IDENTIFICATION OF PROMISING SEGREGANTS IN F_4 AND F_5 GENERATIONS OF THE CROSS *Abelmoschus caillei* (A.Cher.) Steveis x *A.esculentus* (L.)Moench

By

JASEENA. P

THESIS

Submitted in partial fulfillment of the

requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture

Kerala Agricultural University

Department of Olericulture

COLLEGE OF HORTICULTURE

VELLANIKKARA, THRISSUR - 680 656

KERALA, INDIA

2008

DECLARATION

I hereby declare that this thesis entitled **"Identification of promising segregants in F_4 and F_5 generations of the cross *Abelmoschus caillei* (A.Cher.) Steveis x *A.esculentus* (L.) Moench"** is a bonafide record of research work done by me during the course of research and that it has not been previously formed the basis for the award to me of any degree, diploma, fellowship or other similar title, of any other University or Society.

Vellanikkara
2008

JASEENA. P

CERTIFICATE

Certified that this thesis entitled **"Identification of promising segregants in F_4 and F_5 generations of the cross *Abelmoschus caillei* (A.Cher.) Steveis x *A.esculentus* (L.) Moench"** is a record of research work done independently by **Ms. Jaseena. P** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma or fellowship to her.

Vellanikkara
14-08-2008

Dr. K.V. Suresh Babu
(Major advisor, Advisory committee)
Professor
Dept. of Olericulture
College of Horticulture
Kerala Agricultural University
Vellanikkara, Thrissur

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Ms. JASEENA. P,** a candidate for the degree of **Master of Science in Horticulture**, with major field in **Olericulture**, agree that the thesis entitled **"Identification of promising segregants in F_4 and F_5 generations of the cross *Abelmoschus caillei* (A.Cher) Steveis x *A.esculentus* (L.)Moench"** may be submitted by Ms. Jaseena. P**,** in partial fulfillment of the requirement for the degree.

Dr. K.V.Suresh Babu
(Major advisor, Advisory committee)
Professor
Dept. of Olericulture
College of Horticulture
Vellanikkara, Thrissur

Dr. T. E. George
Professor and Head
Department of Olericulture
College of Horticulture, Vellanikkara

Dr. K.P. Prasanna
Professor
Department of Olericulture
College of Horticulture, Vellanikkara

Dr. Sally. K. Mathew
Professor
Department of Plant Pathology
College of Horticulture, Vellanikkara

EXTERNAL EXAMINER

ACKNOWLEDGEMENT

It is with great respect and immense pleasure, I place on record my deep sense of gratitude and indebtedness to ***Dr.K.V.Suresh Babu,*** *Professor, Dept. of Olericulture and chairperson of my Advisory Committee for his sustained and valuable guidance, constructive suggestions, unfailing patience, friendly approach, constant support and encouragement during the conduct of this research work and preparation of the thesis. I gratefully remember his knowledge and wisdom, which nurtured this research project in right direction without which fulfillment of this endeavor would not have been possible.*

I place a deep sense of obligation to ***Dr. T.E. George****, Professor and Head, Department of Olericulture, College of Horticulture and member of my Advisory Committee for the help and co-operation received from him during the entire programme. He in spite of a busy schedule has offered constructive suggestions for the betterment of this manuscript.*

I am deeply indebted to ***Dr. K.P.Prasanna****, Professor, Department of Olericulture, College of Horticulture and member of my Advisory Committee for her unstinted support, critical comments and valuable suggestions during the preparation of this manuscript.*

I am very thankful to ***Dr. Sally.K.Mathew****, Professor, Department of Plant Pathology, College of Horticulture and member of my advisory committee for her whole-hearted-co-operation, candid suggestions, encouragement and valuable help rendered during this period of investigation.*

I am grateful to ***Dr. S. Krishnan****, Professor, Department of Agricultural Statistics, College of Horticulture, Vellanikkara, for his immense help in the statistical analysis of data.*

I am very much obliged to ***Dr. Sali Kutty,*** *Professor, Department of Olericulture, College of Horticulture, Vellanikkara for her eminent suggestions, critical assessment, and timely help at various stages of my work.*

I am especially indebted to my teachers of the Department of Olericulture for their unrivalled teaching, kind concern, sincere advices, timely help and support rendered during the investigation and throughout my study period.

I thankfully acknowledge the extreme co-operation rendered by the labourers of the Department of Olericulture during the field work.

I am extremely thankful to my dear most friends ***Ramju, Radhu, Sameera, Nisha Jose, Shinoji, Jinsi, Deepaku, Navomy, Vijit*** *and also* ***to all my batch mates*** *for the heartfelt help, timely suggestions and back-up which gave me enough mental strength to get through all mind-numbing circumstances.*

Words cannot really express the true friendship that I relished from ***Kimi ,Anu, Alok*** *and* ***Devi Prasad*** *for their sincere support all through out.*

I express my deep sense of gratitude to ***Kerala Agricultural University*** *for extending financial and technical support for pursuance of my study and research.*

I am extremely thankful to my ***parents, mother in law, Jasmitha, Chippimol, Shakeeb aliyan*** *and other* ***family members*** *without whose moral support and affection this would not have been a success.*

I express my deep love to my ***beloved daughter*** *for her boundless affection, prayers and personal sacrifices.*

I express special gratitude and love to my most affectionate ***Yasir*** *who added a new dimension to my life. A work of this nature could not have been completed without his undeviating and sincere support.*

Above all I bow my head before ***THE ALMIGHTY*** *whose blessings enabled me to undertake this venture successfully.*

Jaseena. P

To my beloved daughter

CONTENTS

LIST OF TABLES

LIST OF PLATES

LIST OF FIGURES

LIST OF APPENDICES

Introduction

1. INTRODUCTION

Okra (*Abelmoschus esculentus* (L.)Moench) is one of the important vegetable crops of the world. It is a potential export earner and provides high returns to the farmers. Okra is valued for its tender green fruits, rich in vitamin A (86.67 µg/100 g), riboflavin (0.10µg / 100g), vitamin C (18µg / 100g) and minerals like calcium (66mg/100g), phosphorus , iodine , iron and potassium (Kale *et al.*1986). Average Nutritive Value (ANV) of okra is 3.21 per cent which is higher than tomato, brinjal and cucurbitaceous vegetables (Sharma and Arora, 1993).

Okra is a seed propagated hot weather crop sensitive to frost, low temperature, water logging and drought conditions. It is a multipurpose crop due to its various uses. It is grown in many countries and cultivars from different countries have certain adopted distinguishing characteristics specific to the country to which they belong. Okra can be cultivated with ease, year round and is one of the best adopted vegetables in the tropical region. In home consumption India tops the world. Early bearing, extended period of harvest coupled with short life span of this crop are some other plus points for vegetable growers. Okra exhibits a large extent of genetic variability, so an array of cultivars adapted to different agroclimatic conditions are available in this crop, which display a wide spectrum of variation with respect to important economic and quality characters providing lot of scope for genetic improvement.

Among several *Abelmoschus* species occurring in India, *A. esculentus* is the main cultivated species. *A. moschatus* is semi-wild species and is grown for its aromatic seeds, while *A. caillei* is cultivated in a homestead level in isolated areas. The wild species occupy diverse habitats. Species resistant to Yellow Vein Mosaic Virus (YVMV) are *A. caillei, A. manihot, A. tetraphyllus* and *A. crinitus*. Wild species have not been fully utilized in breeding programmes due to crossing barriers. Resistance to YVMV is not stable in the cultivated species and frequent breakdown of resistance has been observed in developed varieties so that there is an urgent need

to adopt appropriate method of breeding programmes for the development of lines resistant to YVMV.

Among the various biotic factors which limit the production of okra, its vulnerability to YVMV is the most serious one. This virus disease causes heavy economic loss and the extent of loss will vary greatly depending upon the type of damage, which may be either qualitative or quantitative. YVMV disease is transmitted by vector white fly (*Bemisia tabaci*).The reported yield reduction due to this disease infection is in the range of 50 to 90 per cent depending on the stage of the crop growth at which infection occurs (Sastry and Singh, 1974).

The conventional plant protection measures for the control of vectors are inefficient and undesirable from the point of view of environmental pollution. The chemotherapic and physiotherapic procedures used *in vivo* against viruses are not so effective in practice. Therefore the only recourse left to the growers to combat viral diseases is the use of resistant varieties (Horvath, 1984). Unfortunately many of the existing released varieties of okra are showing the signs of susceptibility to YVMV. Several varieties have exhibited tolerance / resistance to this virus at the time of release, but this tolerance / resistance have been broken down with time. Interspecific hybridization for YVMV resistance followed by selection in the segregating generations is an effective method for obtaining desirable recombinants. Several wild species of cultivated okra showed high degree of resistance to YVMV. However resistant varieties developed by various research organizations by interspecific hybridization have also started showing signs of susceptibility probably due to the arrival of new virus strains. Hence it is imperative to find diverse sources of resistance to YVMV and evolve YVMV resistant varieties in a continuous manner by suitable gene introgression programmes.

In this context a semi cultivated okra species *Abelmoschus caillei* (A. Cher.) Steveis deserves importance. It adorns many remarkable traits such as resistance to YVMV, adaptability and perennial nature (Charrier, 1984; Chacko,1996). This

species is a complex polyploid considered to be originated by contributing genomes of *A.esculentus* and *A. manihot* (Siemonsuma, 1982).

In *A. caillei*, a variety 'Susthira' has been developed in the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara by selection from the existing variability expressed by this species (Sureshbabu *et al*., 2004). Although Susthira is highly resistant to YVMV and high yielding, it is more suitable for kitchen garden due to its perennial nature, late bearing habit and less attractive pods. At the same time a popular *A. esculentus* variety 'Salkeerthi' developed by the same Department has a wide range of acceptability owing to its early bearing habit, excellent fruit quality, attractive light green pods and high yield, but it is susceptible to YVMV. Hence it cannot be grown during summer when the disease is more prevalent. In this regard it would be a viable proposal to transfer YVMV resistance from 'Susthira' (*A. caillei*) to 'Salkeerthi' (*A.esculentus*). Accordingly interspecific hybridization between *A. caillei* and *A. esculentus* was done and the generations were advanced up to F_3 (Kousalya, 2005).Thus in order to continue the breeding programme the F_3 generation has to be advanced further along with proper selection for YVMV resistance and other desirable traits.

The present study was conducted with the following specific objectives:

1. To advance the generation up to F_4 and F_5 level out of the cross *Abelmoschus caillei* variety Susthira x Abelmoschus *esculentus* variety Salkeerthi and study the extent of variability.
2. To select individual plants having high level of resistance to YVMV combined with desirable traits in the segregating F_4 and F_5 generations for further advancing the generation in the process of developing YVMV resistant varieties of okra.

Review of Literature

2. REVIEW OF LITERATURE

Okra is an important vegetable crop grown for its tender pods in tropics, subtropics and warmer parts of temperate regions of the world. Okra pod is rich in important vitamins and mineral elements. But the susceptibility of most of the okra varieties to YVMV is a major problem limiting the production of this crop. There is no source of resistance to this disease in *A. esculentus*. Hence it is necessary to breed new okra varieties resistant to YVMV by imparting resistant genes from diverse wild species of *Abelmoschus* by interspecific hybridization followed by selection of promising segregants. The pertinent literature on the present study is reviewed under the following heads citing the research works in okra and other vegetable crops.

