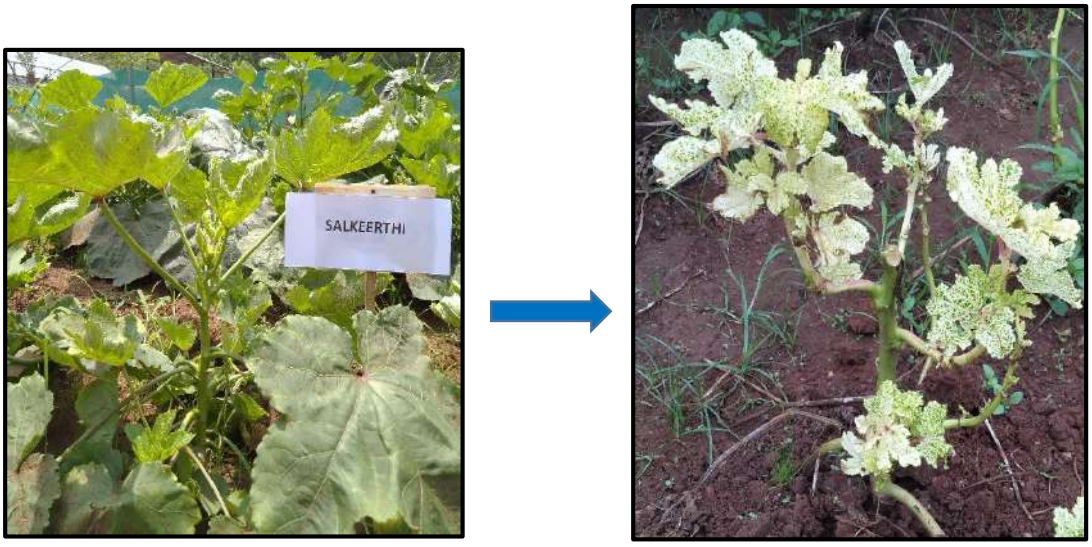
**Plate 8. Variation in disease reaction of selected genotypes at 45 and 90 DAS**

45 Days after sowing

90 Days after sowing




**c) IC 14845**




**d) Salkeerthi**

**Plate 8. Variation in disease reaction of selected genotypes at 45 and 90 DAS (Contd.)**

**a) Plant of Susthira**

**b) Fruits of Susthira**

**Plate 9. Resistant genotype obtained from field screening**

**Table 9. Preference of whiteflies to different okra genotypes**

| Sl. No | Treatments | 60 DAS | 90 DAS |
|---|---|---|---|
| 1 | EC 305635 | 1.25 | 3.50 |
| 2 | EC 305637 | 1.25 | 3.00 |
| 3 | EC 305638 | 2.25 | 3.25 |
| 4 | EC 305639 | 2.00 | 3.50 |
| 5 | EC 305640 | 3.75 | 2.75 |
| 6 | EC 305642 | 2.50 | 2.75 |
| 7 | EC 305643 | 3.25 | 4.75 |
| 8 | EC 305645 | 2.00 | 3.00 |
| 9 | EC 305646 | 0.25 | 2.50 |
| 10 | EC 305647 | 1.25 | 3.25 |
| 11 | EC 305649 | 1.75 | 3.75 |
| 12 | EC 305650 | 0.50 | 4.00 |
| 13 | EC 305651 | 0.50 | 3.75 |
| 14 | EC 305673 | 0.50 | 1.75 |
| 15 | EC 305674 | 0.25 | 2.25 |
| 16 | IC 13664 | 2.50 | 4.50 |
| 17 | IC 13917 | 3.00 | 4.75 |
| 18 | IC 13995 | 0.50 | 4.00 |
| 19 | IC 14018 | 0.25 | 2.75 |
| 20 | IC 14026 | 1.50 | 4.25 |
| 21 | IC 14096 | 0.50 | 3.50 |
| 22 | IC 14600 | 2.50 | 4.25 |
| 23 | IC 14845 | 3.00 | 4.50 |
| 24 | IC 14909 | 2.75 | 5.25 |
| 25 | IC 15027 | 3.50 | 4.75 |
| 26 | IC 15036 | 2.75 | 5.25 |
| 27 | IC 15435 | 1.75 | 4.25 |
| 28 | IC 15438 | 1.75 | 4.50 |
| 29 | IC 15537 | 0.25 | 3.75 |
| 30 | IC 15540 | 4.75 | 5.75 |
| 31 | Aruna | 0.75 | 2.75 |
| 32 | Arka Anamika | 5.00 | 6.50 |
| 33 | Salkeerthi | 4.75 | 8.25 |
| 34 | Susthira | 1.50 | 4.00 |
| | Mean | 1.96 | 3.98 |

DAS- Days after sowing

## 4.4 ESTIMATION OF DISEASE PARAMETERS UNDER PROTECTED CONDITIONS

### 4.4.1 Incubation period of virus

Whitefly mediated artificial inoculation of YVMV was done in three susceptible genotypes (Salkeerthi and EC 305639, Arka Anamika) and Susthira (resistant variety under field conditions). The symptoms observed are shown in Plate 10. The incubation period of virus was noted down and the results are presented in Table 10.

The incubation period of virus for Arka Anamika, Salkeerthi and EC 305639 were 17.20, 16.60 and 16.40 days respectively while symptoms did not appeared in Susthira.

### 4.4.2 Percent transmission

The percent transmission of disease was calculated and the results are presented in Table 10. The percent transmission of disease for Arka Anamika, Salkeerthi and EC 305639 was 100.00 as all the inoculated plants showed symptoms while, it was zero for Susthira as none of the plants showed symptoms of YVMD.

**Table 10. Screening of YVMV under protected conditions**

| Sl. No | Genotype | Incubation period of virus (days) | No. of plants inoculated | No. of plants showing symptoms | Percent transmission of virus (%) |
|---|---|---|---|---|---|
| 1 | Arka Anamika | 17.20 | 5 | 5 | 100.00 |
| 2 | Salkeerthi | 16.60 | 5 | 5 | 100.00 |
| 3 | EC 305639 | 16.40 | 5 | 5 | 100.00 |
| 4 | Susthira | 0.00 | 5 | 0 | 0.00 |

## 4.5 ORGANOLEPTIC EVALUATION OF OKRA GENOTYPES

Organoleptic evaluation of okra genotypes were done to judge the sensory qualities based on scores of 9-point hedonic scale. The data were subjected to statistical analysis. Sensory characters like appearance, colour, flavour, taste, texture, mouth feel and overall acceptability were judged based on mean ranks obtained after statistical analysis and the results were presented in the Table 11.


**a) Symptoms on Salkeerthi**


**b) Symptoms on Arka Anamika**


**c) Symptoms on EC 305639**


**d) Absence of symptoms in Susthira**


**e) Absence of symptoms in control plant**

**Plate 10. Seedlings of okra 25 days after inoculation of YVMV**

### 4.5.1 Appearance

The genotype IC 15438 (25.20) had the highest mean rank for appearance followed by EC 305650 (22.27) and EC 305642 (22.17). The genotype IC 15435 (8.37) had the lowest mean rank for appearance.

### 4.5.2 Colour

The genotype IC 15027 (24.73) had the highest mean rank followed by EC 305650 (22.60) and EC 305647 (21.97). The lowest mean rank was recorded in IC 15435 (9.83).

### 4.5.3 Texture

The highest mean rank for texture was obtained for IC 15540 (24.07) followed by EC 305647 (23.97) and IC 14845 (23.80) while the lowest rank was for IC 15435 (9.83).

### 4.5.4 Flavour

The highest mean rank for flavour was recorded in the genotype IC 15027 (23.37) followed by EC 305647 (23.20) and IC 15540 (22.60) while the lowest rank was for IC 15435 (10.57).

### 4.5.5 Taste

The genotype EC 305647 (23.40) recorded the highest mean rank followed by IC 15540 (22.60) and IC 15027 (22.43) while IC 15435 (12.07) recorded the lowest mean rank.

### 4.5.6 Mouth feel

The genotype IC 15027 (25.20) recorded the highest mean rank followed by EC 305650 (22.30) and EC 305642 (22.13). The lowest mean rank was obtained from the genotype Salkeerthi (11.00).

**Table 11. Organoleptic evaluation of fresh fruits of okra genotypes**

| Sl. No | Treatments | Appearance | Colour | Texture | Flavour | Taste | Mouth feel | Overall acceptability |
|---|---|---|---|---|---|---|---|---|
| 1 | EC 305635 | 17.57 | 21.20 | 17.63 | 18.13 | 18.83 | 16.23 | 18.10 |
| 2 | EC 305637 | 15.13 | 12.43 | 13.40 | 13.10 | 14.33 | 15.43 | 16.63 |
| 3 | EC 305638 | 20.80 | 17.13 | 18.20 | 19.47 | 17.80 | 15.70 | 14.93 |
| 4 | EC 305639 | 17.13 | 13.70 | 15.87 | 14.90 | 20.00 | 13.50 | 16.53 |
| 5 | EC 305640 | 16.97 | 15.10 | 12.83 | 15.80 | 20.60 | 12.47 | 15.47 |
| 6 | EC 305642 | 22.17 | 19.77 | 20.07 | 19.43 | 20.07 | 22.13 | 19.70 |
| 7 | EC 305643 | 20.77 | 18.63 | 21.93 | 17.63 | 19.60 | 16.03 | 19.90 |
| 8 | EC 305645 | 15.57 | 14.50 | 13.20 | 14.43 | 16.87 | 14.70 | 14.23 |
| 9 | EC 305646 | 17.23 | 19.73 | 17.80 | 19.10 | 18.13 | 19.73 | 19.67 |
| 10 | EC 305647 | 21.53 | 21.97 | 23.97 | 23.20 | 23.40 | 20.77 | 22.00 |
| 11 | EC 305649 | 19.03 | 12.73 | 14.30 | 13.10 | 15.90 | 16.67 | 12.70 |
| 12 | EC 305650 | 22.27 | 22.60 | 22.63 | 20.20 | 19.27 | 22.30 | 20.80 |
| 13 | EC 305651 | 21.00 | 18.00 | 16.60 | 16.00 | 15.17 | 18.00 | 15.87 |
| 14 | EC 305673 | 20.63 | 19.07 | 16.67 | 16.37 | 14.47 | 16.17 | 18.13 |
| 15 | EC 305674 | 11.60 | 17.57 | 21.00 | 17.20 | 16.00 | 19.50 | 19.10 |
| 16 | IC 13664 | 10.20 | 13.80 | 15.53 | 13.07 | 14.43 | 15.30 | 15.33 |
| 17 | IC 13917 | 14.67 | 15.90 | 16.17 | 18.37 | 16.67 | 17.83 | 16.20 |

**Table 11. Organoleptic evaluation of fresh fruits of okra genotypes (Contd.)**

| Sl. No | Treatments | Appearance | Colour | Texture | Flavour | Taste | Mouth feel | Overall acceptability |
|---|---|---|---|---|---|---|---|---|
| 18 | IC 13995 | 14.37 | 12.73 | 18.67 | 16.13 | 13.70 | 13.77 | 14.47 |
| 19 | IC 14018 | 18.23 | 20.67 | 22.93 | 18.93 | 16.27 | 19.93 | 18.20 |
| 20 | IC 14026 | 18.83 | 20.00 | 18.97 | 19.27 | 19.07 | 21.27 | 19.73 |
| 21 | IC 14096 | 15.03 | 16.23 | 15.37 | 13.30 | 15.13 | 14.17 | 10.97 |
| 22 | IC 14600 | 21.67 | 19.70 | 14.33 | 16.67 | 17.73 | 18.97 | 19.03 |
| 23 | IC 14845 | 20.90 | 20.17 | 23.80 | 22.03 | 19.67 | 20.23 | 20.80 |
| 24 | IC 14909 | 16.87 | 17.23 | 16.40 | 14.27 | 16.70 | 18.70 | 19.33 |
| 25 | IC 15027 | 20.93 | 24.73 | 19.33 | 23.37 | 22.43 | 25.20 | 23.30 |
| 26 | IC 15036 | 12.87 | 17.57 | 14.27 | 15.37 | 16.90 | 16.87 | 16.60 |
| 27 | IC 15435 | 8.37 | 9.83 | 10.07 | 10.57 | 12.07 | 13.60 | 10.50 |
| 28 | IC 15438 | 25.20 | 21.77 | 19.00 | 21.93 | 20.87 | 21.43 | 20.67 |
| 29 | IC 15537 | 16.10 | 13.40 | 14.77 | 20.27 | 13.07 | 14.67 | 15.90 |
| 30 | IC 15540 | 18.77 | 21.20 | 24.07 | 22.60 | 22.60 | 20.77 | 23.00 |
| 31 | Aruna | 16.93 | 14.07 | 16.90 | 19.03 | 18.60 | 16.03 | 18.87 |
| 32 | Arka Anamika | 16.10 | 20.27 | 15.30 | 17.60 | 16.97 | 17.83 | 18.00 |
| 33 | Salkeerthi | 11.90 | 13.07 | 17.10 | 16.07 | 14.77 | 11.00 | 11.67 |
| 34 | Susthira | 17.67 | 18.53 | 15.93 | 18.10 | 16.93 | 18.10 | 17.67 |

### 4.5.7 Overall acceptability

The genotype IC 15027 (23.3) was ranked highest for overall acceptability followed by IC 15540 (23.00) and EC 305647 (22.00) while the genotype IC 15435 (10.50) was ranked lowest.