2.1 Origin and cytogenetics

Okra belongs to the genus *Abelmoschus* which was established by Medikus (1787). The genus is believed to be of Asiatic origin whereas centre of origin of the major cultivated species *A. esculentus* is controversial- the species is believed to have originated in India (Masters, 1875); Ethiopia (Candolle, 1883); West Africa (Chevalier, 1940; Vavilov, 1951) and Tropical Asia (Grubben, 1977). Index kewensis lists over 30 species of *Abelmoschus* in the old world, four in the new world and four in Australia. Waalkes (1966) has a more conservative point of view retaining only six species. These are *A. moschatus* Medikus, *A. manihot* (L.) Medikus, *A. esculentus* (L.) Moench, *A. ficulneus* (L.) Wt and Art. ex Wt, *A. crinitus* Wall. and *A. angulosus* Wall ex Wt and Art. The former three species consisted of wild and cultivated forms and the latter three species consisted of wild forms only. Bates (1968) suggested some additional modifications like inclusion of *A.tuberculatus* and the grouping of all subspecies and varieties of *A. manihot*. The genus became more complex by discovery of an African cultivated species by Siemonsuma (1982) and described it as *A. caillei* (A. Cher.) Stevies. Based on the available cytogenetical

evidence, the International Okra Workshop (1990) adopted a classification in which nine species were included in the genus *Abelmoschus*. This classification also included the new cultivated species, *Abelmoschus caillei* which was wrongly identified earlier as *A. manihot* ssp. *manihot*.

Joshi and Hardas (1956) proposed a polyphyletic origin for the species. They reported an allopolyploid genome for cultivated okra. The chromosome polymorphism has been reported in okra that is chromosome count within a species exhibit a wide range of variation. The somatic chromosome number reported for *A. esculentus* varied greatly from 2n=72 to 144. However, the most frequently observed chromosome number was 2n=130 (Siemonsuma, 1982). Dutta and Nang (1968) proposed that the 2n numbers, 2n=72,108,120, 132 and 144 were an indication of a regular polyploid series with x=12.

2.2 Yellow Vein Mosaic Virus (YVMV)

Yellow Vein Mosaic Virus (YVMV) of okra is the most destructive virus disease infecting all stages of this crop. The disease was first reported by Kulkarni (1924) in the Bombay region. Later it was studied by Uppal *et al*. (1940) and Kapoor and Varma (1950). The virus is neither sap nor seed transmissible, but it is readily transmitted through whitefly (*Bemisia tabaci*) (Padda, 1968). The loss due to this disease is in the range of 50 to 90 per cent depending on the stage of the crop growth at which infection occur (Sastry and Singh, 1974). The disease not only reduces yield adversely, but also affects marketability of the fruits (Pun and Doraisamy 1999). They also found the yield loss due to YVMV up to 95.7 per cent.

2.2.1 Incidence of YVMV

Chelliah and Murukesan (1976) observed a significant increase in the incidence of YVMV and yield loss in okra sown in March –May compared with rest of the year.

Sinha and Chakrabarthy (1978) confirmed that the disease had an adverse effect on plant height, number of branches, number and size of fruits and seed yield.

Khan (1983) reported 0.35 per cent seed transmission of the virus and established the seasonal nature of the incidence of the disease.

Atiri and Ibidapo (1989) reported that bhindi mosaic virus and leaf curl virus had a synergistic effect in mixed infections.

Goswami and Bhagavathy (1992) in their experiment observed that the lowest disease incidence on okra sown at beginning of October (16.7 %) and highest incidence of crop sown in May-June (100%).

Mazumder *et al.* (1996) conducted experiment on the incidence of YVMV and its vector *Bemisia tabaci* in the cultivars Pusa Sawani, Parbhani Kranti and M-31. Lower disease incidence populations were recorded in crop sown between February 25 and March 20. Positive significant association was observed between disease incidence and white fly population, temperature, relative humidity of the evening, rainfall and rainy days.

Sangar (1997) in his experiment during rainy and summer seasons observed Arka Anamika was highly resistant, Arka Abhay resistant and Parbhani Kranti and V-6 were moderately resistant to YVMV.

Nath *et al.* (1999) observed minimum disease incidence (4.44%) in Parbhani Kranti and Arka Abhay at 90 days after sowing.

Pun and Doraisami (1999) revealed effect of age of plants on susceptibility to YVMV. The greatest loss in the yield of fresh fruit was highest (95.7%) when virus inoculated at one week old plants.

Pun *et al.* (2000) studied influence of weather factors on the incidence of YVMV. The meteorological factors were maximum and minimum temperature, morning and evening RH, sunshine hours, wind velocity and total rainfall with the disease incidence.

Bhagat *et al.* (2001) reported that the maximum rate of disease development was between 35 and 45 days after sowing, irrespective of cultivars during rainy seasons of two consecutive years of study. They suggested that susceptible stage of the crop from 35 to 50 DAS must be supplemented with systemic insecticide spray to reduce whitefly population thereby disease severity was reduced and obtain good harvest.

Jose and Usha (2003) annunciated okra YVM in India is caused by association of a DNA beta satellite with a begomo virus. This disease is caused by a complex consisting of the monopartite begomo virus, Bhindi Yellow Vein Mosaic Virus (BYVMV) and a small satellite DNA beta component. BYVMV can systematically infect bhindi up on agioinoculation but produces only mild leaf curling in this host. DNA beta induces typical symptoms of YVMV when co-agioinoculated with the begomo virus. The DNA beta component associated with BYVMV has a number of factors in common with those reputed for Ageratum Yellow Vein Disease and cotton leaf curl disease. BYVMV represents a new number of emerging group of monopartite begomo viruses requiring a satellite component for symptom induction.

2.2.2 Screening for resistance to YVMV

Naraini and Seth (1958) in their screening experiment for YVMV inferred that, *Hibiscus manihot* var *pungens, H. crinitus, H. vititolius and H. panduraetormis* were immune. Sandhu *et al.* (1974) in their screening test found that accession E31830, 'Asuntemkoko' from Ghana was *A.manihot* (L)Medicus spp. *manihot* was immune to YVMV.

Atiri (1983) reported that several cultivars resistant to YVMV were high yielding. Chelliah and Sreenivasan (1983) reported that *A.manihot* (L)Medicus spp. *Manihot* and *A.manihot* were resistant to YVMV disease.

Raghupathy *et al.* (2000) screened 12 okra cultivars, including then highly susceptible Pusa Sawani and MDU-1. The disease was absent in the highly resistant

cultivars BO-1 and HRB-55. Resistant cultivars were KS-404, HRB 9-2, HY-8, P-7, Parbhani Kranti, Sel-10 and Sel-4 with a disease incidence of 0.5, 0.82, 1.26, 1.68, 2.87, 3.63 and 8.69 % respectively. BO-2 was susceptible (19.55%) and MDU-1 and Pusa Sawani recorded 90.83 and 91.53 % respectively.

Ravisankar (2002) conducted screening experiment by grafting and vector transmission studies. He reported line AE-238 was free from YVMV. AE-265 x AE-190 also did not show disease symptoms in the field screening.

Singh *et al.* (2000) revealed performance of different varieties to YVMV, out of the twelve cultivars screened, disease incidence varied from 0.7 % (Arka Abhay) to 57.4 % (Chhindwala Local).

Kousalya (2005) reported that in the field screening trials, the *Abelmoschus esculentus* line Salkeerthi was highly susceptible to YVMV (CI=70.7) where as *Abelmoschus caillei* variety Susthira was highly resistant (CI=0.1). The interspecific F_1s were moderately resistant to YVMV (CI=18.9) and all the F_2 generation plants were resistant to YVMV.

2.2.3 Breeding for resistance to YVMV

2.2.3.1 Selection

Joshi *et al.* (1960) used resistant line IC 1542 from West Bengal for developing the resistant varieties.

Sureshbabu *et al.* (2002) reported an YVMV resistant edible perennial okra line AE 286 (*A.caillei*) through single plant selection.

2.2.3.2 Hybridization and Selection

Singh *et al.* (1962) bred " Pusa Sawani " from the cross between IC-1542 and Pusa Makhmali . Dhankar *et al.* (1996) developed YVMV resistant okra "Varsha Uphar" out of the cross between Lam Selection 1 x Parbhani Kranti. Rameshpathak

and Syamal (1997) reported that the progenies of the cross Parbhani Kranti x EC 16511 were found to be resistant to YVMV.

Fugro and Rajput (1999) using a partial diallel mating system involving nine genotypes, developed 36 F_1 hybrids , of which Sel 4 x Parbhani Kranti , Pusa Sawani x Punjab 7 and Sel4 x Sel 10 were free from YVMV.

Deo *et al.* (2000) annunciated that Parbhani Kranti and its hybrid Parbhani Kranti x HRB-9-2 were highly resistant to YVMV. Rattan and Bindal (2000) in their programme to develop okra hybrids resistant to YVMV found that lines 407, 409, 417, 430 were completely resistant. The F_1 hybrids between the resistant lines were resistant, and that of susceptible parents susceptible. The studies indicated that resistance to disease is monogenic and dominant. Maximum number of fruits and yield per plant was recorded by hybrid 410 x 407 followed by 409 x 421 and 409 x 408 involving resistant x resistant and resistant x susceptible crosses, respectively.

Ravisankar (2002) crossed fifteen lines with two testers, AE-285 and AE 190 (Parbhani Kranti) in a line x tester mating design to produce 30 hybrids. Among them a parent AE-238 and two hybrids were free from YVMV.

2.2.3.3 Interspecific Hybridization

Interspecific hybridization followed by selection in the segregating generations is an effective method for obtaining YVMV resistant recombinants. It has been carried out in this genus as early as 1930s. Teshima (1933) reported a successful cross between *A. esculentus* and *A. manihot*. Later Chizaki (1934), Skovsted (1935), Ustinova (1937) and Singh *et al.* (1938) reported success of the same cross.

Pal *et al.* (1952) attempted to transfer the true resistance against the YVM disease of *A.manihot* var *pungens* and symptom less type of *A. tuberculatus* to cultivated okra variety, Pusa Makhmali. In the case of crosses with *A. tuberculatus* the F_1 hybrids were completely sterile and no viable seeds were obtained even from backcrosses. They succeeded in overcoming seed sterility through production of

amphidiploidy from F_1 hybrids, but were not free from YVM disease. Similarly the *A. manihot* var *pungens* x *A. esculentus* hybrids also exhibited very high degree of sterility. The F_1 hybrids were vigorous but mostly sterile as most of the meiotic chromosomes remained as univalents.

Joshi and Hardas (1956) reported heterotic hybrids between *A.esculentus* and *A.tuberculatus*. The sterile F_1 hybrids when treated with colchicines produced a fertile plant.

Kuwada (1961) reported that the hybrid between *A. esculentus* and *A. manihot* was partially sterile. Later Kuwada (1966) found that the cross between *A. esculentus* and *A. tuberculatus* was successful in both directions but the hybrids were completely sterile. He also reported that the hybridization between *A. tuberculatus* and *A. manihot* was successful only when *A. tuberculatus* was used as the female parent, but the hybrid was completely sterile.

Gadwal *et al.* (1968) observed that the hybrid embryo failed to grow in cross combinations of *A.esculentus* with *A.moschatus* and *A.ficulneus*, but in vitro culture of embryos could be effectively cultured.