## 4.6 ESTIMATION OF GENETIC PARAMETERS

The performance of 34 genotypes of okra for 22 characters in terms of population mean, range, genotypic variance (GV), phenotypic variance (PV), genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), broad sense heritability (H), genetic advance (GA) and genetic advance as percentage of mean (GAM) were calculated to find out the extent to which observed variations are influenced by genetic factors and are presented in Table 12.

### 4.6.1 Phenotypic and genotypic variance (PV and GV)

The phenotypic variance ranged from 0.02 for yield per plant to 1111.26 for plant height. Similarly, the genotypic variance ranged from 0.01 for yield per plant to 970.79 for plant height. In general, all the 22 characters showed lower values of GV than PV.

### 4.6.2 Phenotypic coefficient of variation (PCV) (%)

The phenotypic coefficient of variation (PCV) ranged from 9.18 per cent (Days to first flowering) to 97.28 per cent (coefficient of infection at 60 DAS). Relatively higher PCV was observed for plant height (22.39), internodal length (23.06), number of seeds per fruit (30.80), number of harvest (20.43), number of fruits per plant (28.15), yield per plant (32.06), coefficient of infection at 60, 70, 80 and 90 DAS (97.28, 45.24, 30.03 and 24.66 respectively). Similarly, moderate value of PCV was recorded for petiole length (11.71), days to first harvest (10.08), first fruiting node (16.66), length of fruit (13.83), number of ridges per fruit (14.42), crop duration (11.59), average fruit weight (14.66), days to first symptom appearance (19.57), number of primary branches (19.78) and 100 seed weight (18.45). The other characters such as days to first flowering (9.18) and girth of fruit (9.73) exhibited lower PCV.

### 4.6.3 Genotypic coefficient of variation (GCV) (%)

The genotypic coefficient of variation (GCV) ranged from 8.62 per cent (girth of fruit) to 56.35 per cent (coefficient of infection at 60 DAS). Relatively higher GCV was observed for plant height (20.93), internodal length (20.71), number of seeds per fruit (25.68), number of fruits per plant (24.45), yield per plant (27.52), coefficient of infection at 60, 70, 80 and 90 DAS (56.35, 33.19, 26.75 and 23.76 respectively). Similarly, moderate value of GCV was recorded for first fruiting node (10.89), length of fruit (10.17), number of primary branches (15.18), number of ridges per fruit (13.17), number of harvest (18.02), crop duration (11.02), average fruit weight (12.75), 100 seed weight (18.03) and days to first symptom appearance (17.85). The other characters such as petiole length (9.79), days to first flowering (8.66), days to first harvest (9.70) and girth of fruit (8.62) exhibited lower GCV.

Analysis of the experimental data revealed that the PCV was higher than GCV for all the characters, clearly demonstrating the influence of environmental factors for expression of the genotypes of the traits.

### 4.6.4 Heritability ($H^2$) (%)

The result of heritability (broad sense) indicated wide variations which varied from 33.56 per cent (coefficient of infection at 60 DAS) to 95.53 per cent (100 seed weight). High heritability of above 60 per cent were observed for plant height (87.36), internodal length (80.67), petiole length (69.77), days to first flowering (89.11), days to first harvest (92.56), girth of fruit (78.46), number of ridges per fruit (83.37), number of seeds per fruit (69.51), crop duration (90.48), average fruit weight (75.66), 100 seed weight (95.53), days to first symptom appearance (83.23), coefficient of infection at 70, 80 and 90 DAS (53.82, 79.33 and 92.90 respectively). Rest of the characters recorded moderate values of heritability.

### 4.6.5 Genetic advance as percentage of mean (GAM) (%)

The genetic advance expressed as per cent of mean ranged from 14.68 (first fruiting node) to 67.25 (coefficient of infection at 60 DAS). Higher GAM was recorded for plant height (40.29), internodal length (38.31), coefficient of infection at 60, 70, 80

## Table 12. Estimation of genetic parameters

| Character | Range | | Mean | Phenotypic variance | Genotypic variance | PCV (%) | GCV (%) | $H^2$ (%) | GAM (%) |
|---|---|---|---|---|---|---|---|---|---|
| | Min | Max | | | | | | | |
| Plant height | 72.50 | 218.25 | 148.88 | 1111.26 | 970.79 | 22.39 | 20.93 | 87.36 | 40.29 |
| Internodal length | 3.25 | 7.55 | 5.03 | 1.345 | 1.09 | 23.06 | 20.71 | 80.67 | 38.31 |
| Petiole length | 23.32 | 37.86 | 30.82 | 13.035 | 9.10 | 11.71 | 9.79 | 69.77 | 16.84 |
| Days to first flowering | 36.17 | 52.75 | 41.76 | 14.69 | 13.09 | 9.18 | 8.66 | 89.11 | 16.85 |
| Days to first harvest | 43.67 | 65.00 | 49.19 | 24.59 | 22.76 | 10.08 | 9.70 | 92.56 | 19.22 |
| First fruiting node | 5.00 | 9.50 | 7.40 | 1.52 | 0.65 | 16.66 | 10.89 | 42.76 | 14.68 |
| Length of fruit | 12.18 | 19.40 | 15.35 | 4.505 | 2.44 | 13.83 | 10.17 | 54.05 | 15.40 |
| Girth of fruit | 4.94 | 7.79 | 5.86 | 0.325 | 0.26 | 9.73 | 8.62 | 78.46 | 15.72 |
| Number of ridges per fruit | 5.00 | 7.50 | 5.43 | 0.61 | 0.51 | 14.42 | 13.17 | 83.37 | 24.77 |
| Number of seeds per fruit | 25.00 | 86.00 | 50.04 | 237.6 | 165.16 | 30.80 | 25.68 | 69.51 | 44.11 |
| Number of harvest | 6.50 | 17.25 | 11.88 | 5.89 | 4.58 | 20.43 | 18.02 | 77.81 | 32.74 |
| Number of fruits per plant | 10.00 | 43.75 | 28.41 | 63.96 | 48.24 | 28.15 | 24.45 | 75.42 | 43.74 |
| Number of primary branches | 2.40 | 5.25 | 3.70 | 0.54 | 0.32 | 19.78 | 15.18 | 58.92 | 24.00 |
| Crop duration | 88.00 | 167.50 | 112.78 | 170.75 | 154.50 | 11.59 | 11.02 | 90.48 | 21.60 |
| Average fruit weight | 11.00 | 19.08 | 15.19 | 4.96 | 3.75 | 14.66 | 12.75 | 75.66 | 22.85 |
| Yield per plant | 0.16 | 0.71 | 0.43 | 0.02 | 0.01 | 32.06 | 27.52 | 73.68 | 48.66 |
| 100 seed weight | 9.10 | 3.58 | 6.78 | 1.565 | 1.50 | 18.45 | 18.03 | 95.53 | 36.31 |
| Days to first symptom appearance | 0.00 | 67.00 | 55.81 | 119.29 | 99.29 | 19.57 | 17.85 | 83.23 | 33.56 |
| Coefficient of infection at 60 DAS | 0.00 | 18.00 | 5.14 | 25.00 | 8.39 | 97.28 | 56.35 | 33.56 | 67.25 |
| Coefficient of infection at 70 DAS | 0.00 | 47.38 | 24.78 | 125.66 | 67.63 | 45.24 | 33.19 | 53.82 | 50.15 |
| Coefficient of infection at 80 DAS | 0.00 | 80.00 | 45.37 | 185.68 | 147.30 | 30.03 | 26.75 | 79.33 | 49.08 |
| Coefficient of infection at 90 DAS | 0.00 | 100.00 | 60.79 | 224.64 | 208.68 | 24.66 | 23.76 | 92.90 | 47.18 |

PCV- Phenotypic coefficient of variation, GCV- Genotypic coefficient of variation**,** $H^2$ - Heritability, GAM- Genetic advance as percentage of mean

and 90 DAS (67.25, 50.15, 49.08 and 47.18 respectively), number of ridges per fruit (24.77), number of seeds per fruit (44.11), number of harvest (32.74), number of fruits per plant (43.74), crop duration (21.60), number of primary branches (24.00), average fruit weight (22.85), yield per plant (48.66), 100 seed weight (36.31) and days to first symptom appearance (33.56). Other traits which exhibited moderate GAM were days to first harvest (19.22), petiole length (16.84), days to first flowering (16.85), length of fruit (15.40), girth of fruit (15.72) and first fruiting node (14.68).

## 4.7 CORRELATION AND PATH COEFFICIENT ANALYSIS

### 4.7.1 Phenotypic correlation

Phenotypic correlations of various characters with yield were estimated and presented in Table 13. At phenotypic level, plant height was significantly and positively correlated with internodal length (0.63), length of fruit (0.36), number of harvest (0.45), number of fruits per plant (0.29) and yield per plant (0.25). It was significantly and negatively correlated with days to first flowering (-0.46), days to first harvest (-0.58), first fruiting node (-0.29) and number of branches per plant (-0.43).

Internodal length was significantly and positively correlated with length of fruit (0.36). It was significantly and negatively correlated with days to first flowering (-0.27), days to first harvest (-0.32), first fruiting node (-0.32) and number of primary branches (-0.35).

Days to first flowering was significantly and positively correlated with days to first harvest (0.82), first fruiting node (0.36), girth of fruit (0.43), number of ridges per fruit (0.40), crop duration (0.47), number of primary branches (0.41) and average fruit weight (0.29). It was significantly and negatively correlated with length of fruit (-0.27) and days to first symptom appearance (-0.51).

Days to first harvest was significantly and positively correlated with first fruiting node (0.33), crop duration (0.27) and number of primary branches (0.55). It was significantly and negatively correlated with number of harvest (-0.31), number of fruits per plant (-0.44), days to first symptom appearance (-0.38) and yield per plant (-0.30).

**Table 13. Phenotypic correlation**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 1** | | | | | | | | | | | | | | | | | |
| **2** | 0.63** | 1** | | | | | | | | | | | | | | | | |
| **3** | -0.46** | -0.27* | 1** | | | | | | | | | | | | | | | |
| **4** | -0.58** | -0.32** | 0.82** | 1** | | | | | | | | | | | | | | |
| **5** | -0.29* | -0.32** | 0.36** | 0.33** | 1** | | | | | | | | | | | | | |
| **6** | 0.36** | 0.36** | -0.27* | -0.16NS | -0.32** | 1** | | | | | | | | | | | | |
| **7** | -0.07NS | -0.02NS | 0.43** | 0.23NS | -0.19NS | 0.03NS | 1** | | | | | | | | | | | |
| **8** | 0.45** | 0.07NS | -0.06NS | -0.31* | -0.18NS | 0.18NS | 0.18NS | 1** | | | | | | | | | | |
| **9** | 0.16NS | -0.002NS | 0.47** | 0.27* | -0.08NS | 0.12NS | 0.43** | 0.46** | 1** | | | | | | | | | |
| **10** | 0.29* | -0.15NS | -0.19NS | -0.44** | -0.09NS | -0.15NS | -0.08NS | 0.70** | 0.22NS | 1** | | | | | | | | |
| **11** | -0.43** | -0.35** | 0.41** | 0.55** | 0.41** | -0.05NS | -0.09NS | 0.004NS | 0.10NS | -0.12NS | 1** | | | | | | | |
| **12** | -0.06NS | -0.11NS | 0.29* | 0.23NS | 0.02NS | -0.03NS | 0.25* | 0.01NS | 0.16NS | -0.02NS | 0.29* | 1** | | | | | | |
| **13** | -0.12NS | -0.07NS | -0.51** | -0.38** | 0.14NS | -0.21NS | -0.55** | -0.27* | -0.69** | 0.14NS | 0.02NS | -0.20NS | 1** | | | | | |
| **14** | 0.01NS | 0.08NS | -0.14NS | 0.04NS | 0.05NS | 0.37** | -0.10NS | 0.04NS | -0.04NS | -0.15NS | 0.08NS | -0.16NS | -0.02NS | 1** | | | | |
| **15** | -0.06NS | 0.12NS | -0.15NS | -0.001NS | 0.15NS | 0.23NS | -0.16NS | -0.15NS | -0.36** | -0.30* | 0.02NS | -0.10NS | 0.17NS | 0.74** | 1** | | | |
| **16** | -0.16NS | 0.13NS | -0.26* | -0.11NS | 0.19NS | 0.06NS | -0.30* | -0.37** | -0.68** | -0.39** | -0.09NS | -0.16NS | 0.40** | 0.50** | 0.79** | 1** | | |
| **17** | -0.11NS | 0.08NS | -0.41** | -0.19NS | 0.18NS | 0.07NS | -0.43** | -0.40** | -0.78** | -0.30* | -0.05NS | -0.24* | 0.62** | 0.39** | 0.67** | 0.86** | 1** | |
| **18** | 0.25* | -0.18NS | -0.08NS | -0.30* | -0.11NS | -0.07NS | 0.04NS | 0.69** | 0.32** | 0.87** | 0.08NS | 0.34** | 0.03NS | -0.20NS | -0.32** | -0.48** | -0.44** | 1** |

* Significant at 5% level ** Significant at 1 and 5% level

1. Plant height 2. Internodal length 3. Days to first flowering 4. Days to first harvest 5. First fruiting node 6. Length of fruit

7. Girth of fruit 8. Number of harvest 9. Crop duration 10. No. of fruits per plant 11. No. of primary branches 12. Average fruit weight

13. Days to first symptom appearance 14. CI at 60 DAS 15. CI at 70 DAS 16. CI at 80 DAS 17. CI at 90 DAS 18. Yield per plant

Days to first symptom appearance was significantly and positively correlated to coefficient of infection of YVMD at 70, 80 and 90 DAS (0.36, 0.58 and 0.75 respectively).

First fruiting node was significantly and positively correlated with number of primary branches (0.41) and it was significantly and negatively correlated with length of fruit (-0.32).

Girth of fruit was significantly and positively correlated with crop duration (0.43) and average fruit weight (0.25). It was significantly and negatively correlated with days to first symptom appearance (-0.55).

Number of harvest was significantly and positively correlated with crop duration (0.46), number of fruits per plant (0.70) and yield per plant (0.69). It was significantly and negatively correlated with days to first symptom appearance (-0.27).

Crop duration was significantly and positively correlated with yield per plant (0.32). It was significantly and negatively correlated with days to first symptom appearance (-0.69).

Number of fruits per plant was significantly and positively correlated with yield per plant (0.87). Number of primary branches was significantly and positively correlated with average fruit weight (0.29).

Average fruit weight was significantly and positively correlated with yield per plant (0.34). It was significantly and negatively correlated with 100 seed weight (-0.28).

Days to first symptom appearance was significantly and positively correlated with coefficient of infection of infection of YVMD at 80 and 90 DAS (0.40 and 0.62 respectively).

Coefficient of infection of YVMD at 60 DAS was significantly and positively correlated with coefficient of infection of YVMD at 70, 80 and 90 DAS (0.74, 0.50 and 0.39 respectively).

Coefficient of infection of YVMD at 70 DAS was significantly and positively correlated with coefficient of infection of YVMD at 80 and 90 DAS (0.79 and 0.67

respectively). It was significantly and negatively correlated with yield per plant (-0.32), crop duration (-0.36) and number of fruits per plant (-0.30).

Coefficient of infection of YVMD at 80 DAS was significantly and positively correlated with coefficient of infection of YVMD at 90 DAS (0.86). It was significantly and negatively correlated with yield per plant (-0.48), crop duration (-0.68), number of fruits per plant (-0.39) and number of harvest (-0.37).

Coefficient of infection of YVMD at 90 DAS was significantly and negatively correlated with yield per plant (-0.44), girth of fruit (-0.43), crop duration (-0.78), number of fruits per plant (-0.30) and number of harvest (-0.40) and average fruit weight (-0.24).

Yield per plant was significantly and positively correlated with plant height, number of harvest, crop duration, number of fruits per plant and average fruit weight. It was significantly and negatively correlated with days to first harvest, coefficient of infection at 70, 80 and 90 DAS.

### 4.7.2 Genotypic correlation

Genotypic correlations of various yield components with yield were estimated and presented in the Table 14. Plant height was significantly and positively correlated with internodal length (0.70), length of fruit (0.44), number of harvest (0.49), number of fruits per plant (0.30) and yield per plant (0.26). It was significantly and negatively correlated with days to first flowering (-0.51), days to first harvest (-0.60), first fruiting node (-0.47) and number of primary branches (-0.58).

Internodal length was significantly and positively correlated to length of fruit (0.53) and number of seeds per fruit (0.31) while it was significantly and negatively correlated with days to first flowering (-0.27), days to first harvest (-0.34), first fruiting node (-0.29), number of primary branches (-0.48) and yield per plant (-0.28).

Days to first flowering was significantly and positively correlated with days to first harvest (0.87), first fruiting node (0.40), girth of fruit (0.46), crop duration (0.54), number of primary branches (0.47) and average fruit weight (0.32). It was significantly

and negatively correlated to length of fruit (-0.37) and days to first symptom appearance (-0.53).

Days to first harvest was significantly and positively correlated with first fruiting node (0.51), girth of fruit (0.26), crop duration (0.31) and number of primary branches per plant (0.66). It was significantly and negatively correlated with number of harvest (-0.34), number of fruits per plant (-0.50), days to first symptom appearance (-0.40) and yield per plant (-0.32).

First fruiting node was significantly and positively correlated with number of primary branches (0.33) and days to first symptom appearance (0.37). It was significantly and negatively correlated with length of fruit (-0.52), girth of fruit (-0.35) and number of harvest (-0.43).

Length of fruit was significantly and negatively correlated with number of ridges per fruit (-0.59), number of seeds per fruit (-0.35) and days to first symptom appearance (-0.27).

Girth of fruit was significantly and positively correlated with number of ridges per fruit (0.31), number of harvest (0.25), crop duration (0.55) and average fruit weight (0.31). It was significantly and negatively correlated with days to first symptom appearance (-0.66).

Number of harvest was significantly and positively correlated with crop duration (0.50), number of fruits per plant (0.75) and yield per plant (0.74). It was significantly and negatively correlated with days to first symptom appearance (-0.40).

The duration of crop was significantly and positively correlated with number of fruits per plant (0.25) and yield per plant (0.35). It was significantly and negatively correlated with days to first symptom appearance (-0.82).

Number of fruits per plant was significantly and positively correlated with yield per plant (0.90). Number of primary branches was significantly and positively correlated with average fruit weight (0.54). Average fruit weight was significantly and positively correlated with yield per plant (0.45).

**Table 14. Genotypic correlation**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 1** | | | | | | | | | | | | | | | | | |
| **2** | 0.70** | 1** | | | | | | | | | | | | | | | | |
| **3** | -0.51** | -0.27* | 1** | | | | | | | | | | | | | | | |
| **4** | -0.60** | -0.34** | 0.87** | 1** | | | | | | | | | | | | | | |
| **5** | -0.47** | -0.29* | 0.40** | 0.51** | 1** | | | | | | | | | | | | | |
| **6** | 0.44** | 0.53** | -0.37** | -0.21$^{NS}$ | -0.52** | 1** | | | | | | | | | | | | |
| **7** | -0.06$^{NS}$ | 0.04$^{NS}$ | 0.46** | 0.26* | -0.35** | 0.02$^{NS}$ | 1** | | | | | | | | | | | |
| **8** | 0.49** | 0.03$^{NS}$ | -0.06$^{NS}$ | -0.34** | -0.43** | 0.20$^{NS}$ | 0.25* | 1** | | | | | | | | | | |
| **9** | 0.18$^{NS}$ | 0.002$^{NS}$ | 0.54** | 0.31* | -0.18$^{NS}$ | 0.17$^{NS}$ | 0.55** | 0.50** | 1** | | | | | | | | | |
| **10** | 0.30* | -0.18$^{NS}$ | -0.22$^{NS}$ | -0.50** | -0.16$^{NS}$ | -0.20$^{NS}$ | -0.05$^{NS}$ | 0.75** | 0.25* | 1** | | | | | | | | |
| **11** | -0.58** | -0.48** | 0.47** | 0.66** | 0.33** | -0.08$^{NS}$ | -0.12$^{NS}$ | -0.13$^{NS}$ | 0.06$^{NS}$ | -0.17$^{NS}$ | 1** | | | | | | | |
| **12** | -0.08$^{NS}$ | -0.23$^{NS}$ | 0.32** | 0.26* | 0.08$^{NS}$ | -0.10$^{NS}$ | 0.31* | 0.07$^{NS}$ | 0.22$^{NS}$ | 0.08$^{NS}$ | 0.54** | 1** | | | | | | |
| **13** | -0.15$^{NS}$ | -0.10$^{NS}$ | -0.53** | -0.40** | 0.37** | -0.27* | -0.66** | -0.40** | -0.82** | 0.11$^{NS}$ | 0.11$^{NS}$ | -0.18$^{NS}$ | 1** | | | | | |
| **14** | 0.11$^{NS}$ | 0.19$^{NS}$ | -0.15$^{NS}$ | -0.09$^{NS}$ | 0.003$^{NS}$ | 0.67** | -0.01$^{NS}$ | 0.05$^{NS}$ | -0.20$^{NS}$ | -0.04$^{NS}$ | -0.38** | -0.26* | 0.018$^{NS}$ | 1** | | | | |
| **15** | -0.03$^{NS}$ | 0.17$^{NS}$ | -0.20$^{NS}$ | -0.09$^{NS}$ | 0.35** | 0.31* | -0.16$^{NS}$ | -0.18$^{NS}$ | -0.56** | -0.31* | -0.10$^{NS}$ | -0.08$^{NS}$ | 0.360** | 0.947** | 1** | | | |
| **16** | -0.14$^{NS}$ | 0.18$^{NS}$ | -0.30* | -0.17$^{NS}$ | 0.37** | 0.07$^{NS}$ | -0.46** | -0.34** | -0.80** | -0.29* | -0.17$^{NS}$ | -0.25* | 0.577** | 0.727** | 0.961** | 1** | | |
| **17** | -0.11$^{NS}$ | 0.11$^{NS}$ | -0.46** | -0.22$^{NS}$ | 0.31** | 0.08$^{NS}$ | -0.53** | -0.40** | -0.85** | -0.27* | -0.09$^{NS}$ | -0.267* | 0.750** | 0.597** | 0.836** | 0.919** | 1** | |
| **18** | 0.25* | -0.28* | -0.07$^{NS}$ | -0.32** | -0.16$^{NS}$ | -0.07$^{NS}$ | 0.12$^{NS}$ | 0.74** | 0.35** | 0.90** | 0.156$^{NS}$ | 0.45** | -0.042$^{NS}$ | -0.120$^{NS}$ | -0.310* | -0.424** | -0.407** | 1** |

* Significant at 5% level ** Significant at 1 and 5% level

1. Plant height 2. Internodal length 3. Days to first flowering 4. Days to first harvest 5. First fruiting node 6. Length of fruit

7. Girth of fruit 8. Number of harvest 9. Crop duration 10. No. of fruits per plant 11. No. of primary branches 12. Average fruit weight

13. Days to first symptom appearance 14. CI at 60 DAS 15. CI at 70 DAS 16. CI at 80 DAS 17. CI at 90 DAS 18. Yield per plant

Coefficient of infection of YVMD at 60 DAS was significantly and positively correlated with coefficient of infection at 70, 80 and 90 DAS (0.95, 0.73 and 0.60 respectively). It was significantly and negatively correlated with length of fruit (-0.67), number of primary branches (-0.38) and average fruit weight (-0.26).

Coefficient of infection of YVMD at 70 DAS was significantly and positively correlated with coefficient of infection at 80 and 90 DAS (0.96 and 0.84) while it was significantly and negatively correlated with yield per plant (-0.31), crop duration (-0.56) and number of fruits per plant (-0.31).

Coefficient of infection of YVMD at 80 DAS was significantly and positively correlated with coefficient of infection at 90 DAS (0.92) while it was significantly and negatively correlated with yield per plant (-0.42), girth of fruit (-0.46), number of harvest (-0.34), crop duration (-0.80), number of fruits per plant (-0.29) and average fruit weight (-0.25).

Coefficient of infection of YVMD at 90 DAS was significantly and negatively correlated with yield per plant (-0.41), girth of fruit (-0.53), number of harvest (-0.40), crop duration (-0.85), number of fruits per plant (-0.27) and average fruit weight (-0.27).

Yield per plant was significantly and positively correlated with plant height, number of harvest, crop duration, number of fruits per plant and average fruit weight. It was significantly and negatively correlated with internodal length, days to first harvest, coefficient of infection at 70, 80 and 90 DAS.

### 4.7.3 Path coefficient analysis

Path coefficient analysis of 10 characters were carried out in order to find out the cause and effect relationship on yield per plant. The correlations of fruit yield with other characters were divided into direct and indirect effects to identify the direct and indirect contribution of component characters to yield. The genotypic correlation coefficient was used in path analysis and the results are presented in Table 15.

#### *4.7.3.1 Direct effects on yield*

Number of fruits per plant had highest direct positive effect on yield (0.608) followed by coefficient of infection of YVMD at 80 DAS (0.441), average fruit weight

(0.407), plant height (0.226) and number of harvest (0.140). Remaining characters showed negative direct effect on yield being highest in coefficient of infection at 70 DAS (-0.336) followed by internodal length (-0.277), days to first harvest (-0.041) and coefficient of infection at 90 DAS (-0.010).

#### *4.7.3.2 Indirect effects on yield*

Plant height had direct positive effect on yield (0.226). It also had indirect positive effect on yield through number of fruits per plant (0.184), number of harvest (0.068), crop duration (0.031) and days to first harvest (0.025).

Internodal length had direct negative effect (-0.277) on yield and indirect positive effect on yield was noticed through plant height (0.158), days to first harvest (0.014) and number of harvest (0.005).

Days to first harvest had direct negative effect on yield (-0.041) and indirect positive effect on yield through average fruit weight (0.106), internodal length (0.093) and crop duration (0.052).