Joshi *et al.* (1974) reported that the F_1 hybrid between *A.esculentus* (n=65) and *A. moschatus* (n=36) through in-vitro culture showed very little genome affinity.

Arumugham *et al.* (1975) reported that several exotic accessions of *A. manihot* and crosses made between *A.esculentus* and *A. manihot* yielded viable F_1 seeds, however up to 40 per cent sterility appeared in F_2 generation.

Singh *et al.* (1975) reported that the hybrids of an accession from Ghana (*Abelmoschus caillei)*, which was identified as being immune to YVMV with an Indian okra were only partially fertile while those between this accession and *Abelmoschus tetraphyllus* were completely sterile.

Self sterile F_1 but with many fruits without seeds and virus resistance was developed by Hossain and Chattopathyay (1976) by crossing *A.esculentus* x *A. ficulneus*.

Thakur (1976) reported that YVMV resistance in an interspecific cross involving *A. esculentus* cv. Pusa Sawani and *A. manihot* ssp. *manihot* cv. Ghana was conditioned by two dominant complementary genes.

Nair and Kuriachan (1976) reported that a spontaneous hybrid between *A.tuberculatus* and *A.esculentus* was highly pollen sterile and seed sterile in which selfing, open pollination and backcrossing produced only fruits with empty seeds.

A successful cross between *A. esculentus* and *A. tetraphyllus* was reported by Ugale *et al*. (1976). Almost perfect pairing of genome of *A. esculentus* with the chromosomes of the other species was observed in the meiosis of the hybrid. One of its genomes manifested a good homology with *A. esculentus*.

Arumugham and Muthukrishnan (1978) developed four YVMV resistant F_1s by crossing two resistant forms of *A. manihot* with susceptible okra cultivars, Pusa Sawani and CO 1.

Mamidwar *et al*.(1980) while studying crosses between cultivars of *A.esculentus* and *A. manihot* resistant to YVMV and found that fruit set was higher when *A.esculentus* was used as female parent with 8.33 as the near value for per cent fruit set .

Mehram and Dhapke (1981) reported that the hybrid between *A. esculentus* and *Abelmoschus tetraphyllus* was spreading in habit, dwarf in stature and highly male sterile.

Interspecific crosses between two cultivars of *A.esculentus* and a cultivar of YVMV resistant *A. manihot* and one of the reciprocals were successful. On comparison of parental F_1, F_2, BC_1 and BC_2 genotypes, heterosis over the better parent was observed for number of fruits per plant, plant height and number of branches (Dhillon and Sharma, 1982).

Nirmaladevi (1982) reported that *A. manihot* was crossable with *A.esculentus*. The interspecific F_1 hybrid exhibited significant heterobeltiosis for many of the

economic characters and resistance to YVMV. She observed significant genetic distance between *A.esculentus* and *A. manihot.*

Jambhale and Nerkar (1982) induced amphidiploidy in the F_1 hybrid between *Abelmoschus esculentus* (n=65) and *Abelmoschus tetraphyllus* (n=69) to overcome sterility. They also reported colchicine induced amphidiploidy in the cross *Abelmoschus esculentus* (2n=130) x *A. manihot* ssp. *manihot* (2n=194).

Martin (1982) reported interspecific hybrids between unnamed West African species of *Abelmoschus* and *A. esculentus*. The F_1 hybrids were comparatively sterile but a few produced germinable seeds. Back crosses were mere fertile with almost complete fertility in BC_2.

Siemonsuma (1982) reported two distinct types of okra called Soudanien and Guineen type. Soudanien corresponded to botanical descriptions and previously reported chromosome numbers of *Abelmoschus esculentus*. Guineen was thought to be a natural amphidiploid of *Abelmoschus esculentus* (2n=130 to144) and *A. manihot* (2n=60 to 68) and had 2n=185 to 199. Soudanien and Guineen types crossed readily in both directions and the progenies were intermediate in character.

Jambhale and Nerkar (1983) identified some plants resistant to YVMV which were obtained from backcrosses of *A. esculentus* and *A. manihot* to *A. esculentus* cv. Pusa Sawani. Seed fertility in the plants was 58 to 88 per cent.

Sharma and Dhillon (1983) reported that YVM virus was controlled by two dominant complementary genes with additive effects based on their studies on the genetics of resistance to YVM from the segregation of back crosses of *A. esculentus* x *A. manihot*. They also suggested that genes responsible for resistance to virus were sensitive to environmental changes. Therefore the possibility that resistance to YVM virus in *A. manihot* ssp. *manihot* is conditioned by polygenes cannot be ruled out.

In an interspecific breeding programme between *A. esculentus* and *A. manihot*, Sujatha (1983) observed high degree of pollen fertility (33.4 to 64.5 per

cent) in the hybrids but there was hardly any seed set. The seeds formed were shriveled and small in size.

Pillai (1984) produced interspecific hybrids from *A. manihot* and from YVMV susceptible *A.esculentus* cultivars. Though the hybrids produced fruits, number of seeds per fruit count was very much low (8-12) as against that of parents (50 to 90). Further, the hybrids were found to be resistant to the YVMV disease. A decrease in percentage of pollen fertility in the hybrids (28.7-57.4) as against the parents (98-99) is presumably the reason for scanty hybrid seed recovery.

Sharma and Sharma (1984) confirmed the results of Sandhu *et al.* (1974) and used *A. manihot* as a male parent in hybridization with Pusa Sawani for developing resistant 'Punjab Padmini'.

Nerkar and Jambhale (1985) used the YVMV resistant Ghana line *A.manihot* ssp. *manihot i*n their hybridization programme which resulted in the cultivar 'Parbhani Kranti', which is used as one of the tester in this hybridization programmes. They also confirmed the resistance of *A. tetraphyllus* which was used earlier by Dutta (1984) for developing YVMV resistant lines Sel-4 and Sel-10.

Cheriyan (1986) found that *A. manihot* and *A. manihot* ssp. *tetraphyllus* were cross compatible with *A. esculentus*. But the F_1 plants did not bear normal seeds and pollen fertility of the hybrids was much lower than the parents. There was preponderance of characters of wild species in the interspecific hybrids.

Mathews (1986) observed preponderance of low yielding YVM resistant plants similar to semi-wild parent among the F_2 population of the interspecific hybrids between the YVM susceptible cultivars of *A. esculentus* and YVM resistant semi wild species of *A. manihot* . Varying degrees of sterility were observed in the F_2 progenies. He also reported high phenotypic and genotypic coefficients of variation for weight of fruits per plant, number of leaves per plant and height of plants.

Prabha (1986) crossed the YVMV disease susceptible varieties of *A. esculentus* with resistant wild/ semi wild species *A. manihot*. The first generation

hybrids though did not produce viable seeds profusely were not totally sterile. The scanty viable seed recovery from the hybrids against the parents was suspected to be due to chromosomal differentiation that could have taken place during speciation in the genus.

Prabha (1986) studied the cross compatibility between *A. esculentus* and *A. manihot,* wild species like *A.tetraphyllus , A. manihot ssp. tetraphyllus, A. ficulneus, A.moschatus* and *Hibiscus huegetic* which were resistant to YVMV. Interspecific hybridization was done in the above mentioned resistant wild species with the locally adapted high yielding variety Kiran. Normal fruits and seeds are produced in the cross combinations involving *A.tetraphyllus* and *A. manihot.*

Sheela (1986) attempted to induce desirable genetic recombinants combining resistance to YVMV in the interspecific crosses of *A. esculentus* x *A.moschatus, A. esculentus* x *A. caillei* and *A. esculentus* x *A. tetraphyllus,* fruit set in the interspecific crosses was found to be less (28-42%) compared to the female parents (81-97.81%). It was high when cultivated varieties were used as female parents. The crossed fruit resembled the fruits of wild parent in all the crosses irrespective of the pollen source. In the crosses with *A. moschatus,* 100 seed weight was categorically low compared to other crosses. All the crossed seeds showed good germination percentage except in the crosses with *A. moschatus* .Crosses with *A.moschatus* provided shriveled and non-viable seeds. Eleven days old embryos of the crosses *A. moschatus* x *A. esculentus* cv."Anakomban" were found to be brown at the time of excision. Ten days old embryos of the same crosses showed no response in ½ MS, MS and MS+BA 0.5 mg/lit + CW 150 mg/lit media. Embryos less than 10 days old could not be cultivated in vitro, as excision was difficult. In the irradiated crosses, *A. caillei* x "Anakomban" (*A. esculentus*) and, *A. caillei* x "Eanivenda" were identified as better crosses for isolating recombinants.

Pushparajan(1986) reported reproductive isolation of *A. moschatus* from all other species of the genus *Abelmoschus*. Cheriyan (1986) reported there was no

reciprocal difference in the crossability index in crosses of *A. esculentus* with *A. manihot* and *A.tetraphyllus*.

Madhusoodanan and Nazeer (1986) carried out successful intercrossing between a 'Saudanien' and a 'Guinean' type of okra, of which the latter is reported to be immune to YVMV disease. However due to difference in chromosome number of the parents the hybrid exhibited abnormal meiosis leading to sterility and thereby hinders fruitful incorporation of the disease resistant gene to the former one.

Fatokun (1987) reported successful crosses between two cultivars from each of the *Abelmoschus esculentus* varietal groups Soudanien and Guineen. The hybrids showed meiotic abnormalities which resulted in production of microspores of variable size. Pollen viability was low (35.8and 39.4 per cent) and only few seeds were produced.

Sureshbabu (1987) reported vigorous F_1 hybrid between *A. esculentus* and *A. manihot* ssp. *tetraphyllus* var. *tetraphyllus*. Sterility in the hybrid was attributed to the failure of development of female gamete.

Kondaiah *et al*. (1990) made reciprocal crosses between *A.manihot* ssp. *manihot* and *A. tetraphyllus* and also between *A. manihot* ssp. *manihot* and induced amphidiploid of (1) *A. esculentus* x *A. tetraphyllus* and (2) *A. esculentus* x *A. manihot*. The study revealed that *A. manihot* ssp. *manihot* (hexaploid) contained two genomes from *A. tetraphyllus* and a third from *A. manihot*.

Sureshbabu and Dutta (1990) obtained heterotic hybrids from crosses of *A. esculentus* with *A. tetraphyllus*. Meiosis was abnormal in hybrids leading to hybrid sterility. They produced fully fertile amphidiploid *A. esculentus* x *A. tetraphyllus* by colchicines treatment, resembling the F_1 plants with YVMV resistance and larger fruits. They also reported that progenies from the back cross of the amphidiploid of the cross between *A. esculentus* and *A. tetraphyllus* with the cultivated parent was readily feasible and they combined the YVMV resistance of the wild species and the desirable fruit characters of the cultivated species. Failure of seed formation in

interspecific hybrids of *Abelmoschus* species may be due to slow pollen tube growth, abnormal pollen tube, and abortion of fertilized ovules or sparsity of pollen grains (Swami and Khanna, 1991)

Dutta (1991) reported that the development of okra lines having high yield, quality and resistance to YVMV by interspecific hybridization between *A.esculentus* and YVMV resistant wild species *A. manihot ssp. tetraphyllus*

Nerkar (1991) revealed the use of wild okra (*Abelmoschus* spp.) with resistance to okra YVMV, powdery mildew (*Erysiphae cichoracearum*), Jassids (*Empoasca* spp.) in breeding programmes to develop pest and disease resistant varieties.

Sindhu (1993) observed that the fruit set in direct crosses of *A.esculentus* cv. Anakomban x *A. manihot* and *A. esculentus* cv. Anakomban x *A. manihot* ssp. *tetraphyllus* was very low compared to the reciprocal crosses exhibiting partial incompatibility consequent on the slow pollen tube growth of *A. manihot* and *A. manihot* ssp.*tetraphyllus*. Seed set was low in the crossed fruits and there was recovery of shriveled seeds which may be attributed to the poor endosperm development. The crossed seeds exhibited good viability. Four hybrids recorded pollen sterility which may be attributed to meiotic abnormalities due to difference in chromosome number between the species. Seed set in the hybrids was very low and was inversely proportional to pollen sterility. Recovery of empty seeds which appeared normal may be ascribed to endosperm degeneration; viability of F_2 seeds was very low.

Sheela (1994) attempted combining the economic attributes of cultivars and Yellow Vein Mosaic disease resistance of wild relatives. Varietal difference in compatibility of *A. esculentus* with the donor parents, *A. caillei and A. tetraphyllus* was noticed .Reciprocal crosses registered higher compatibility than the direct crosses. Natural crossing of *A. tetraphyllus* with *A. esculentus and A. caillei* was also observed. She further observed a higher proportion of low yielding YVMV resistant

types similar to the wild types in F_2 and F_2M_2 populations indicating strong genetic mechanisms preventing recombinations. However more recombinants appeared in the F_2M_2 generation indicating the breakage of undesirable linkage through irradiation.

Manjuchandran (1996) successfully cultured 12 and 15 days old interspecific embryos of *Abelmoschus esculentus* var. "Kiran" x *A. moschatus and A. esculentus* cv. "Anakomban"x *A. moschatus* in MS medium supplemented with BA 0.5 mg/lit and CW 150ml/lit. Twelve days old embryos gain lesser germination percentage than fifteen days old embryos. For the multiplication of interspecific hybrids produced by embryo culture, MS medium supplemented with BA 1mg/lit and CW 150ml/lit was found optimum for enhanced release of axillary buds. In this medium, the number of multiple shoots per culture was 7.80 and 5.16 respectively for *A. esculentus* variety "Kiran" x *A. moschatus and A.esculentus* cv. "Anakomban"x *A. moschatus*. Ex-vitro survival per cent was 36.0 and 30.0 for *A. esculentus* variety "Kiran" x *A. moschatus and A. esculentus* cv. "Anakomban" x *A. moschatus* respectively.

Chandran *et al*. (1996) reported that transplantable seedlings could be obtained by embryo rescue technique through culturing twelve and fifteen days old embryos of the cross between *A. esculentus* x *A. moschatus* . This suggested the potential of tissue culture methods to overcome the post zygotic incompatibility barriers in interspecific crosses.

Chacko (1996) reported that interspecific hybridization between *A. esculentus* and *A. manihot* was successful when *A. manihot* was kept as the female parent. The fruit set in the successful direction of crosses was 62.85 per cent and crossability was worked out as 40.6 per cent.

Chandran and Rajamony (1997) reported that when cultivated types were used as the female parent in hybridization using wild donors, maximum fruit set was obtained in crosses where *Abelmoschus manihot* used as pollen source. The percentage of viable seeds obtained was also maximum in crosses involving *Abelmoschus manihot*.

John (1997) estimated the extent of variability in the F_2M_2 and F_3M_3 generations as a result of hybridization and irradiation of the interspecific hybrids between *A. esculentus* and *A. manihot*. In the F_2M_2 generation, the irradiated treatments were late flowering and had more number of leaves, flowers and fruits. Irradiation increased pollen sterility and was maximum at 10 KR. Seed set was lower in the irradiated treatments.

Philip (1998) observed that the families in the F_4M_4 generation of interspecific hybrids of the cross *A.esculentus* variety "Kiran" x *A. manihot*, resistant to YVMV were late flowering. He recorded higher mean value for number of leaves, branches, flowers and fruits compared to the cultivated parent. The fruit yield per plant was higher than the parents in spite of the reduction noticed in average fruit weight. In the F_5M_5 generation, the families were early flowering and recorded increase in leaf area, pollen sterility and number of branches per plant. The fruit yield per plant, average fruit weight and number of seeds/ fruit were higher in the F_5M_5 families.

Kousalya (2005) observed that in the crossability studies between *A.esculentus* and *A.caillei*, the crosses were more successful when *A.caillei* was used as female parent (Crossability Index = 42.64 %). The F_1 hybrid was also secured in the cross *A.esculentus* x *A.caillei* but in this direction crossability index was less (15.3%). The cross *A.caillei* x *A.esculentus* was more successful , probably due to the higher ploidy level of female parent *A.caillei* which provided better embryo endosperm balance.

2.2.3.3.1 Interspecific Hybrid Sterility

Teshima (1933) observed that *A. esculentus* and *A. manihot* crossed only when the former was used as female parent. He reported that the F_1 hybrids were partially fertile. The interspecific hybrid sterility may be genic or chromosomal (Stebbins, 1950). Genetic sterility is typically due to the genetic constitution of the

organism and so is diplontic (Dobzhansky, 1951). He pointed out that the only practical criteria to distinguish between genic and chromosomal sterility is provided by effects of doubling the chromosome number. The chromosomal sterility results from the structural differences between chromosomes which cause deficiency, duplication and other disharmonious combinations of chromosome segment to be distributed to the gamates. Doubling of the chromosome number results in the presence of meiosis a complete homology for every chromosome in the organism, pairing and segregation are therefore usually regular and no chromosomal imbalance results. If the sterility is genic and diplontic the imbalance in the somatic tissue of the diploid is retained in the corresponding tissue of tetraploid, hence the sterility persists.

Pal *et al.* (1952) conducted interspecific crosses between five species of *Abelmoschus* viz. *Abelmoschus esculentus, A.tuberculatus , A. ficulneus, A. manihot*
and *A. manihot* var pungens and reported that the crosses mostly resulted in shriveled or empty seeds. The various F_1 hybrids studied were sterile. Pollen fertility ranged from 40 to 95 percent in different crosses, the highest being in the cross *A. esculentus* x *A. manihot*.

According to Stebbins (1958) the immediate cause of failure of embryo development in interspecific hybrid can be grouped into three categories viz., the disharmony may reside entirely or chiefly in the chromosomes and genes of the two parental species as they are combined in the hybrid nuclei. There may be disharmonious interaction between the chromosomes or genes of one species and the cytoplasm of other as it has been contributed by egg or maternal parent. The hybrid embryo may be perfectly capable of developing so far as its on constitution is concerned, but may be inhibited action of maternal tissue surrounds it or in higher plants by the endosperm which nourishes it.

Stebbins (1958) reported that the failure of embryo development is due to the incompatibility between parental chromosomes and genes, reciprocal hybrids

between the two parents will be equally weak or inviable , thus the removal of the embryo from it maternal surrounding will not help to develop.

About 90 per cent sterility was reported in interspecific hybrid between
A. esculentus x *A. manihot* by Arumugham *et al.* (1975). In interspecific hybridization between different *Abelmoschus* spp. viable seeds could be obtained only in cross between *A. ficulneus* (2n=72) and *A. tuberculatus* (2n=58), resulting plants were sterile (Siemonsuma, 1982). Partial seed fertility of 5.9 per cent and 7.1 per cent were obtained in crosses *A. esculentus* x *A. manihot and A. esculentus* x *A. manihot* ssp. *manihot* respectively by Jambhale and Nerkar (1985).

Bhargava (1989) observed embryo deterioration in ovules resulting from crosses between *A. manihot* and *A. esculentus*. Endosperm deterioration was first noticed five days after pollination in the cross *A. esculentus* x *A. manihot* and was accompanied by a decrease in ovule weight. Cell division at this stage was random and within six days embryos had formed an undifferentiated cell mass surrounded by multiple layers of endothelium.

Chacko (1996) observed that in the interspecific hybrid of *A. esculentus* x *A. manihot* pollen stainability was only 18.26 per cent. The mean diameter of fertile pollen grains was o.062 µm and that of sterile pollen grains was 0.03 µm.

Kousalya (2005) observed that in the cross *A.caillei* x *A.esculentus* the F_1 hybrid was partially sterile. This can be attributed to the cytological irregularities including the presence of lagging chromosomes, occurrence of micronuclei and multipolar spindle formation.

2.2.3.3.2 Segregating progenies

Mathews (1986) evaluated the F_2 population of interspecific cross of *Abelmoschus manihot* x *Abelmoschus esculentus* along with the parents and F_1s. A preponderance of low yielding yellow vein mosaic resistant plants similar to the

semi-wild parents was observed among the F_2 populations, suggesting the presence of powerful genetic mechanisms which restrict free recombinations.

According to Kalloo (1988) two species of genus *Lycopersicon* involved in hybridization have enormous distinction for many characteristics. As a consequence such species hybrids should produce an F_2 population with a wide range of variation. Also extreme recombinants are expected in F_2 but in practice, the possibility of appearance of such individuals is remote. Wild or semi wild parental types appeared frequently and recombinants produced in F_2 exhibit rather a narrow range. Usually, F_2 populations show a pronounced shift towards wild parent especially when one is cultivated and other is wild. This situation is extensively demonstrated in the F_2 segregants of the crosses like *Lycopersicon esculentum* x *L.peruvianum, Lycopersicon esculentum* x *L. pimpinellifolium, Lycopersicon esculentum* x *L.hirsutum, Cucumis melo* x *C.metuliferus and Cucurbita maxima* x *C. lundelliana*. The most probable reason for this one sided segregation may be reduced pairing, chromosome differentiation, restricted recombination, linkage , gametic and zygotic eliminations.

Gill *et al.* (1983) successfully transferred Yellow Mosaic Virus resistance from black gram (*Phaseolus mungo*) to mung bean (*Phaseolus aureus*) by advancing the segregating generations and subsequent selections. Kalloo and Banerjee (1990) developed six tomato line H-2, H-11, H-17, H-23, H-24 AND H-36 resistant to TLCV transmitted by the white fly *B. tabaci* with controlled introgression of resistant gene from *L.hirsutum f.glabratum* into *Lycopersicon esculentum* through pedigree selection in the BC-6 population. The fruit size and days to maturity in resistant lines were close to those of the cultivated susceptible varieties included. YVMV resistant mung bean lines were recovered in advanced generations of interspecific cross involving the mosaic susceptible mung bean line SML32 and the resistant black gram variety Saradhu, without backcrossing (Pal *et al.*, 1991).

Ali *et al.* (2000) crossed an okra variety, IPSA Okra 1, tolerant to Yellow Vein Mosaic Virus (YVMV) with three susceptible genotypes viz. Parbhani Kranti, SL-44 and SL-46 to determine the nature of inheritance of tolerance of IPSA Okra 1. Grafting test was also done to know the nature of tolerance. It was revealed from the results of grafting test that the tolerance in IPSA Okra 1 is genetic, not due to escape. The F_1 hybrids were tolerant to YVMV. From the segregation pattern for disease reaction in F_2 and BC_1 generations of the three crosses, it could be hypothesized that the tolerance to YVMV in IPSA Okra 1 is quantitative, with possibly two major factors, and dependent on gene dosage with incompletely dominant gene action.