Number of harvest had direct positive effect on yield (0.140). It had indirect positive effect on yield through plant height (0.110), days to first harvest (0.014), crop duration (0.084), number of fruits per plant (0.457) and average fruit weight (0.030).

Crop duration had direct positive effect on yield (0.169). It had indirect positive effect on yield through plant height (0.041), number of harvest (0.069), number of fruits per plant (0.151) and average fruit weight (0.089).

Number of fruits per plant had direct positive effect on yield. It also had indirect positive effect through plant height (0.068), internodal length (0.050), days to first harvest (0.021), number of harvest (0.105), crop duration (0.042) and average fruit weight (0.030).

Average fruit weight had direct positive effect on yield (0.407). It had indirect positive effect on yield through internodal length (0.062), number of harvest (0.010), crop duration (0.037) and number of fruits per plant (0.045).

**Table 15. Path coefficient analysis in okra**

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| **1** | **0.226** | -0.194 | 0.025 | 0.068 | 0.031 | 0.184 | -0.034 | 0.009 | -0.062 | 0.001 |
| **2** | 0.158 | **-0.277** | 0.014 | 0.005 | 0.000 | -0.110 | -0.092 | -0.056 | 0.077 | -0.001 |
| **3** | -0.136 | 0.093 | **-0.041** | -0.047 | 0.052 | -0.305 | 0.106 | 0.030 | -0.074 | 0.002 |
| **4** | 0.110 | -0.009 | 0.014 | **0.140** | 0.084 | 0.457 | 0.030 | 0.062 | -0.150 | 0.004 |
| **5** | 0.041 | -0.001 | -0.013 | 0.069 | **0.169** | 0.151 | 0.089 | 0.189 | -0.351 | 0.008 |
| **6** | 0.068 | 0.050 | 0.021 | 0.105 | 0.042 | **0.608** | 0.030 | 0.104 | -0.128 | 0.003 |
| **7** | -0.019 | 0.062 | -0.011 | 0.010 | 0.037 | 0.045 | **0.407** | 0.026 | -0.110 | 0.003 |
| **8** | -0.006 | -0.046 | 0.004 | -0.026 | -0.095 | -0.189 | -0.031 | **-0.336** | 0.424 | -0.008 |
| **9** | -0.032 | -0.048 | 0.007 | -0.048 | -0.134 | -0.176 | -0.101 | -0.323 | **0.441** | -0.009 |
| **10** | -0.024 | -0.031 | 0.009 | -0.056 | -0.143 | -0.167 | -0.110 | -0.281 | 0.405 | **-0.010** |

1. Plant height
2. Internodal length
3. Days to first harvest
4. No. of harvest
5. Crop duration
6. No. of fruits per plant
7. Average fruit weight
8. CI at 70 DAS
9. CI at 80 DAS
10. CI at 90 DAS

Coefficient of infection of YVMD at 70 DAS had direct negative effect on yield (-0.336).

Coefficient of infection of YVMD at 80 DAS had direct positive effect on yield (0.441). It had indirect negative effect on yield through coefficient of infection at 70 DAS (-0.323), number of fruits per plant (-0.176), crop duration (-0.134) and average fruit weight (-0.101).

Coefficient of infection of YVMD at 90 DAS had direct negative effect on yield (-0.010). It also had indirect negative effect on yield through coefficient of infection at 70 DAS (-0.281), average fruit weight (-0.110), number of fruits per plant (-0.167) and crop duration (-0.143).

## 4.8 LOGISTIC REGRESSION ANALYSIS

The analysis was conducted using three independent variables *viz.*, number of fruits per plant, average fruit weight and length of fruit. The characters *viz*., number of fruits per plant and average fruit weight had high positive direct effect on yield. Hence, these two characters along with length of fruit which is an important character for selection of okra genotypes were chosen for logistic regression analysis. The dependent variable is yield per plant. The results of the analysis are presented in Table 16.

**Table 16. Logistic estimates of variables affecting yield per plant**

| Parameters | Coefficient | Standard error | Wald | Significance | Exp (B) | Expected per cent of improvement over population (%) |
|---|---|---|---|---|---|---|
| No. of fruits per plant** | 0.784 | 0.330 | 5.128 | 0.024 | 2.114 | 67.90 |
| Average fruit weight** | 1.223 | 0.769 | 2.528 | 0.012 | 3.399 | 77.26 |
| Length of fruit | -0.145 | 0.406 | 0.128 | 0.720 | 0.865 | |
| Constant | -35.598 | 16.481 | 4.468 | 0.035 | 0.000 | |

** Significant values less than 0.035

Two parameters *viz*., number of fruits per plant and average fruit weight expressed significance value less than 0.035 which is the value of the constant. Based on Exp (B) value from the regression model, expected percentage of improvement over the base population was calculated. The expected per cent of improvement over base population for the characters *viz.*, number of fruits per plant and average fruit weight were 67.90 and 77.26 per cent respectively.

## 4.9 SELECTION CRITERIA FOR EVALUATION OF GERMPLASM OF OKRA

The genotypes were scored based on their yielding potential and the characters *viz.*, number of fruits per plant and average fruit weight (Table 17). The total score for a genotype was calculated from the individual scores of the characters. Based on the values of total score, the genotypes were ranked and the top ranking genotypes were selected for fixing the selection criteria for okra genotypes from a population.

**Table 17. Scoring of okra genotypes for fixing selection criteria**

| Sl. No | Genotypes | Yield/ plant (kg) | Score | No. of fruits/plant | Score | Average fruit weight (g) | Score | Total score | Rank |
|---|---|---|---|---|---|---|---|---|---|
| 1 | EC 305635 | 0.64 | 1 | 40.05 | 2 | 16.05 | 2 | 5 | 3 |
| 2 | EC 305637 | 0.39 | 3 | 30.05 | 2 | 13.73 | 3 | 8 | 6 |
| 3 | EC 305638 | 0.46 | 2 | 26.50 | 3 | 16.60 | 2 | 7 | 5 |
| 4 | EC 305639 | 0.24 | 4 | 21.43 | 3 | 13.27 | 3 | 10 | 8 |
| 5 | EC 305640 | 0.31 | 3 | 24.80 | 3 | 11.00 | 4 | 10 | 8 |
| 6 | EC 305642 | 0.71 | 1 | 43.75 | 1 | 17.02 | 1 | 3 | 1 |
| 7 | EC 305643 | 0.42 | 2 | 25.69 | 3 | 16.75 | 2 | 7 | 5 |
| 8 | EC 305645 | 0.25 | 4 | 22.50 | 3 | 12.08 | 3 | 10 | 8 |
| 9 | EC 305646 | 0.46 | 2 | 28.64 | 2 | 13.21 | 3 | 7 | 5 |
| 10 | EC 305647 | 0.47 | 2 | 30.85 | 2 | 15.30 | 2 | 6 | 4 |
| 11 | EC 305649 | 0.45 | 2 | 30.00 | 2 | 14.58 | 2 | 6 | 4 |
| 12 | EC 305650 | 0.50 | 2 | 31.62 | 2 | 13.73 | 3 | 7 | 5 |

**Table 17. Scoring of okra genotypes for fixing selection criteria (Contd.)**

| Sl. No | Genotypes | Yield/ plant (kg) | Score | No. of fruits/plant | Score | Average fruit weight (g) | Score | Total score | Rank |
|---|---|---|---|---|---|---|---|---|---|
| 13 | EC 305651 | 0.36 | 3 | 23.21 | 3 | 15.18 | 2 | 8 | 6 |
| 14 | EC 305673 | 0.62 | 1 | 40.05 | 1 | 15.13 | 2 | 4 | 2 |
| 15 | EC 305674 | 0.28 | 3 | 20.75 | 3 | 12.75 | 3 | 9 | 7 |
| 16 | IC 13664 | 0.46 | 2 | 24.50 | 3 | 19.00 | 1 | 6 | 4 |
| 17 | IC 13917 | 0.55 | 2 | 29.91 | 2 | 19.08 | 1 | 5 | 3 |
| 18 | IC 13995 | 0.39 | 3 | 29.78 | 2 | 13.75 | 3 | 8 | 6 |
| 19 | IC 14018 | 0.40 | 3 | 31.00 | 2 | 12.79 | 3 | 8 | 6 |
| 20 | IC 14026 | 0.60 | 1 | 36.50 | 1 | 15.75 | 2 | 4 | 2 |
| 21 | IC 14096 | 0.27 | 4 | 16.00 | 4 | 15.50 | 2 | 10 | 8 |
| 22 | IC 14600 | 0.34 | 3 | 17.00 | 4 | 17.12 | 1 | 8 | 6 |
| 23 | IC 14845 | 0.34 | 3 | 20.92 | 3 | 16.13 | 2 | 8 | 6 |
| 24 | IC 14909 | 0.58 | 4 | 36.25 | 1 | 18.50 | 1 | 6 | 4 |
| 25 | IC 15027 | 0.50 | 2 | 29.05 | 2 | 16.63 | 2 | 6 | 4 |
| 26 | IC 15036 | 0.33 | 3 | 26.05 | 3 | 13.40 | 3 | 9 | 7 |
| 27 | IC 15435 | 0.56 | 1 | 35.52 | 2 | 17.50 | 1 | 4 | 2 |
| 28 | IC 15438 | 0.48 | 2 | 33.46 | 2 | 13.69 | 3 | 7 | 5 |
| 29 | IC 15537 | 0.41 | 3 | 30.00 | 2 | 12.90 | 3 | 8 | 6 |
| 30 | IC 15540 | 0.48 | 2 | 36.00 | 1 | 13.00 | 3 | 6 | 4 |
| 31 | Aruna | 0.39 | 3 | 20.50 | 3 | 18.55 | 1 | 7 | 5 |
| 32 | Arka Anamika | 0.63 | 1 | 41.36 | 1 | 14.88 | 2 | 4 | 2 |
| 33 | Salkeerthi | 0.16 | 4 | 10.00 | 4 | 15.25 | 2 | 10 | 8 |
| 34 | Susthira | 0.41 | 3 | 22.30 | 3 | 16.80 | 2 | 8 | 6 |

The selected genotypes were EC 305642, EC 305673, IC 14026, IC 15435, and Arka Anamika. The selection criteria was fixed considering the highest and lowest values of these selected genotypes and the results are presented in Table 18.

**Table 18. Selection criteria for evaluation of germplasm of okra**

| Parameters | Range |
|---|---|
| Yield per plant (kg) | 0.56-0.71 |
| Number of fruits per plant | 35.42-43.75 |
| Average fruit weight (g) | 14.88-17.02 |

## 4.10. SELECTION OF SUPERIOR GENOTYPES OF OKRA

The selection of genotypes for future breeding programmes were done using the selection criteria along with the character length of fruit and overall acceptability of organoleptic evaluation. The genotypes were scored using these characters and the total score was calculated. The results are presented in Table 19.

Based on the values of total score, the genotypes were ranked and the top ranking genotypes were selected. The genotypes selected were IC 15027, IC 15540, EC 305647, EC 305650 and EC 305642 which were found superior for these characters (Plate 11). The characters of selected genotypes are presented in Table 20.

**Table 19. Scoring of okra genotypes for selection of superior genotypes**

| Sl. No | Genotypes | Length of fruit (cm) | Score | Overall acceptability (mean rank) | Score | Total score from other characters | Total score | Rank |
|---|---|---|---|---|---|---|---|---|
| 1 | EC 305635 | 17.23 | 1 | 18.10 | 16 | 5 | 22 | 9 |
| 2 | EC 305637 | 16.67 | 2 | 16.63 | 19 | 8 | 29 | 13 |
| 3 | EC 305638 | 18.34 | 1 | 14.93 | 27 | 7 | 35 | 17 |
| 4 | EC 305639 | 14.42 | 3 | 16.53 | 21 | 10 | 34 | 16 |
| 5 | EC 305640 | 16.94 | 2 | 15.47 | 25 | 10 | 37 | 18 |
| 6 | EC 305642 | 15.79 | 2 | 19.70 | 8 | 3 | 13 | **3** |
| 7 | EC 305643 | 19.06 | 1 | 19.90 | 6 | 7 | 14 | 4 |
| 8 | EC 305645 | 16.62 | 2 | 14.23 | 29 | 10 | 41 | 21 |

**Table 19. Scoring of okra genotypes for selection of superior genotypes (Contd.)**

| Sl. No | Genotypes | Length of fruit (cm) | Score | Overall acceptability (mean rank) | Score | Total score from other characters | Total score | Rank |
|---|---|---|---|---|---|---|---|---|
| 9 | EC 305646 | 17.27 | 1 | 19.67 | 9 | 7 | 17 | 6 |
| 10 | EC 305647 | 14.32 | 3 | 22.00 | 3 | 6 | 12 | **2** |
| 11 | EC 305649 | 16.19 | 2 | 12.70 | 30 | 6 | 38 | 19 |
| 12 | EC 305650 | 17.48 | 1 | 20.80 | 4 | 7 | 12 | **2** |
| 13 | EC 305651 | 15.25 | 2 | 15.87 | 24 | 8 | 34 | 16 |
| 14 | EC 305673 | 15.76 | 2 | 18.13 | 15 | 4 | 21 | 8 |
| 15 | EC 305674 | 16.08 | 2 | 19.10 | 11 | 9 | 22 | 9 |
| 16 | IC 13664 | 14.10 | 3 | 15.33 | 26 | 6 | 35 | 17 |
| 17 | IC 13917 | 13.93 | 3 | 16.20 | 22 | 5 | 30 | 14 |
| 18 | IC 13995 | 14.60 | 2 | 14.47 | 28 | 8 | 38 | 19 |
| 19 | IC 14018 | 14.46 | 3 | 18.20 | 14 | 8 | 25 | 11 |
| 20 | IC 14026 | 13.32 | 3 | 19.73 | 7 | 4 | 14 | 4 |
| 21 | IC 14096 | 13.32 | 3 | 10.97 | 32 | 10 | 45 | 23 |
| 22 | IC 14600 | 14.26 | 3 | 19.03 | 12 | 8 | 23 | 10 |
| 23 | IC 14845 | 15.03 | 2 | 20.80 | 4 | 8 | 14 | 4 |
| 24 | IC 14909 | 12.73 | 3 | 19.33 | 10 | 6 | 19 | 7 |
| 25 | IC 15027 | 13.40 | 3 | 23.30 | 1 | 6 | 10 | **1** |
| 26 | IC 15036 | 12.18 | 3 | 16.60 | 20 | 9 | 32 | 15 |
| 27 | IC 15435 | 12.95 | 3 | 10.50 | 33 | 4 | 40 | 20 |
| 28 | IC 15438 | 13.83 | 3 | 20.67 | 5 | 7 | 15 | 5 |
| 29 | IC 15537 | 13.07 | 3 | 15.90 | 23 | 8 | 34 | 16 |
| 30 | IC 15540 | 15.35 | 2 | 23.00 | 2 | 6 | 10 | **1** |
| 31 | Aruna | 19.40 | 1 | 18.87 | 13 | 7 | 21 | 8 |
| 32 | Arka Anamika | 16.88 | 2 | 18.00 | 17 | 4 | 23 | 10 |
| 33 | Salkeerthi | 17.50 | 1 | 11.67 | 31 | 10 | 42 | 22 |
| 34 | Susthira | 17.06 | 2 | 17.67 | 18 | 8 | 28 | 12 |

**Table 20. Characters of selected genotypes of okra**

| Sl. No | Genotypes | Yield per plant (kg) | Average fruit weight (g) | No. of fruits/plant | Length of fruit (cm) | Overall acceptability (mean rank) |
|---|---|---|---|---|---|---|
| 1 | IC 15027 | 0.50 | 16.63 | 29.05 | 13.40 | 23.30 |
| 2 | IC 15540 | 0.48 | 13.00 | 36.00 | 15.35 | 23.00 |
| 3 | EC 305647 | 0.47 | 15.30 | 30.85 | 14.32 | 22.00 |
| 4 | EC 305650 | 0.50 | 13.73 | 31.62 | 17.48 | 20.80 |
| 5 | EC 305642 | 0.71 | 17.02 | 43.75 | 15.79 | 19.70 |


**a) Plant of IC 15027**

**b) Plant of IC 15540**

**c) Fruits of IC 15027**

**d) Fruits of IC 15540**

**Plate 11. Selected superior genotypes of okra**


**c) Plant of EC 305647**

**d) Plant of EC 305650**

**c) Fruits of EC 305647**

**d) Fruits of EC 305650**

**Plate 11. Selected superior genotypes of okra (Contd.)**


**a) Plant of EC 305642**

**b) Fruits of EC 305642**

**Plate 11. Selected superior genotypes of okra (Contd.)**

# *Discussion*

# 5. DISCUSSION

In the present investigation, thirty four genotypes of okra were evaluated for morphological characters, yield and disease parameters. Data was subjected to statistical analysis to get the average performance of accessions with respect to yield and disease resistance.

## 5.1 Evaluation of genotypes for qualitative characters

All the genotypes used in the study had erect and branching growth habit. Leaf lobing varied from narrowly lobed to deeply lobed among the genotypes. Twenty eight genotypes (82.35%) had deeply lobed leaves and six genotypes (17.65%) had narrowly lobed leaves. Colour of leaf vein was light green in 27 genotypes (79.41%), green in six genotypes and red in Aruna. Colour of leaf base was green in 16 genotypes (47.05%), green with red tinge in 17 genotypes (50%) and red in Aruna. Similar variation in leaf characters were reported by Singh *et al*. (2015).

Flower colour was yellow for all the genotypes and they had purple throat at the base of corolla. Majority of the genotypes had medium (88.23%) sized flowers except Susthira, Aruna, IC 14096 and IC 14600 which had large flowers. Variations in flower characters were reported by Singh *et al*. (2015).

Fruit colour varied from light green, green and red and almost all the genotypes had either light green or green colour fruits except Aruna. Most of the genotypes (82.35%) had flat surface between ridges whereas some had concave surface. Majority of the fruits had downy surface while some had slightly rough fruit surface. Variations in fruit characters were reported by Singh *et al*. (2015) and Saurabh *et al*. (2016).

## 5.2 Evaluation of genotypes for quantitative characters

The present study revealed significant differences between the 34 genotypes for all the quantitative characters studied *viz*., plant height, internodal length, petiole length, days to first flowering, days to first harvest, first fruiting node, length of fruit, girth of fruit, number of ridges per fruit, number of seeds per fruit, number of harvest, crop duration, number of fruits per plant, number of primary branches, average fruit weight, 100 seed weight and yield per plant.

Plant height varied from 72.5 cm (Salkeerthi) to 218.25 cm (EC 305649) among the genotypes. Out of 34 genotypes, 28 were classified as tall (>120 cm), three (IC 14096, IC 14026 and IC 14909) as medium (90-120 cm) and remaining three (IC 14600, IC 15036 and Salkeerthi) as short (<90 cm). Variations in plant height among different genotypes were reported previously by Adiger (2015); Singh *et al*. (2015) and Hareesha (2016). The lower plant height of Salkeerthi in the present study may be due to its high susceptibility to YVMD which lead to the stunting of the plant.

Internodal length varied from 3.25 cm (IC 14026) to 7.55 cm (EC 305645). Similar variations in internodal length among genotypes were reported by Adiger (2015) and Mahalik (2018). In okra, flowering and fruiting occurs at the nodes. Hence, the genotypes having shorter internodes are preferred as it produces more fruits.

Petiole length ranged from 23.32 cm (IC 13995) to 37.86 cm (IC 13917). Variations in petiole length among genotypes were previously reported by Singh *et al.* (2015).

Days to first flowering varied from 36. 17 days (EC 305643) to 52.75 days (Susthira). Out of 34 genotypes, none were early in flowering (<35 days), 28 genotypes were medium (35-45 days) and remaining were late flowering (>45 days). Similar variations among genotypes for days to first flowering were reported by Adiger (2015); Singh *et al*. (2015) and Hareesha (2016).

First fruiting node varied significantly among the genotypes and it ranged from 5.00 (EC 305643) to 9.50 (IC 15036, IC 14600). Earlier reports of variation in first fruiting node were made by Mahalik (2018). Early flowering and flowering at lower nodes are desirable characters in okra which can be used for developing early maturing types.

Days to first harvest varied significantly among the genotypes and it ranged from 43.67 days (EC 305651) to 65.00 days (IC 14096). Variation in days to first harvest among genotypes were reported by Hareesha (2016).

Fruit length, girth and average fruit weight had remarkable variation among the genotypes in the present study. These results were in agreement with the findings of Adiger (2015); Singh *et al*. (2015); Hareesha (2016) and Mahalik (2018).

Number of ridges per fruit ranged from 5.00 to 7.50 among the genotypes which itself indicated significant variations among them. Most of the genotypes (70.58%) recorded five ridges per fruit. Variations for this character were reported previously by Hareesha (2016).

Number of primary branches had significant variations among the genotypes and it varied from 2.40 (EC 305645) to 5.25 (IC 14096). Similar variations were reported by Adiger (2015); Singh *et al*. (2015) and Mahalik (2018).

Considerable variation was noted among the different genotypes for number of seeds per fruit and 100 seed weight and it ranged from 25.00 (IC14096) to 86.00 (IC13664) and 3.57 (IC 13664) to 9.10 g (EC 305643) respectively. Variations in 100 seed weight among genotypes were reported by Adiger (2015).

Number of harvests and crop duration had commendable variation among the genotypes and it ranged from 6.50 (IC 14096) to 17.25 (EC 305642) and 88.00 days (Salkeerthi) to 167.50 days (Susthira) respectively. The duration of Salkeerthi was reduced due to the heavy incidence of YVMD. Variation in crop duration among different genotypes were reported by Duggi (2012) and Kishor (2012).

Conspicuous variation was noticed in number of fruits per plant and it varied from 10.00 (Salkeerthi) to 43.75 (EC 305642) among the genotypes. Yield in okra was highly variable among genotypes and it ranged from 0.16 kg (Salkeerthi) to 0.71 kg (EC 305642). Variation in number of fruits per plant and yield per plant was previously reported by Adiger (2015); Hareesha (2016) and Mahalik (2018).The lowest yield in Salkeerthi was due to the incidence of YVMD which retarded its growth and subsequent fruiting.

### 5.3 Reaction of genotypes to YVMV under field conditions

The genotypes of okra were screened under natural conditions to select the resistant/tolerant genotypes. The reaction of genotypes to YVMV were estimated using parameters like days to first symptom appearance, percent disease incidence (PDI), percent disease severity (PDS) and coefficient of infection (CI). The parameters PDI, PDS and CI were recorded at periodic intervals.

The disease symptoms first appeared in the genotype IC 15027 (49.5 days) followed by Aruna and Arka Anamika at 51 days after sowing.

Percent disease incidence (PDI) varied from 0.00 to 16.67 per cent at 50 DAS, 0.00 to 87.50 per cent at 60 DAS and 0.00 to 100.00 per cent at 70, 80 and 90 DAS. At 50 DAS, 11 genotypes (32.35%) showed symptoms of YVMD whereas all other genotypes were free of disease symptoms. The genotypes EC 305639, EC 305645, EC 305649, IC 14026, IC 14096, IC 14600, IC 15036, EC 305635, EC 305638, EC 305642, EC 305650, EC 305651, EC 305673, EC 305674, IC 13664, IC 13995, IC 14909, IC 15435, IC 15438, IC 15537, IC 15540, Salkeerthi and Susthira were free of disease symptoms up to 50 DAS. Thereafter at 60 days all the genotypes except EC 305639 and Susthira exhibited symptoms of the disease *i.e.*, within 10 days the disease spread to 32 genotypes (94.11%) out of 34 genotypes indicating the fast secondary spread of virus. PDI reached 100 per cent in Arka Anamika at 70 DAS whereas other genotypes recorded 0.00 to 91.67 per cent PDI except Susthira in which disease symptoms were absent. At 80 DAS, disease symptoms were absent in Susthira whereas all the other genotypes showed more than 75 per cent disease incidence. All these genotypes showed 100 per cent disease incidence at 90 DAS. The percentage of genotypes infected at different days is illustrated in Figure 1.

PDI alone cannot be used as a criteria for determining the resistance or susceptibility of a genotype. Therefore, PDI along with PDS was used to determine coefficient of infection. PDS varied from 0.00 to 3.16 per cent at 50 DAS, 0.00 to 23.00 per cent at 60 DAS, 0.00 to 66.96 per cent at 70 DAS, 0.00 to 80.00 per cent at 80 DAS and 0.00 to 100.00 per cent at 90 DAS.