Singh *et al.* (2000) observed that when ten okra genotypes and five F_1s derived from them was screened for resistance to yellow vein mosaic virus. HRB-55 x Arka Anamika, Prabhani Kranti x HRB-9-2 and BO-1 x P-7 derived from highly resistant parents were highly resistant to the virus, while BO-1 x Pusa Sawani was susceptible.

Singh and Singh (2000) treated three improved genotypes of okra, viz., Parbhani Kranti, Hisar Unnat and Satdhari with gamma rays (15, 30, 45 and 60 kR) and EMS (0.25, 0.50, 0.75 and 1.0%) and progenies derived from each treatments were screened during the summer and rainy seasons of 1996 and 1997 in M_2, M_3 and M_4 against YVMV, respectively. Among all the doses of mutagens, 45 and 60 kR gamma rays and 0.75 and 1.0% EMS gave highly resistant to resistant plants in both M_2 and M_3 generations. Hence, incidence of yellow vein mosaic virus showed dose dependent relationship and increase in doses of mutagens decreased the disease infection. Highly resistant plants were found in all the mutants of okra genotypes except S-2 and S-5 mutants of Satdhari, where resistant plants were noticed in M_4 generations.

The interspecific hybridization between *Abelmoschus esculentus* x *Abelmoschus caillei* showed that F_1 and F_2 generations were partially fertile, Kousalya (2005). She also observed that the F_2 plants were free of YVMV infection.

Thangam and Veeraragavathatham (2006) observed that there were many F_3 families of the cross CO3, a known susceptible genotype of *Lycopersicon*, to TLCV with CLN 2123A, an established genotype for its resistance to TLCV, with resistance to Tomato Leaf Curl Virus (TLCV) after grafting, and also exhibited acceptable fruit size. These lines can be used as resistant donor parents for further breeding of varieties resistant to TLCV or for the development of potential hybrids. Apart from this, these lines can also be used as a source of resistance for gene pyramiding to obtain cultivars with more durable resistance.

2.3 Achievements in breeding for resistance to YVMV

Since some of the tolerant varieties as well as intervarietal hybrid derivatives of okra lost their resistance to YVMV disease in due course, attempts have been made to incorporate the resistant genes from wild species to otherwise superior but susceptible commercial types of okra through interspecific breeding programmes.

Pusa Sawani, once most widely cultivated variety of okra was one of the earlier attempts in this regard. It was developed from a cross between 1C 1542, an indigenous stock with symptom less carrier type of resistance and Pusa Makhmali, a high yielding, adapted but susceptible variety of *A. esculentus* (Singh *et al.*, 1962). However the initial resistance was given way to high susceptibility due to genetic and environmental factors.

Punjab Padmini, an YVMV resistant variety was evolved by interspecific hybridization between *A. esculentus and A. manihot* ssp. *manihot* and the segregating generations were advanced upto F_8 followed by selection (Sharma, 1982)

MDU-1 was evolved by the Tamilnadu Agricultural University, Coimbatore, in 1978. It is an induced mutant isolated from Pusa Sawani and had been notified by the Central Seed Committee in 1985 (Ram, 1998).

The Maharashtra state seed Committee in 1985, released an YVMV resistant variety Parbhani Kranti developed from cross of *A. esculentus* cv Pusa Sawani x *A. manihot* (Jambhale and Nerkar, 1986)

P-7, an YVMV resistant variety was evolved from the cross between *Abelmoschus esculentus* cv Pusa Sawani and *A. manihot* ssp. *manihot*. The F_1 was backcrossed to the cultivated parent for four generations and selection was followed in the selfing generations up to F8 (Thakur and Arora, 1988).

Selections from IIHR, Bangalore, Viz., Selection-4, Selection-7, Selection-9, Selection 10 and Selection- 12 were found to have YVM disease resistance and was derived from the cross of *A. esculentus* x *A. manihot* var. *tetraphyllus* (Markose and Peter , 1990).

Arka Anamika, high yielding YVMV resistant variety obtained by interspecific hybridization between *A. esculentus and A. manihot* ssp *tetraphyllus* was released for cultivation at National level by IIHR Bangalore. Arka Abhay, another high yielding and resistant line derived from the same cross was released for state level cultivation (Dutta, 1991).

Varsha Uphar (HRB 9-2),an YVMV resistant variety has been developed by Haryana Agricultural University , Hisar from the cross, Lam Selection-1 x Parbhani Kranti following pedigree selection method. It was released in 1992 and notified in 1995 by the Central Sub- Committee on Crop Standards (Ram, 1998).

Pusa A4 has been released by IARI in 1994 as a substitute for Pusa Sawani. It is also resistance to YVMV (Ram, 1998).

Hisar Unnat (HRB 55), an YVMV resistant variety developed by Haryana Agricultural University, Hisar from the cross , Sel-2 x Parbhani Kranti has been released by the Central Variety Release Committee and notified in 1996 (Ram, 1998).

EMS-8 (Punjab-8) had been developed by B.R. Sharma and S.K. Arora in 1989 at PAU, Ludhiana. It is an induced mutant derived from Pusa Sawani treated

with 1%EMS. The final selection was made in the M_8 generation. It has field resistance to YVMV (Ram, 1998).

A. caillei variety Susthira has been developed in the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara by selection from the existing variability expressed by this species, Sureshbabu *et al.* (2004).

KAU had released two yellow vein mosaic resistant varieties, 'Manjima' of the cross Goreesapattom local x NBPGR/ TCR- 874 and 'Anjitha ' by interspecific hybridization followed by mutation breeding and selection (KAU, 2007).

IIVR Varanasi, released several YVMV resistant varieties like Kashi Vibhuti, Kashi pragati, Kashi Satdhari, Kashi Bhirav, Kashi Mahima (Pradeepkumar *et al.,* 2008)

2.4 Genetic variability in okra

Presence of variability among genotypes is a prerequisite for any crop improvement programme. Considerable variation has been reported for several characters in okra by various researchers (Thaker *et al.,* 1981; Chedda and Fatokun, 1982; Palaniveluchamy *et al.,* 1983 and Soubanbabu and Sharma, 1983).Considerable genetic variation for YVMV infection, fruit yield and number of fruits per plant in okra was reported by Kaul *et al.* (1979).

Length and number of fruits and yield per plant exhibited considerable variability (Murthy and Bavaji, 1980). Parthap *et al.* (1980) reported that fruit length contributed maximum to genetic divergence of okra. Vashita *et al.* (1982) observed significant difference for yield and agronomic characters except for ridges per fruit.

In a study of six *A. eseulemus* types over two seasons, the highest yield was recorded for Dwarf GLP and Penta Green whereas Clamson Spineless also was a high yielder (Blennerhasset and EL-Zaftawi, 1986).Twenty eight accessions of okra

varied for plant height, node at first fruit set, fruits and yield per plant and the highest yielder was Pusa Selection 6-2 (Korla and Sharma, 1987)

Genetic variability in ten morphological characters among eighteen okra accessions was measured by Ariyo (1990). When the performance of seven okra varieties was studied, Bhubaneswari had the credit of being the best yielder with the highest fresh pod weight while AE-180 was the earliest bearer and Pusa Sawani was the tallest with maximum pods (Nandi, 1990). Jeyapandi and Balakrishnan (1992) observed the highest variability for yield per plant followed by plant height.

During a comparison of eight genotypes and their 28 hybrids, considerable variation was observed for the characters under study (Kumbhani *et al*., 1993). Among the six YVM resistant / tolerant okra varieties from various regions of India compared with Pusa Sawani, during various seasons AROH-1 had the highest mean yield followed by Arka Anamika and Sel-4 (Mathews *et al*, 1993). In an evaluation involving six yield related traits of eight okra cultivars at Tarai region of Uttar Pradesh, Singh *et al*.(1993) observed the highest mean yield over two years for Parbhani Kranti (9.1 t/ha) followed by Punjab-7 and Punjab Padmini (9.0 and 8.8 t/ha) respectively.

Damarany and Farag (1994) noticed significant variation for twelve characters while evaluating thirteen cultivars of okra for two successive summer seasons at Assiut. Blondy was the earliest and the highest yielder with maximum pods per plant.

Gondane and Lal (1994) evaluated 50 genotypes of okra and concluded that high level of variability existed in eleven yield components. Genotypic differences for ten quantitative characters in six local and six exotic cultivars and their hybrids were evaluated by Hussein (1994).

In an evaluation of 30 genotypes across four environments, Pusa Sawani and strain 6316 were the most stable genotypes with respect to days to 50 per cent flower while White Velvet Strain 7116 had the highest stability for days to first flower and plant height respectively (Mandal and Dana, 1994). Sheela (1994) reported good

genetic diversity in okra germplasm which consisted of 56 accessions for all the characters under investigation except, YVM incidence.

Bhindu *et al*. (1997) observed wide range of variation for most of the traits including branches per plant, fruit length, days to first flower, plant height and fruit weight per plant. Significant variation among six parental strains and their 30 F_1 hybrids was reported by Rajani and Manju (1997) for days to first flower, first fruiting node, number of branches and fruits per plant, length and girth of fruits yield per plant, plant height and YVM incidence. Yassin and Anbu (1997) observed wide variability for plant height, branches, fruits and yield per plant but not for length and girth of fruits.

Significant variability was observed for all the characters studied in F_2M_2 and F_3M_3 families by John (1997) and John *et al*. (1999) and in F_4M_4 and F_5 M_5 families by Philip (1998). Out of the twelve okra varieties evaluated, Panchsira was the best performer with maximum yield (15.4 t/ ha) as well as fruits per plant (35.1) while Pusa Sawani also performed well (Dutta, 1999).

During a two year yield evaluation at Iran, Annie Oakley and Dashtestan were identified as the high yielding cultivars (Langaroodi and Kazerani, 1999). IC-39135, IC- 9856 and Punjab Padmini were the highest yielders among 48 okra types which varied for characters including nodes per plant, fruit weight and marketable fruit yield per plant (Sood, 1999).

Twenty two okra genotypes exhibited wide variation for plant height, days to flower, fruits per plant and yield (Hazra and Basu, 2000).Variation was moderate for fruit length and primary branches whereas low for node of first flower and ridges per fruit.

Philip *et al*. (2000) studied the variability in F_4 generation of irradiated interspecific hybrids in okra and observed significant variation for branches and fruits per plant, yield and incidence of YVM. Singh (2000) reported that Parbhani Kranti

produced the highest yield and pod weight besides being YVM resistant for all the three years tried.

In a comparative study conducted by Amjad *et al*. (2001) in Faisalabad, Pakistan involving four Indian cultivars viz., Pusa Sawani, Parbhani Kranti, Hybrid Bhindi Sakshi and Krisma -51, a local cultivar Sabz Pari excelled for earliness and yield of green pods. Green pod length was maximum in Hybrid Bhindi Sakshi (12-18 cm) which was on par with Sabz Pari (12-15 cm).

The study of 44 okra genotypes collected from NBPGR by Gandhi *et al*. (2001) revealed significant variability for all the thirteen traits under investigation including plant height, height at fruit set, internodal length, fruits and branches per plant, length and girth of fruits and yield per plant. Lal *et al*. (2001) assessed the response of three okra varieties to varying sowing dates under Tarai foot hills of Himalayas and obtained the highest green pod yield (85.9 q/ha) for Parbhani Kranti, followed by Pusa Sawani (8.4 q /ha) and P-7 (72.5 q/ ha), P-7 exhibited the lowest YVM virus infection (0.3 %) while Pusa Sawani showed the highest (41.4%).