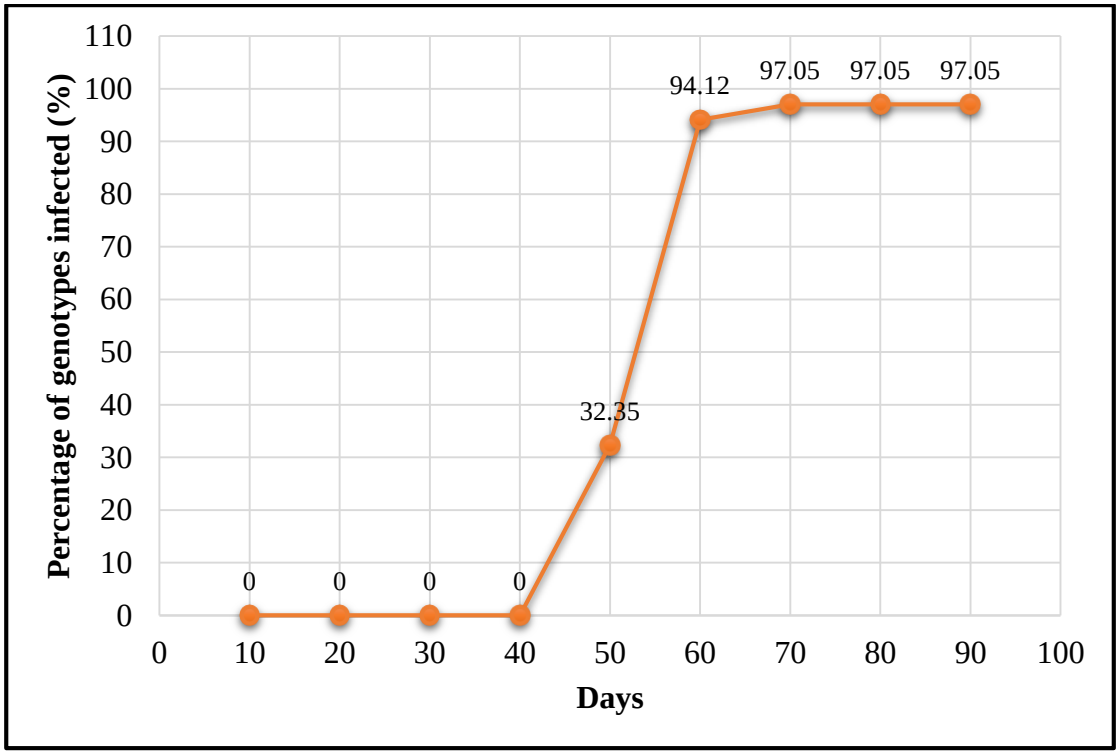



**Figure 1. Percentage of genotypes infected at different days**

Coefficient of infection of YVMD varied from 0.00 to 1.52 per cent at 50 DAS, 0.00 to 18.00 per cent at 60 DAS, 0.00 to 47.5 per cent at 70 DAS, 0.00 to 80.00 per cent at 90 DAS and 0.00 to 100.00 per cent at 90 DAS. The variation in coefficient of infection of genotypes at different days is illustrated in Figure 2. Based on the values of CI, the genotypes were classified as highly resistant, susceptible and highly susceptible. Out of 34 genotypes, six genotypes (EC 305645, EC 305651, EC 305674, IC 13995, IC 14845 and Arka Anamika) had CI in the range 69.1-100 (Highly susceptible), 27 genotypes had CI in the range 39.1-69 (Susceptible) and Susthira had CI=0 (Highly resistant). The classification of genotypes based on coefficient of infection were previously reported by Arunkumar (2015); Kumar *et al*. (2015); Saurabh *et al*. (2016); Kumar and Raju (2017); Kumari *et al*. (2018); Chinju (2019) and Sarkar *et al* (2019). In the present study, it was observed that there was presence of highly resistant, susceptible and highly susceptible genotypes. Susthira was recorded as highly resistant, 27 genotypes (79.41%) as susceptible and six genotypes (17.64%) as highly susceptible.

The susceptibility of the genotypes IC 14018, IC 15027, IC 14909, IC 14600, IC 14026 and IC 15036 were previously reported by Solankey *et al*. (2014). The susceptibility of IC 14600 was also reported by Kumar *et al*. (2015). The genotype IC 13664 was reported as susceptible by Kolakar *et al*. (2018). The genotypes EC 305672 and EC 305619 were reported as susceptible by Manjua *et al*. (2018). These reports were in agreement with the results of the present study.

Salkeerthi was reported as a susceptible variety by Kousalya (2005); Jaseena (2008), Mogili (2013); Sindhumole and Manju (2013); Arunkumar (2015) and Chinju (2019). The susceptibility of Aruna was reported by Sindhumole and Manju (2013). These reports were in agreement with the results of the present study.

Arka Anamika was originally released as a resistant variety for YVMD but, later it became highly susceptible due to the appearance of new strains of virus or due the recombination in virus strain (Sanwal *et al*., 2016). The susceptibility of Arka Anamika was previously reported by Kumari *et al*. (2018); Jamir *et al*. (2020) and Sarkar *et al*. (2019).

The genotypes EC 305646, EC 305647, EC 305649 and EC 305650 were reported as resistant under field conditions by Prashanth *et al*. (2008). But, present study revealed the susceptibility of these genotypes to YVMD.

Among the genotypes evaluated, the variety Susthira showed resistance to YVMD at all stages of crop growth. Susthira is a selection from *Abelmoschus caillei* accession and distinctly different from other okra varieties with respect to pod characters. It is a perennial type with short fibrous pods which is a typical character of wild/semi wild okra. Hence, it can be used as a source of resistance in crop improvement programmes. Resistance of Susthira under field conditions were previously reported by Kousalya (2005); Jaseena (2008); Mogili (2013) and Arunkumar (2015).

### 5.3.1 Whitefly count at 60 and 90 DAS

The number of whiteflies at 60 and 90 days varied from 0.25 to 5.00 and 1.75 to 8.25 respectively. Similar variations in whitefly count were reported by Kishor (2012) and Sindhumole and Manju (2013).

## 5.4 Artificial inoculation of YVMV under protected conditions

Artificial inoculation of YVMV by whitefly transmission was done in three susceptible genotypes (Salkeerthi, Arka Anamika and EC 305639) and resistant variety Susthira. All the susceptible genotypes had symptoms of the disease within 17.2 days after inoculation of virus. 100 per cent transmission of virus was observed within 17.2 days. Earlier reports on whitefly mediated artificial inoculation of YVMV were made by Arunkumar (2015) and Chinju (2019). The variety Susthira remained resistant and did not show any disease symptoms even after 30 days of inoculation. There were no earlier reports on the confirmation of disease resistance in Susthira by artificial inoculation.

## 5.5 Organoleptic evaluation of okra genotypes

Among the 34 genotypes, IC 15438, EC 305650 and EC 305642 recorded highest mean rank for appearance. High mean rank for colour was recorded in the genotypes IC 15027, EC 305650 and EC 305647. High mean rank for flavour was

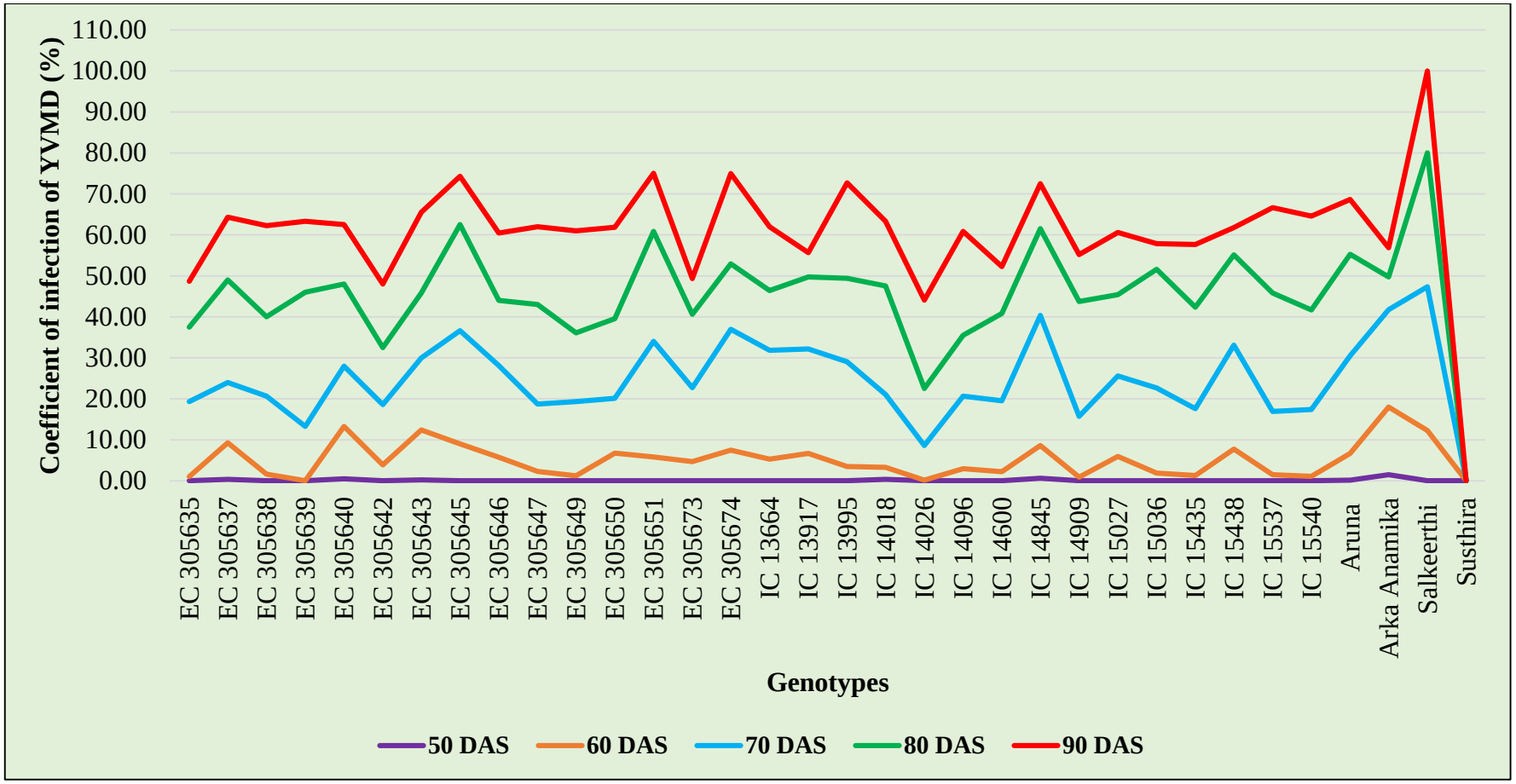



**Figure 2. Difference in coefficient of infection of genotypes at 10 days interval**

recorded in the genotypes IC 15027, EC 305647 and IC 15540. With respect to texture, high rank was recorded in IC 15540, EC 305647 and IC 14845. High mean rank for taste was recorded in the genotypes EC 305647, IC 15540 and IC 15027. With respect to mouth feel, the genotypes IC 15027, EC 305650 and EC 305642 recorded highest mean rank. Overall acceptability was highest in the genotypes *viz.*, IC 15027, IC 15540 and EC 305647. The resistant variety Susthira was found inferior for all the sensory parameters.

### 5.6 Estimation of genetic parameters

The results of the present study indicated wide range of both phenotypic and genotypic variance for all the characters. All the characters showed higher value of phenotypic variance than genotypic variance indicating the influence of environmental factors in the expression of genotype of these characters.

In the present study, genotypes were found to possess high to low phenotypic and genotypic coefficients of variation. PCV and GCV was high for plant height, internodal length, number of fruits per plant, yield per plant, number of seeds per fruit and coefficient of infection of YVMD at 60, 70, 80 and 90 DAS. Moderate PCV and GCV was recorded for first fruiting node, length of fruit, average fruit weight, 100 seed weight, number of primary branches, crop duration, days to first symptom appearance and number of ridges per fruit. Low magnitude of PCV and GCV was reported for days to first flowering and girth of fruit. Moderate PCV and low GCV was reported for the characters petiole length and days to first harvest. The characters having high GCV possess better potential for improvement through selection. These results were in accordance with the findings of Mohapatra *et al*. (2007) for fruit weight, Ramanjinappa *et al.* (2011) for plant height and Koundinya *et al*. (2013) for fruit width and days to first flowering. Kumar *et al*. (2015) reported similar results for fruit length, number of fruits per plant, yield per plant and coeffcient of infection of YVMD.

High GCV, heritability and genetic advance as per cent of mean were observed for the characters plant height, internodal length, number of fruits per plant, number of seeds per fruit, yield per plant and coefficient of infection of YVMD at 80 and 90 DAS which suggest the influence of additive gene action for the expression of these

characters. Therefore, selection using these characters will be effective for improvement in okra. These results were in agreement with the findings of Koundinya *et al*. (2013) for internodal length and Hareesha (2016) for plant height. Kumar *et al*. (2015) reported similar results for number of fruits per plant and coefficient of infection of YVMD.

The characters like crop duration, number of ridges per fruit, 100 seed weight, average fruit weight, number of harvest and days to first symptom appearance recorded high heritability coupled with high genetic advance as per cent of mean indicating that these traits were under the strong influence of additive gene action hence simple selection based on phenotypic performance of these traits would be more effective. Similar results were reported by Phanikrishna *et al*. (2015) for number of ridges per fruit.

High heritability and moderate genetic advance as per cent of mean were reported for the characters petiole length, days to first flowering, days to first harvest and girth of fruit. This indicates the influence of non additive gene action and considerable influence of environment on the expression of these characters. Similar results were reported by Koundinya *et al*. (2013) for days to first flowering and Phanikrishna *et al*. (2015) for fruit width.

**5.7 Correlation studies**

In the present study, significant and positive correlations of yield per plant were recorded with plant height, petiole length, number of ridges per fruit, number of harvest, crop duration, number of fruits per plant and average fruit weight. On the other hand, fruit yield was significantly and negatively correlated with internodal length, days to first harvest and coefficient of infection of YVMD at 70, 80 and 90 DAS.

Positive correlation of yield per plant with plant height were reported by Kumar *et al*. (2015); Kumar and Reddy (2016); Prasath *et al.* (2017); Singh *et al*. (2017) and Mahalik (2018). Similar results on number of fruits per plant was reported by Kumar *et al*. (2015); Hareesha (2016); Kumar and Reddy (2016); Prasath *et al.* (2017); Singh *et al*. (2017) and Mahalik (2018). Hareesha (2016) reported positive correlation of yield with number of ridges per fruit. Positive correlation of average fruit weight with yield

were reported by Kumar *et al*. (2015); Hareesha (2016); Kumar and Reddy (2016); Prasath *et al.* (2017); Singh *et al*. (2017) and Mahalik (2018). Similar results on crop duration were recorded by Hareesha (2016) and Prasath *et al.* (2017). Positive correlation of yield per plant with number of harvest was reported by Prasath *et al.* (2017). Similar results on internodal length were reported by Reddy *et al*. (2013) and Kumar and Reddy (2016).

Days to first symptom appearance was significantly and negatively correlated with days to first flowering, days to first harvest. It does mean that as disease appears early in a genotype the flowering and harvest will be delayed.

Coefficient of infection of YVMD was significantly and positively correlated with days to first symptom appearance. It was significantly and negatively correlated with girth of fruit, number of harvest, crop duration, number of fruits per plant, average fruit weight and days to first flowering. It indicated that as coefficient of infection increases, crop duration, girth of fruit, number of harvest, number of fruits per plant and average fruit weight decreases. This in turn will lead to reduction in yield. For rest of the characters, it showed non significant correlation. Similar results on fruit girth and days to first flowering was reported by Hareesha (2016). Negative correlation of YVMD incidence with fruit girth and crop duration was reported by Prasath *et al.* (2017). There were no reports on the relation between days to first symptom appearance and coefficient of infection.

Plant height was significantly and positively correlated with internodal length, length of fruit, number of harvest and number of fruits per plant. It was significantly and negatively correlated with days to first flowering, days to first harvest, first fruiting node, number of ridges per fruit and number of primary branches. Positive correlation of plant height with internodal length were reported by Adiger (2015) and Kumar and Reddy (2016); Prasath *et al.* (2017) and Singh *et al*. (2017). Earlier reports on positive correlation of fruit length with plant height were made by Kumar and Reddy (2016); Prasath *et al.* (2017); Singh *et al*. (2017) and Mahalik (2018). Positive correlation of number of fruits per plant with plant height were made by Adiger (2015); Kumar *et al*. (2015); Kumar and Reddy (2016); Prasath *et al.* (2017) and Mahalik (2018). Positive correlation of plant height with number of harvest were reported by Prasath *et al.*

(2017). Negative correlation of plant height with number of primary branches were reported by Reddy *et al*. (2013) which is in agreement with the current results. Negative correlation of first fruiting node with plant height were reported by Reddy *et al*. (2013) and Kumar and Reddy (2016). Negative correlation of plant height with days to first harvest was reported by Hareesha (2016) and Prasath *et al.* (2017). Prasath *et al.* (2017) also reported negative correlation of days to first flowering with plant height. Hareesha (2016) also reported negative correlation of plant height with number of ridges per fruit.

Internodal length was significantly and positively correlated to length of fruit and number of seeds per fruit. Similar results on length of fruit were reported by Adiger (2015); Kumar and Reddy (2016); Prasath *et al.* (2017) and Mahalik (2018). Positive correlation of internodal length with number of seeds per fruit were reported by Prasath *et al.* (2017) and Singh *et al*. (2017). Internodal length was significantly and negatively correlated with days to first flowering, days to first harvest, first fruiting node, number of ridges per fruit and number of primary branches. Reports of negative correlation of internodal length with first fruiting node were made by Reddy *et al*. (2013) and Kumar and Reddy (2016). These results were in agreement with the findings of Singh *et al*. (2017) for number of primary branches and Prasath *et al.* (2017) for days to first flowering and harvest. However, similar results on number of ridges per fruit were not reported so far.

Days to first flowering was significantly and positively correlated with days to first harvest, first fruiting node, girth of fruit, number of ridges per fruit, crop duration, number of primary branches and average fruit weight. These results were in accordance with the findings of Hareesha (2016) for number of ridges per fruit and Kishor (2012) for first fruiting node. Positive correlation of days to first flowering with days to first harvest were made by Balai *et al*. (2014) and Prasath *et al.* (2017). However, similar results on girth of fruit, crop duration, number of primary branches and average fruit weight has not been reported so far. Days to first flowering was significantly and negatively correlated to length of fruit and number of fruits per plant. Similar reports on length of fruit and number of fruits per plant were made by Prasath *et al.* (2017).

Days to first harvest was significantly and positively correlated with first fruiting node, girth of fruit, crop duration, number of primary branches and average

fruit weight. It was significantly and negatively correlated with number of harvest and number of fruits per plant. Positive correlation of first fruiting node and average fruit weight with days to first harvest was reported by Hareesha (2016).

First fruiting node was significantly and positively correlated with number of primary branches. It was significantly and negatively correlated with length of fruit, girth of fruit, number of harvest and 100 seed weight. Positive correlation of first fruiting node with number of primary branches was reported by Reddy *et al*. (2013). Negative correlation of fruit length with first fruiting node was reported by Reddy *et al*. (2013).

Girth of fruit was significantly and positively correlated with number of ridges per fruit, number of harvest, crop duration and average fruit weight. Positive correlation of fruit girth with average fruit weight was reported by Adiger (2015); Kumar and Reddy (2016) and Prasath *et al.* (2017). Positive correlation of fruit girth with crop duration and number of harvest was reported by Prasath *et al.* (2017).

Length of fruit was significantly and negatively correlated with number of ridges per fruit and number of seeds per fruit. It does mean that as length of fruit increases, the number of ridges and seeds per fruit decreases. Similar results on the correlation of fruit length with number of ridges and seeds per fruit were not reported so far.

Number of ridges per fruit was significantly and positively correlated with number of seeds per fruit, number of harvest, crop duration and number of fruits per plant. The increase in number of seeds per fruit with increase in ridges is due to increased number of locules in which seeds are present. Positive correlation of number of fruits per plant with number of ridges was reported by Hareesha (2016). Association of number of ridges per fruit with number of seeds per fruit, number of harvest and crop duration were not reported so far.

Number of primary branches was significantly and positively correlated with average fruit weight. Similar results were reported by Kumar and Reddy (2016) and Prasath *et al.* (2017).

Number of harvest was significantly and positively correlated with crop duration and number of fruits per plant. Similar results were reported by Prasath *et al.* (2017).

Average fruit weight was significantly and negatively correlated with 100 seed weight. Similar results on average fruit weight were not reported so far.

Number of seeds per fruit was significantly and negatively correlated with 100 seed weight. As the number of seeds increased, the weight of individual seeds decreased resulting in reduction of 100 seed weight. Similar result was reported by Singh *et al*. (2017).

**5.8 Path Coefficient analysis in okra**

Path coefficient analysis was done using the characters which had significant correlation with yield per plant. The path diagram is presented in Figure 3. The residual effect was very low (0.0345), indicating that most of the variability present in the genotypes was explained with the characters under study. Number of fruits per plant had highest positive direct effect on yield followed by coefficient of infection of YVMD at 80 DAS, average fruit weight, plant height, crop duration and number of harvest. Coefficient of infection of YVMD at 70 DAS showed highest negative direct effect on yield followed by internodal length.

Number of harvest showed very high positive indirect effect on yield followed by number of fruits per plant and crop duration. Coefficient of infection of YVMD at 80 days had high negative indirect effect on yield followed by days to first harvest.

Plant height had significant positive correlation and moderate positive direct effect on yield. It also had indirect positive effect on yield through number of fruits per plant. Similar findings were reported by Reddy *et al*. (2013) and Singh *et al*. (2017).

Internodal length had negative correlation and moderate negative direct effect on yield. Here the correlation coefficient value is almost equal to the value of direct effect. Negative direct effect of internodal length on yield were reported by Reddy *et al*. (2013); Kumar and Reddy (2016) and Singh *et al*. (2017).

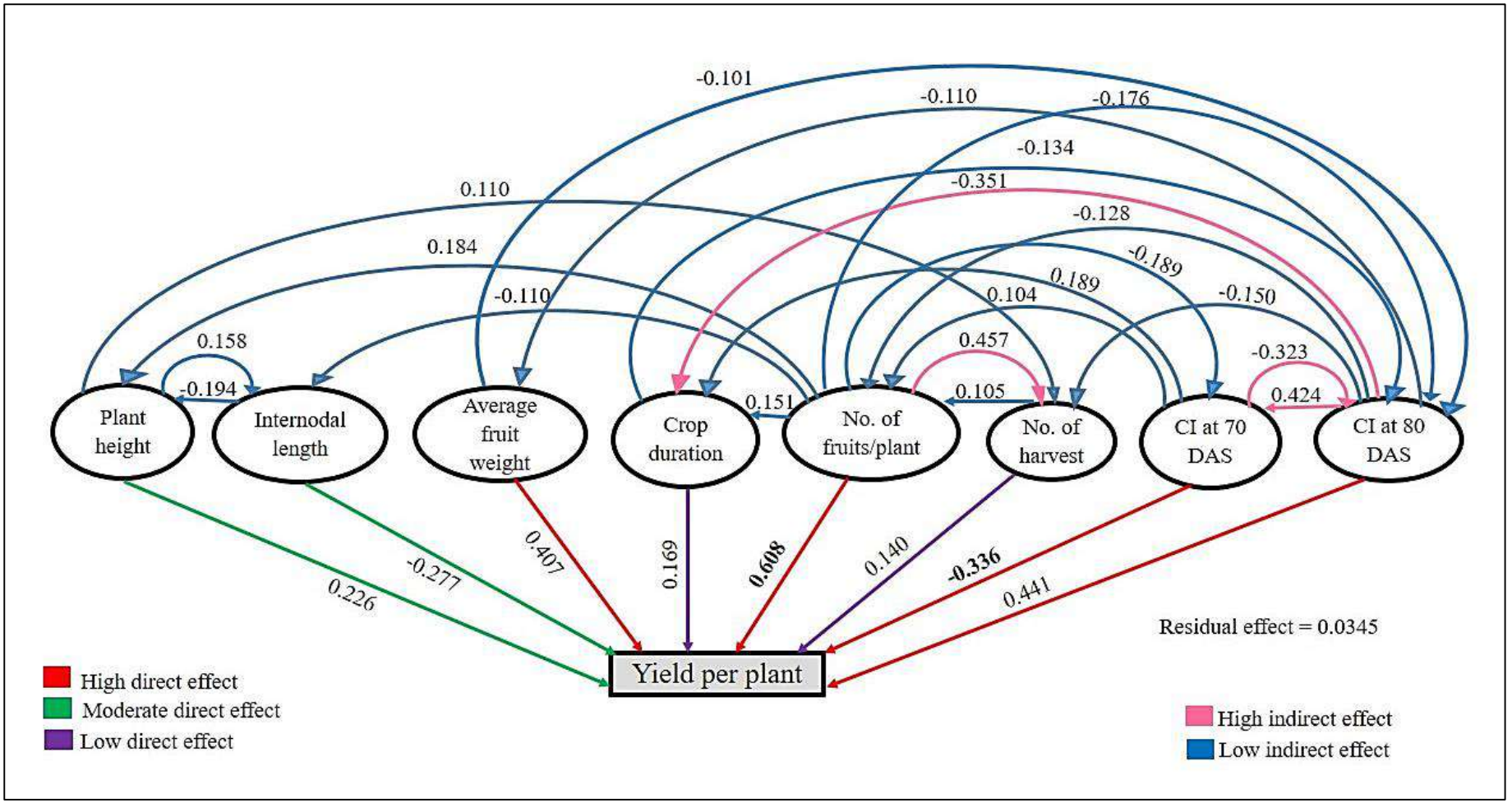



**Figure 3. Path diagram based on selected characters**

Number of harvest had significant positive correlation and low direct positive effect on yield. It had positive indirect effect on yield through number of harvest and plant height.

Crop duration had significant positive correlation and low positive direct effect on yield. It also had positive indirect effect on yield through number of fruits per plant. The positive direct effect of crop duration on yield was reported by Prasath *et al*. (2017).

Number of fruits per plant had significant positive correlation and high positive direct effect on yield. Similar results were reported by Reddy *et al*. (2013); Kumar and Reddy (2016); Prasath *et al*. (2017); Singh *et al*. (2017) and Mahalik (2018). It also had positive indirect effect on yield through number of harvest.

Average fruit weight had significant positive correlation and high positive direct effect on yield. Similar results of positive direct effect on yield were reported by Reddy *et al*. (2013); Kumar and Reddy (2016); Singh *et al*. (2017) and Mahalik (2018).

Coefficient of infection at 70 DAS had negative correlation and high negative direct effect on yield. These results were in accordance with the findings of Prasath *et al*. (2017) and Mahalik (2018). Here the correlation coefficient value is almost equal to the direct effect.

Coefficient of infection at 80 DAS had negative correlation and high positive direct effect on yield. But, it had high negative indirect effect on yield through crop duration, number of fruits per plant, average fruit weight and coefficient of infection at 70 DAS.

Based on the results of present investigation, it can be concluded that the characters *viz*., plant height, average fruit weight, number of fruits per plant, crop duration and coefficient of infection at 80 DAS are the main characters contributing towards fruit yield in okra and selection of genotypes based on these characters is useful for further crop improvement.