Broad range of variation and high mean values were noticed in rainy season and in spring- summer season for fruit yield and plant height as reported by Dhankar and Dhankar (2002).

2.5 Coefficient of variation

High genotypic coefficient of variation coupled with high estimates of heritability and genetic advance for yield and yield components were observed by Rao (1972).

Majumdar *et al*. (1974) observed high magnitude of genotypic coefficient of variation for characters like yield per plant, number of fruits and weight of fruits per plant.

Thaker *et al*. (1981) noticed high GCV for plant height, fruit number, fruit weight and yield per plant. According to Balachandran (1984), number and yield of

fruits had high PCV and GCV while branches per plant exhibited high GCV. Reddy *et al*. (1985) recorded the highest GCV as well as PCV for fruit yield and plant height while high estimates of PCV and GCV were observed for plant height and fruit weight per plant by Mathews (1986). Estimates of GCV were high for plant height and yield per plant but moderate for number and length of pods noticed by Yadav (1986). As per reports of Balakrishnan and Balakrishnan (1990), fruits and yield per plant had high PCV and GCV.

Pods, branches and pod yield per plant were found to have high GCV compared to other characters studied (Vijay and Manohar, 1990). Jeyapandi and Balakrishnan (1992) reported high PCV for pod weight while along with pod number had high GCV also. Maximum and minimum GCV were observed for fruit weight per plant and days to first flower respectively (Bindu, 1993).

Damarany and Farag (1994) reported low coefficients of variation for all the twelve characters studied including plant height, earliness and yield per plant. High GCV was exhibited by fruit weight per plant, plant height, fruits per plant and branches per plant. High PCV was observed for fruits and yield per plant (Lakshmi *et al*., 1996).

John (1997) noticed high GCV for branches per plant in all the irradiated treatments in F_2M_2 and F_3M_3 generations and high to moderately high for fruits and fruit weight per plant in F_3M_3 generations of irradiated interspecific hybrids of okra.

According to Panda and Singh (1997), branches, pods and yield per plant showed high GCV and PCV. Rajani and Manju (1997) reported that PCV and GCV were the highest for fruit yield per plant but low for fruit girth, YVM incidence, days to first flower, first fruiting node and fruit length. PCV and GCV were high for branches and yield per plant where as low for plant height (Yassin and Anbu, 1997).

In the F_4 generation of interspecific hybrids between, *A. esculentus* and *A. manihot,* evaluated by Alex (1988) the genotypic coefficient of variation was maximum for number of branches per plant and minimum for first fruiting node.

Philip (1998) noticed high GCV and PCV for flower number and YVM disease. GCV was the highest for number of primary branches where as moderate for plant height, fruits and yield per plant (Hazra and Basu, 2000)

Dhankar and Dhankar (2002) noticed high PCV and GCV for branches, fruits, yield and plant height in both rainy and spring-summer seasons. For fruit yield and plant height, values of PCV and GCV were almost equal indicating the environment had little effect but days to first flower and fruits and branches per plant had some influence by environment. Moreover, PCV and GCV were higher for all the traits during rainy season than spring summer.

Sindhumole (2003) observed high PCV and GCV for most of the traits including yield and its major components. However GCV was moderate for fruit girth, ridges and seeds per fruit and leaf axil bearing first flower but low for plant duration and YVM incidence at 30 days after sowing.

2.6 Heritability and Genetic advance

Rao and Kulkarni (1977) concluded that estimates of heritability and genetic advance were highest for number of fruits per plant.

Genetic advance was maximum for plant height followed by fruit number, days to first flower and yield (Murthy and Bavaji, 1980). Moreover, maximum heritability (narrow sense) was recorded for days to flower followed by plant height and fruits per plant.

Phenotypic selection was suggested to be promising for pod number and yield due to their high heritability (Rao and Ramu, 1981). Thaker *et al.* (1981) noticed moderate heritability for plant height, fruit length and fruit number but low heritability for yield whereas all these trials except fruit number displayed high genetic advance. Among the various yield contributing factors, the highest estimates of both heritability and genetic advance were displayed by plant height as reported by Palaniveluchamy *et al.* (1982). High heritability was established by first fruiting node

(Parthap *et al.*, 1982). Scope for improving the traits viz., fruits, plant height and fruit length was indicated by their high estimates of heritability and genetic advance (Vashista *et al.*, 1982).

As per the reports of Balachandran (1984), heritability was high for branches per plant while both heritability and genetic advance were moderately low in the case of length and number of fruits. However plant yield displayed low estimates of heritability and genetic advance.

Reddy *et al.*, (1985) reported high heritability and genetic advance for plant height, branches and yield per plant while high heritability was reported by Alex (1988) for plant height and days to flower and by El- Macksoud *et al.* (1984) for earliness in flowering, fruits and fruit weight. Sheela (1986) recorded moderate to high heritability but low genetic advance for number and weight of fruits per plant and YVM disease.

Heritability estimates were high in F_2 than in F_1 for yield and some of its related characters except days to flower (Singh, 1986). Yadav (1986) reported high heritability for all the traits studied including plant height, pod length and yield per plant. Heritability was high for fruit girth and fruit weight (Sadashiva, 1988). High heritability of plant height, days to flowering and fruiting phase was recorded by Alex (1988).

Variability studies Balakrishnan and Balakrishnan (1990) revealed high heritability and genetic advance for fruit yield per plant. This suggested the efficiency of taking number of fruits per plant and fruit weight as reliable indices for improving yield in okra.

High heritability for branches per plant was recorded by Ariyo (1990) while Vijay and Manohar (1990) opined that plant height, branches per plant and ridges per pod had maximum high heritability and genetic advance over mean. High heritability and genetic advance were observed for number, length and weight of pods as well as yield per plant (Jeyapandi and Balakrishnan, 1992). Days to first flower and branches

per plant were highly influenced by environment as reported by (Patel and Dalal, 1992).

Among the eleven yield components studied, pods and primary branches per plant were associated with high genetic advance but medium heritability (Gondane and Lal, 1994). Meghwal and Khandelwal (1994) observed high heritability coupled with high genetic advance for the characters plant height, internodal distance, fruit weight and yield. Heritability as well as genetic advance was high for fruit weight per plant and plant height but low for YVM incidence as reported by Sheela (1994).

A study of eleven characters in okra revealed high heritability for all the traits except total pods per plant (Patil, 1995). However, the values of genetic advance revealed that real progress in improvement of characters could be made only for weight of marketable fruits and plant height.

Bindhu *et al.* (1997) reported that fruit length, fruit weight per plant and plant height established high heritability coupled with moderately high genetic advance. Moderate heritability and low genetic advance were noticed for fruit girth. High heritability and genetic advance were noticed for branches per plant in F_2M_2 generation and for fruits and fruit weight per plant in F_3M_3 generation of irradiated interspecific hybrids (John, 1997).

Yield per plant had high estimates of heritability and genetic advance (Rajani and Manju, 1997). High heritability but low genetic advance was observed for branches and first fruiting node. Estimates of heritability were moderate to high for yield per plant, plant height and YVM incidence and low for fruits per plant. According to Yassin and Anbu (1997), plant height, branches, fruit and yield per plant displayed high heritability whereas genetic advance (as % of mean) was maximum for branches per plant followed by fruits and yield per plant. Low values were observed for both heritability and genetic advance for plant height.

Philip (1998) noticed maximum GCV and PCV for flowers per plant followed by YVM incidence and branches per plant where as maximum for days to first flower

in F_4M_4 generation. The highest GCV and PCV were observed for YVM incidence while the lowest value was for plant duration followed by fruit girth and days to first flower.

Gandhi *et al.* (2001) observed medium to high heritability for all characters of which fruit length (64.4 %) and fruit girth (43.60 %) were the highest. However these grains were coupled with varied genetic advance i.e, high, medium and low respectively suggesting the complexity of genetic mechanism in the expression of these characters.

High heritability coupled with genetic advance was displayed by all the characters except days to 50 per cent flower in spring summer season (Dhankar and Dhankar, 2002).

More or less equal influence of genetic and environmental factors in the case of pollen sterility, plant duration and YVM incidence was evident from their moderate heritability (Sindhumole, 2003). However in view of Philip (1998) all these traits possessed high heritability.

Sindhumole (2003) also observed high values of heritability in the characters studied including yield and its major components viz., days to first flower, leaf area, fruits per plant, average fruit weight, fruit length, fruit girth, fruit colour, fruit pubescence and ridges per pod indicating the prominence of genetic component and low environmental influence on these characters. She observed high genetic advance for fruit yield per plant which clearly indicates the additive gene action involved in this trait which makes the selection highly effective.

2.7 Correlation analysis in okra

Several studies with regard to yield and yield components in okra have been done in the past to identify the effect of yield contributing characters.

The yield of okra was directly correlated with the length and girth of the fruit and number of fruits per plant (Kohle and Chavan, 1967).

Thamburaj and Kamalanathan (1973) reported significant positive correlation between yield, fruit weight and total number of nodes per plant. Majumdar *et al.* (1974) observed negative correlation between yield and days to flowering.

Rao *et al.* (1977) concluded that the number of fruits per plant, branches per plant, plant height and fruit length were the important yield components in okra. Rao and Kulkarni (1977) observed significant positive correlation between plant height and number of pods per plant.

Arumugham and Muthukrishnan (1979) reported that there was significant association between YVM disease reaction and plant height, number of branches, days to flowering, fruit length and girth, number of seeds per fruit and number of fruits per plant which limited the scope for selection for resistance in the F_3, F_4 and backcross generation of interspecific crosses between *Abelmoschus esculentus* and *Abelmoschus manihot*.

Yield had a positive correlation with plant height, number of fruits per plant, number of fruits per plant and fruit length (Mahajan and Sharma, 1979). Parthap *et al.* (1979) considered stem diameter, number of flowers per plant, pods per plant and plant height as the primary yield determining components and should be given major emphasis while practicing selections.

Number of branches and fruit traits viz., number, length and width could be considered as the primary yield determining components in okra (Elangovan *et al.*, 1980). Genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients as reported by Murthy and Bavaji (1980).

Fruit yield was highly correlated with number and length of fruits but only to a lower degree with plant height and days to flower (Arumugham and Muthukrishnan, 1981). Parthap *et al.* (1982) observed a direct positive contribution of fruit number towards yield. Vashista *et al.* (1982) noticed that yield in bhindi depended primarily on plant height, fruit number and fruit length.

Important yield contributing characters were number and length of fruits, earliness and flowering duration (Balachandran, 1984). On noticing positive correlation for plant height with length and width of fruits, El- Macksoud *et al.* (1984) concluded that selection for short stature could lead to yield reduction. They also observed positive association for late flowering with more and larger fruits. Due to the existence of positive association between fruit number and yield, selection of either fruit number alone and or in combination with plant height may improve the yield, as suggested by Korla *et al.* (1984).

According to Mishra and Singh (1985), yield was positively correlated with plant height, nodes and length, number and weight of fruits among which higher direct effects were observed for fruit weight and fruit number while Reddy *et al.* (1985) observed significant direct effect on yield by plant height.