### 5.9 Logistic regression analysis

In the present study, logistic regression analysis was conducted to find out the influence of three characters *viz.*, average fruit weight, number of fruits per plant and

length of fruit on yield per plant. The results of logistic regression analysis revealed that the expected per cent of improvement over base population for the characters *viz.*, number of fruits per plant and average fruit weight were 67.90 and 77.26 per cent respectively which is depicted in Figure 4. It was found that if selection is based on number of fruits per plant, new population formed from the base population will express 67.90 per cent improvement over base population regarding yield per plant. Similarly, if average fruit weight is considered as the selection parameter it leads to 77.26 per cent improvement in the newly formed population when compared to the base population with respect to yield per plant. Hence, these two characters along with yield per plant was used for fixing the selection criteria for okra genotypes.

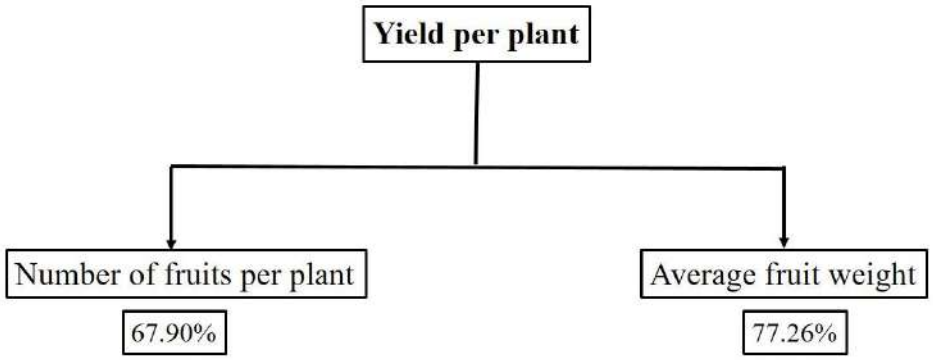



**Figure 4. Characters contributing to yield per plant**

### 5.10 Selection of superior genotypes of okra

The resistant variety Susthira was found inferior with respect to yield and sensory qualities. Hence, the genotypes of okra used in the present study was scored based on the characters *viz*., yield per plant, number of fruits per plant, average fruit weight, length of fruit and overall acceptability of organoleptic evaluation for the selection of superior genotypes. It was observed that all the 34 genotypes came within four ranks for the characters *viz*., yield per plant, number of fruits per plant, average fruit weight and length of fruit which indicated the similarity between the genotypes for these characters. However, variations among genotypes were observed for the overall acceptability of organoleptic evaluation. Considering all these characters, five

genotypes (IC 15027, IC 15540, EC 305647, EC 305650 and EC 305642) were selected. The selection of superior genotypes of okra based on yield per plant, average fruit weight and number of fruits per plant were previously reported by Saifullah and Rabbani (2009) and Reddy *et al*. (2012).

The selected genotypes had yield in the range 0.50 to 0.71 kg, average fruit weight in the range 13.00 to 17.02 g, number of fruits per plant in the range 29.05 to 43.75 and length of fruit in the range 13.40 to 17.48 cm. These genotypes were found superior for these characters even though they were susceptible to YVMD which indicates that their true potential is beyond this value which needs to be studied. Hence, the selected genotypes *viz*., IC 15027, IC 15540, EC 305647, EC 305650 and EC 305642 can be crossed with the resistant variety Susthira for developing YVMD resistant varieties.

# *Summary*

## 6. SUMMARY

Okra is one of the most important vegetable crops grown in India. Year round cultivation of okra is possible in our country due to its adaptability to warm tropical climate. Okra is affected by many pests and diseases. The most important problem in okra is Yellow Vein Mosaic Disease (YVMD), a viral disease. It causes serious losses to okra cultivators by adversely affecting the yield and quality of fruits. The only practical solution to this problem is development of resistant/tolerant varieties. Many researches had been done in the past in this arena which lead to the development of resistant varieties. However, resistance to YVMD is not stable and repeated breakdown of resistance to this disease has been observed in popular varieties like Arka Anamika. Hence, there is a need of continous breeding for developing resistant varieties. It was in this background that the present study was undertaken with the objective of evaluating and identifying resistant varieties/lines of okra against Yellow vein mosaic virus for augmenting effective resistant breeding programme in okra.

The present study was carried out at Department of Vegetable Science, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur, during the period of 2018 - 2020. The experimental material consisted of 34 genotypes of okra. Out of 34 genotypes, 30 were collected from NBPGR Regional station, Akola. Remaining genotypes included Arka Anamika and KAU varieties namely Aruna, Salkeerthi and Susthira. The genotypes were evaluated for their qualitative, quantitative and disease parameters. They were sown in randomized block design with two replications.

All the genotypes had erect and branching growth habit. Variations among genotypes were observed for leaf, flower and fruit characters.

Significant variations were observed among genotypes for all the quantitative characters studied. The genotype EC 305642 recorded the highest number of fruits and yield per plant. Average fruit weight was highest in IC 13917. Crop duration was highest for Susthira. Earliest flowering was recorded in EC 305643 followed by EC 305651 and EC 305650. Significantly lowest node of first fruiting was recorded in the genotype EC 305643 followed by Susthira and EC 305635. Early flowering and

flowering at lower nodes are preferable characters in okra which can be used for developing early maturing types.

The genotypes were evaluated for YVMD resistance under natural conditions to identify the resistant/tolerant ones. The parameters like percent disease incidence, percent disease severity and coefficient of infection of YVMD were estimated at periodic intervals. Disease symptoms first appeared in the genotype IC 15027 followed by Aruna and Arka Anamika. Hundred per cent disease incidence was noted in all the genotypes at 90 DAS except in Susthira. Variations among genotypes were observed for percent disease severity and coefficient of infection. Based on the values of coefficient of infection, the genotypes were grouped as resistant, susceptible and highly susceptible. There was presence of highly resistant to highly susceptible genotypes in the present study. Out of 34 genotypes, six genotypes (EC 305645, EC 305651, EC 305674, IC 13995, IC 14845 and Arka Anamika) had CI in the range 69.1-100 (Highly susceptible), 27 genotypes had CI in the range 39.1-69 (Susceptible) and Susthira had CI=0 (Highly resistant).

Among the genotypes evaluated, the variety Susthira showed resistance to YVMD at all stages of crop growth under field conditions. However, it was found inferior for most of the characters studied. Resistance of Susthira was further confirmed using whitefly mediated artificial inoculation of YVMD under protected conditions. Hence, it can be used as a source of resistance for developing YVMD resistant/tolerant varieties.

Genetic variability present in the germplasm were studied based on phenotypic and genotypic coefficient of variation (GCV and PCV). PCV and GCV was high for plant height, internodal length, number of fruits per plant, yield per plant, number of seeds per fruit and coefficient of infection of YVMD at 60, 70, 80 and 90 DAS.

High GCV, heritability and genetic advance were observed for the characters plant height, internodal length, number of fruits per plant, number of seeds per fruit, yield per plant and coefficient of infection of YVMD at 80 and 90 DAS. The characters *viz*., crop duration, number of ridges per fruit, 100 seed weight, average fruit weight, number of harvest and days to first symptom appearance recorded high heritability

coupled with high genetic advance as per cent of mean which suggest the influence of additive gene action for the expression of these characters.

The results of correlation and path coefficient analysis revealed that the characters plant height, average fruit weight, number of fruits per plant, crop duration and number of harvest had positive correlation and positive direct effect on yield. Hence, direct selection using these traits would enhance yield. Coefficient of infection at 70 and 90 DAS had negative correlation and negative direct effect on yield. Coefficient of infection at 80 DAS had highest negative indirect effect on yield.

Organoleptic evaluation of all the 34 genotypes were done. The results revealed that the genotypes IC 15027, IC 15540 and EC 305647 were found having better sensory qualities.

The selection of superior genotypes of okra were done based on the characters *viz*., number of fruits per plant, average fruit weight, fruit length, yield per plant and overall acceptability of organoleptic evaluation. Five genotypes were selected which were found superior for these characters even though they were susceptible to YVMD. The selected genotypes were IC 15027, IC 15540, EC 305647, EC 305650 and EC 305642. Hence, these genotypes can be crossed with Susthira for developing high yielding YVMD resistant varieties.

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# *Appendix*

## ABBREVIATIONS

| | |
|---|---|
| NBPGR | National Bureau of Plant Genetic Resources |
| IBPGR | International Board for Plant Genetic Resources |
| PDI | Percent Disease Incidence |
| PDS | Percent Disease Severity |
| CI | Coefficient of Infection |
| YVMV | Yellow Vein Mosaic Virus |
| YVMD | Yellow Vein Mosaic Disease |
| PCV | Phenotypic Coefficient of Variation |
| GCV | Genotypic Coefficient of Variation |
| $H^2$ | Heritability |
| GA | Genetic Advance |
| GAM | Genetic Advance as percentage of mean |
| DAS | Days after Sowing |
| NHB | National Horticulture Board |
| OYVMV | Okra Yellow Vein Mosaic Virus |
| DNA | Deoxyribonucleic Acid |
| KAU | Kerala Agricultural University |
| PV | Phenotypic Variance |
| GV | Genotypic Variance |
| kg | Kilogram |
| g | Gram |
| h | Hours |
| cm | Centimetre |
| mg | Milligram |
| µg | Microgram |
| kJ | Kilo Joule |
| kcal | Kilo calorie |
| $^0C$ | Degree celsius |

# BREEDING FOR YELLOW VEIN MOSAIC VIRUS (YVMV) RESISTANCE IN OKRA

## [*Abelmoschus esculentus* (L.) Moench]

*by*

**ALPHY MATHEW**

**(2018-12-001)**

**ABSTRACT OF THE THESIS**

**Submitted in partial fulfilment of the requirement for the degree of**

## MASTER OF SCIENCE IN HORTICULTURE

**(VEGETABLE SCIENCE)**

**Faculty of Agriculture**
**Kerala Agricultural University**

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**2020**

## ABSTRACT

Okra is one of the most important vegetable crops grown in India for its tender green fruits. The cultivation of okra is constrained by various pests and diseases. Among the diseases, Yellow Vein Mosaic Disease (YVMD) is the most dreadful disease which affects both the quality of fruit and yield adversely. It is a viral disease caused by Yellow Vein Mosaic Virus (YVMV) and is transmitted by whiteflies (*Bemisia tabaci*). The only practical solution to this problem is development of resistant or tolerant varieties. The resistant varieties released in the past became susceptible due to the development of new strains of virus or due to the recombination in the virus strain. In this background, the present study entitled "Breeding for Yellow Vein Mosaic Virus (YVMV) resistance in okra [*Abelmoschus esculentus* (L.) Moench]" was undertaken with the objective of evaluating and identifying resistant varieties/lines of okra against YVMV for augmenting effective resistant breeding programme in okra.

The present study was carried out at Department of Vegetable Science, College of Horticulture, Vellanikkara during the period of 2018-2020. The experimental material consisted of 34 genotypes of okra which were sown in randomized block design with two replications. Out of 34 genotypes, 30 were collected from NBPGR Regional station, Akola. Remaining genotypes included Arka Anamika and KAU varieties namely Aruna, Salkeerthi and Susthira.

The genotypes were evaluated for their qualitative and quantitative characters and described based on the NBPGR Minimal Descriptor for Characterization and Evaluation of Agri-Horticultural Crops (2000). All the 34 genotypes were evaluated under natural conditions for the selection of resistant/tolerant ones. The disease reaction of genotypes to Yellow Vein Mosaic Disease (YVMD) were evaluated based on the parameters *viz*., percent disease incidence, percent disease severity and coefficient of infection. Based on the values of coefficient of infection, the genotypes were classified as resistant, susceptible and highly susceptible. The results revealed the presence of highly resistant to highly susceptible genotypes in the present study. Six genotypes (EC 305645, EC 305651, EC 305674, IC 13995, IC 14845 and Arka Anamika) were grouped as highly susceptible, 27 genotypes as susceptible and Susthira as highly resistant. Among the genotypes evaluated, Susthira showed resistance to YVMD at all

stages of crop growth under field conditions. Resistance of Susthira was further confirmed under protected conditions using vector transmission method. Hence, Susthira can be used as a source of resistance for developing YVMD resistant/tolerant varieties.

The extent of variability present in the germplasm were studied using the parameters *viz*., phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), heritability and genetic advance. High heritability and genetic advance were observed for the characters *viz.*, plant height, internodal length, number of fruits per plant, number of seeds per fruit, crop duration, number of ridges per fruit, 100 seed weight, average fruit weight, number of harvest, days to first symptom appearance, yield per plant and coefficient of infection of YVMD at 80 and 90 days after sowing. The results of correlation and path coefficient analysis revealed that the characters *viz*., plant height, average fruit weight, number of fruits per plant, crop duration and number of harvest had positive correlation and positive direct effect on yield. Hence, direct selection using these traits would enhance yield.

Organoleptic evaluation of all the 34 genotypes were also done. The results revealed the superiority of genotypes IC 15027, IC 15540 and EC 305647 with respect to sensory qualities.

The selection of superior genotypes were done based on the characters *viz*., number of fruits per plant, average fruit weight, fruit length, yield per plant and overall acceptability of organoleptic evaluation. The genotypes *viz*., IC 15027, IC 15540, EC 305647, EC 305650 and EC 305642 were found superior for these characters even though they were susceptible to the disease. Hence, these genotypes can be crossed with Susthira for developing high yielding YVMD resistant varieties.