Alex (1988) observed positive correlation for yield with number, length and weight of fruits per plant. In all the three generations studied, major contributing yield traits were plant height, earliness, flowers and fruits (Mathews, 1986). She reported that up to F_2 generation of interspecific hybrids of *Abelmoschus*, number of fruits per plant, number of flowers per plant, plant height and earliness to flower were the major yield components. Significant positive association of YVM disease intensity with number of branches per plant and length of fruits were revealed in the study. Negative association was reported between the intensity of mosaic incidence and days to flowering.

Correlation studies revealed that fruits, length and girth were the important contributing characters towards yield (Sheela, 1986).

Yadav (1986) noticed positive correlation of plant height, pod length and pod number with yield.

Correlation coefficients for yield per plant were calculated among fifteen characters using 30 okra genotypes by Ariyo *et al.* (1987) yield, mature pod length and branch number phenotypically with edible pod length and branches per plant and

environmentally with length and weight of edible pods and plant height. Although edible pod weight was the best index of yield, since it can not be assessed visually in the field, edible pod width was suggested as better criterion for selection in view of its close association with pod weight. The directly influencing traits of yield were plant height , branches, fruit length and fruits per plant (Kale *et al.*, 1989).

According to Balakrishnan and Balakrishnan (1990) number and weight of fruits were the direct and positive contributory factors on yield due to their high direct effects. Yield correlations were derived from the data on eleven component traits in eighteen families from their crosses involving four parents by Jeyapandi and Balakrishnan (1990). Mishra *et al.* (1990) reported that the positive association of yield with plant height and number, length and height of pods. Days to flower, nodes, fruits and average fruit weights had high contributions towards yield (Shukla, 1990) Veeraraghavathatham and Irulappan (1990) unveiled the positive association of yield with internodal length and number and girth of fruits. In 55 okra genotypes, correlation coefficients of fourteen yield traits were estimated by Vijay and Manohar (1990).

Ariyo (1992) suggested number and weight of pods as the major yield components. Positive association of fruit yield with plant height, number of fruits, length and diameter of fruits and days of maturity was noticed by Fageria *et al.* (1992). Among the eighteen component characters studied, positive association with green fruit yield per plant was noticed for plant height and fruit characters viz., number, length, girth and weight of fruits (Mishra and Singh, 1992). Sivagamasundhari *et al.* (1992) reported that the number of pods per plant, pod weight, pod girth, pod length and Internodal length should be considered together as primary yield components in okra.

Bindhu (1993) reported that yield per plant had positive genotypic correlation with fruits and branches per plant. She further suggested that the model for selection of high yielding okra varieties should be based on the number of fruits and branches

owing to their high direct influence of yield. Plant height displayed significant correlation with node at first fruit, days to first flower and internodal length (Patel *et al.*, 1993).

According to Sheela (1994), branches per plant and fruit girth could be considered as the major characters contributing to yield in okra. Fruit number displayed maximum positive and negative direct effects on yield were as with regard to YVM incidence, maximum positive and negative direct effects were recorded for branch number and single fruit weight respectively. Selection of early flowering types with increased fruit weight was suggested for enhancing the level of YVM resistance.

Fruit yield per plant showed positive correlation with branches per plant and fruit attributes, viz., length and girth (Das and Mishra, 1995). A study involving 50 genotypes to assess the interrelationships among eleven characters revealed pod number and weight of edible pods as the most important traits contributing towards yield (Gondane *et al.*, 1995).

Lakshmi *et al.* (1996) reported the positive association of yield with nodes, branches and fruits per plant. Moreover high direct effects were exerted by nodes, pods and pod weight on yield.

John (1997) analyzed correlation in F_2M_2 and F_3M_3 generations of gamma irradiated interspecific crosses between *A. esculentus* var. Kiran and generations. Positive association was noticed for weight of fruits per plant, fruits per plant and also between number of fruits and branches. Fruit yield per plant at 30 kR was associated positively with plant duration. Average fruit weight exhibited negative correlation with fruits per plant in the treatment with 20 kR and 30 kR in F_2M_2 generation and in all the treatments in F_4M_4 generation.

As per the reports of Philip (1998), fruit yield per plant displayed positive association with plant height, branches and fruits per plant in both F_4M_4 and F_5M_5 generations of irradiated interspecific hybrids between *A. esculentus* and *A. manihot*.

Based on the association, analysis conducted in F_1 hybrids of okra, Indurani (1999) reported a strong positive association between number and yield of fruits per plant. Marketable yield per plant, fruit weight, fruit length, fruits per plant and plant height exhibited positively significant correlation as well as high direct effect with total yield per plant (Dhall *et al*. 2000).

Correlation analysis using 62 inbred lines during rainy and spring- summer seasons revealed that during both seasons, fruit yield was associated positively with fruits and branches per plant and plant height while fruits per plant was correlated positively with branches per plant and negatively with days to 50 per cent flower (Dhankar and Dhankar, 2002). Maximum direct effect on yield was exerted by plant height and branches per plant. The researchers suggested the selection of plants with more number of fruits, branches and medium plant height for improving the yield.

Correlation analysis of nineteen traits in the F_5 M_5 generation of interspecific hybrids of okra revealed the positive significant correlation of yield per plant with branches, fruits per plant, average fruit weight and plant height (Philip and Manju, 2002).

Sindhumole (2003) observed that most of the character combinations had higher genotypic correlation coefficients than phenotypic, though both had the same direction. Fruit yield displayed positive genotypic association with, fruits per plant, average fruit weight, fruit length, fruit girth and crop duration and negative correlation with days to first flower, pollen sterility and incidence of YVM.

Jaiprakashnarayan and Mulge (2004) showed that total yield per plant was positively and significantly correlated with number of fruits per plant, average fruit weight, number of nodes on main stem, fruit length, plant height at 60 and 100 days after sowing and number of leaves on 45 and 100 days after sowing, where as total yield per plant had negative and significant association with number of locules per fruit, number of nodes at first flowering and first fruiting.

According to Singh and Singh (2006) the fruit yield per plant had highly positive association with fruit length , tapering length , plant height, fruits per plant , width of the fruit where as days to first flower and first fruiting node were negatively correlated with fruit yield per plant. Therefore, the positively associated characters could be used for increased yield by selecting early flowering types.

Dakahe *et al*. (2007) found that for increasing green fruit yield in okra due emphasis should be given to number of fruits, number of internodes, plant height and fruit length. All these characters had high heritability and highly significant positive association with fruit yield, which can be increased through selection in okra.

Materials and Methods

3. MATERIALS AND METHODS

This research work was conducted in the vegetable research farm of the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur. The experimental site is located at an altitude of 22.5m above MSL. The research farm experiences a typical warm humid tropical climate. The experiment was conducted in two seasons, April to September 2007 and October '07 to February '08. The weather data during the period of investigation is presented in the Appendix.1.

The investigations were carried out under the following heads,

A. Evaluation of the F_4 generation selections for the selection of desirable segregants
B. Evaluation of F_5 generation out of the selection from the F_4 generation.
C. Screening for resistance to YVMV

MATERIALS

The present study was carried out as a continuation of the research work (Kousalya, 2005) undertaken in the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, which accomplished an interspecific hybridization between *Abelmoschus caillei* variety Susthira (a semi wild yellow vein mosaic resistant species) (Plate1) and *Abelmoschus esculentus* variety Salkeerthi (a high yielding, widely adapted, but YVMV susceptible variety (Plate2). The F_1, F_2, and F_3 generations were genetically evaluated and the superior recombinants were isolated in the previous studies.

The seeds of selected selfed F_3 population generated the F_4 population needed for the present study. Superior segregants from the F_4 generation were selected on the

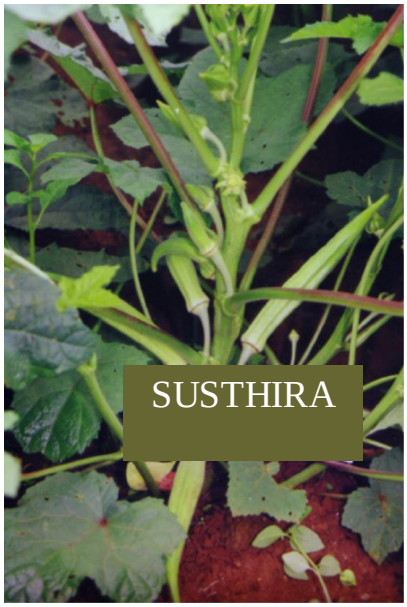


Plate 1. *Abelmoschus caillei* variety Susthira

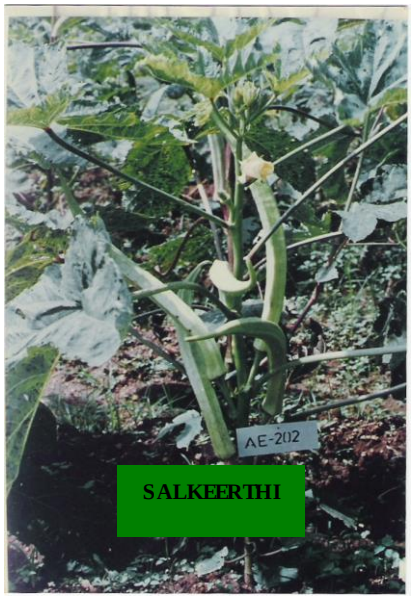


Plate 2. *Abelmoschus esculentus* variety Salkeerthi

basis of plant morphology, fruit characters, fruit yield, pollen fertility and field resistance to yellow vein mosaic virus disease. The selfed seeds obtained from the selected F_4 plants were used to rise the F_5 generation. These generations were genetically evaluated along with the parents. The source of materials used in the study is given in the Table 1.

METHODS

3.1 Evaluation of the F_4 generation selections

Fourteen F_4 selections along with their parents were evaluated during April to September (2007) in a Randomized Completely Block Design (RCBD) with two replications. The spacing adopted was 60 cm x 45 cm. Eight plants were raised in each selection in each replication in the plot size of 86.4m^2. Highly susceptible okra line (AE-202) was raised all around the field. The treatments received timely management and care as per the package of practice recommendation of KAU 2006. Five plants selected at random from each treatment were used to take observations. No plant protection measures were taken up as it would reduce the vector population and thereby hinder the natural epiphytotic condition for Yellow Vein Mosaic Disease.

3.2 Evaluation of the F_5 generation selections

Seven F_5 selections along with their parents were evaluated during October 2007 to February 2008 in a Randomized Completely Block Design (RCBD) with three replications. The spacing adopted was 60 cm x 45 cm. Ten plants were raised in each selection in each replication in the plot size of 100m^2. Five plants selected at random from each treatment were used to take observations. All other practices were adopted as mentioned above.

Table 1. Source of materials used for the study

Sl. No	Variety/selection used	Species/others	Mode of evolution /parents	Reaction to YVMV	Evolved from
1.	Salkeerthi (P2)* (T1)	*A. esculentus*	Pure line Selection	Susceptible	Department of Olericulture COH Vellanikkara
2.	Susthira (P1)* (T16)	*A. caillei*	Pure line Selection	Resistant	„
3.	F_4 -1 (T2)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„
4.	F_4 -2 (T3)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„
5.	F_4 -3 (T4)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„
6.	F_4 -4 (T5)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„
7.	F_4 -5 (T6)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„
8.	F_4 -6 (T7)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„
9.	F_4 -7 (T8)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„
10.	F_4 -8 (T9)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„
11.	F_4 -9 (T10)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„
12.	F_4 -10 (T11)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„
13.	F_4 -11 (T12)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„
14.	F_4 -12 (T13)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„
15.	F_4 -13 (T14)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„
16.	F_4 -14 (T15)	Interspecific hybrid derivative	Susthira x Salkeerthi	To be tested	„

P1* - Female parent

P2* - Male parent

3.3 Biometrical observations recorded

All the observation plants were tagged individually in each replication and their morphological characters were noted separately in the F_4 and F_5 generations. The following observations were recorded and analyzed statistically.

3.3.1 Qualitative characters:

1. Plant characters
    a. Plant habit : Branched or unbranched
2. Leaf characters
    a. Leaf lobing : Deeply lobed/narrowly lobed/serrated
    b. Colour of leaf base : Green /green with red tinge/red with green tinge
    c. Colour of leaf vein : Green/whitish green
3. Flower characters
    a. Flower colour : Yellow/golden yellow
    b. Flower size : Small/medium/large
    c. Nature of corolla : Red throat/purple throat
4. Fruit characters
    a. Colour of fruit : Green/dark green/yellowish green/red/ deep red / others
    b. Pod pubescence : Smooth/less pubescent/ highly pubescent

Leaf characters like leaf lobing, colour of leaf base and the colour of the leaf vein were recorded from seventh leaf of each observation plant. Flower characters such as flower colour, flower size and nature of corolla were noted at the time of anthesis. Fruit characters such as fruit colour and fruit pubescence were recorded at the time of harvest.

3.3.2 Quantitative characters

1. Plant height (cm)

   The height of the plant was measured from the base of the plant to tip at 100 days after sowing.

2. Internodal length (cm)

   The length of the internode between sixth and seventh node of the plant was measured at 100 days after sowing.

3. Number of primary branches

   The number of primary branches was counted at 60 days after sowing .

4. Length of epicalyx segment

   Length of epicalyx segment of the ripe flower bud was recorded at 60 days after sowing.

5. Width of epicalyx segment

   Width of epicalyx segment of the ripe flower bud was recorded at 60 days after sowing.

6. Petiole length (cm)

   Length of petiole of the seventh leaf was recorded at 60 days after sowing.

7. Days to flower

   In each observation plant date of opening of the first flower was recorded and the number of days from sowing to flowering was worked out.

8. Days to first harvest

   The number of days taken to harvest the first fruit was noted and expressed in numbers.

9. First fruiting node

   The node at which first fruit was formed was noted and expressed in numbers.

10. Length of fruit (cm)

    Three fruits were harvested from each plant tagged for observation at seven days after flowering and the fruit length was measured from basal cap to the tip of the fruit

11. Girth of fruit (cm)

    Three fruits were harvested from each plant at seven days after flowering and the circumference of the fruit was recorded at the point of maximum bulging.

12. Locules per pod

    Three fruits were harvested from each plant at seven days after flowering and the number of locules per pod was recorded by taking cross section of the pod.

13. Number of ridges per pod

    The number of ridges per pod of each plant was noted.

14. Number of fruits per plant

    Total number of fruits borne on the plants was recorded

15. Number of harvests

    Total number of harvests was recorded from first to final harvest.

16. Crop duration

    Time taken for last harvest from sowing was done separately.

17. Yield per plant

    Weight of fruits harvested from the observation plants in each segregant was taken and their average was taken to get yield per plant.

18. Incidence of other pests and diseases

Incidence of other pests and diseases such as shoot and fruit borer, *Cercospora* leaf spot, jassids etc., were recorded.

3.4 Statistical analysis

The observations taken from the experimental plants were tabulated and subjected to statistical analysis.

3.4.1 Analysis of variance

Analysis of variance for Randomized Block Design was carried out for comparison among different treatments and replications and to estimate variance components.

3.4.2 Estimation of variability components

The phenotypic and genotypic components of variance for each character were estimated by equating the expected value of mean squares (MS) to the respective variance components (Jain, 1982).

3.4.2.1 Phenotypic variance ($V_{(P)}$)

$V_{(P)} = V_{(G)} + V_{(E)}$

Where $V_{(G)}$ = Genotypic variance

$V_{(E)}$ = Environmental variance estimated as mean square due to error

3.4.2.2 Genotypic variance(($V_{(G)}$)

$$V_{(G)} = \frac{\text{Mean square (treatment) - Mean square (error)}}{\text{Number of replications}}$$

The phenotypic and genotypic coefficients of variation were worked out for each character by making use of the estimates of $V_{(P)}$ and $V_{(G)}$ and were expressed in percentage.

3.4.2.3 Phenotypic coefficient of variance (PCV)

$$PCV = \frac{\sqrt{V_{(P)}}}{Mean} \times 100$$

3.4.2.4 Genotypic coefficient of variance (GCV)

$$GCV = \frac{\sqrt{V_{(G)}}}{Mean} \times 100$$

In all cases, the mean of a character was calculated over all the treatments.

3.4.3 Estimation of heritability

The heritability (in broad sense) for each character was worked out as the ratio of genotypic variance to the phenotypic variance and was expressed as percentage (Jain, 1982).

$$\text{Heritability (h2)} = \frac{V_{(G)}}{V_{(P)}} \times 100$$

3.4.4 Estimation of genetic advance

The expected genetic improvement by selection was proportional to the product of heritability and phenotypic standard deviation (Allard, 1960).

Genetic advance (GA) = $k.h^2 \sqrt{V_{(P)}}$

Where, 'k' is the standardized selection differential, usually taken as 2.06 (at 5% selection) in large samples.

3.4.5 Correlation

The analysis of covariance was done between each pair of observations and the correlations were computed. The phenotypic correlation coefficient between two characters x and y was estimated as γp (x,y)

$$\gamma p\,(x,y) = \frac{Cov(p)\,(x,y)}{\sqrt{V_{(P)}\,x \;x\; V_{(P)}\,y}}$$

Where $Cov_{(P)}$ (x,y) denote the phenotypic covariance between the characters x and y estimated by taking the respective expected values of mean sum of products. $V_{(P)}\,x$ and $V_{(P)}\,y$ indicate the estimated phenotypic variances for x and y respectively.

The genotypic correlation coefficient between the characters x and y were estimated in the similar manner, replacing the phenotypic covariance by the genotypic covariance between the two characters and the phenotypic variances by the genotypic variances.

$$\gamma_G\,(x,y) = \frac{Cov(G)\,(x,y)}{\sqrt{V_{(G)}\,x \;x\; V_{(G)}\,y}}$$

3.5 Screening for resistance to YVMV

The parental species, F_4 and F_5 generation plants were subjected to different screening techniques to assess their reaction to YVMV.

3.5.1 Field Screening

The desirable segregants of F_4 and F_5 generations were selected for testing resistance to YVMV by providing sufficient amount of virus inoculum by planting highly susceptible check (AE-202) around the field. Observations on disease incidence and disease severity were recorded.

Observations on disease incidence and disease severity were recorded as per the standard methods. Disease severity was scored using 0-5 scale as suggested by Deo *et al*. (2000).

Grade	Per cent leaves infected
0	Symptom absent
1	< 25
2	25-50
3	51-75
4	76-90
5	> 90

Per cent Disease Incidence (PDI) was calculated using the formula given below,

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

Per cent Disease Severity (PDS) was calculated using the formula given below,

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

Based on the per cent disease incidence and severity, coefficient of infection (CI) was calculated as suggested by Datar and Mayee (1981)

$$CI = \frac{\text{Per cent disease incidence} \times \text{Per cent disease severity}}{100}$$

Based on the CI the genotypes were categorized into six categories as shown below,

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)

3.5.2 Artificial inoculation of virus

Artificial inoculation of YVMV was done through grafting techniques. The method suggested by Kapoor and Varma (1950) was followed to confirm the level of resistance to YVMV in the selected treatment segregants.

The promising segregants which were found to be resistant in the field screening were subjected to artificial inoculation by grafting. In this method healthy

resistant segregants were grafted with highly disease susceptible line (AE 202) raised in polybags by approach grafting. Nearly one month old seedlings were selected for grafting.

The grafted portions were tied with polythene tape. The complete graft union occurred within a month. The daily observations were taken for about a month for symptom expression in resistant genotypes.

3.6 Pollen fertility studies

To study the pollen fertility in the F_4 and F_5 generation plants, pollen grains were collected from flowers within half to one hour after anthesis. Pollen grains were dusted on a clean slide using a camel hair brush and a drop of one per cent acetocarmine stain was added to it. It was kept for five minutes for staining then covered with a cover slip and observed under a microscope at different fields. In each field, the numbers of stained and unstained pollen grains were noted. The pollen fertility per cent was assessed by calculating the mean stained and unstained pollen grains.

Results

4. RESULTS

The data collected from the evaluation of F_4 and F_5 generations along with the parental varieties were tabulated and subjected to statistical analysis. The results obtained are presented below.

4.1 Evaluation of F_4 generation

4.1.1 Qualitative characters

Leaf margin was deeply fid in *A.esculentus* but that in *A.caillei* and most of the segregants were narrowly fid. Flower colour was yellow in both the parents and segregants. Flower size was medium in both the parental species where as segregants had large, medium and small sized flowers. Both parents and segregants had purple throat at base of corolla and inside. Colour of leaf vein was green with purple tinge. Colour of fruit was light green in *A.esculentus* whereas that in *A.caillei* was green. Segregants produced green, light green and dark green fruits. Pod pubescence was absent in both the parents but the segregants were slightly pubescent (Table 2). The variability expressed by the F_4 generation for pod size and shape is shown in the Plate 3.

4.1.2 Quantitative characters

The mean values for the 17 characters relating to different treatments are given in Table 3. The analysis of variance for the 17 characters studied in the F_4 generation which was used to compare the performance among the different families and with both the parents are presented in Table 4.

Height of the plant varied significantly among the different families and with the two parents. The mean values ranged from 125.44 cm in T1 (P2) to 161.07 cm in T15. Significant differences were observed for internodal length with the wild parent, P1 (T16). The mean values for the character ranged from 7.89 cm in T16 to 12.21 cm in T1.

Plate 3a. Variability in fruit shape and size in the F_4 segregants

Plate 3b. L.S.of fruits of F_4 segregants

Table 2. Comparison of qualitative characters of parental species and F_4 segregants

Sl.No.	Characters	*A.esculentus*	*A.caillei*	Segregants
1	Leaf margin	Deeply fid	Narrowly fid	Narrowly fid
2	Flower colour	Yellow	Yellow	Yellow
3	Flower size	Medium	Medium	Large, medium and Small
4	Purple throat at base of corolla	Present inside	Present inside	Present inside
5	Colour of leaf vein	Green with purple tinge	Green with purple tinge	Green with purple tinge
6	Colour of fruit	Light green	Green	Green, Light green and Dark green
7	Pod pubescence	Absent	Absent	Slightly pubescent

Table 3. Mean values for the different quantitative characters in F_4 generation

Treatments	Plant Height (cm)	Internodal length (cm)	No. of primary branches	Length of epicalyx segment (cm)	Width of epicalyx segment (cm)	Petiole length (cm)	Days to flower	Days to first harvest
	1	2	3	4	5	6	7	8
T1(P2)*	125.44	12.21	3.25	2.29	0.51	30.36	39.50	45.50
T2	139.07	8.34	2.75	1.85	0.63	34.75	53.19	59.19
T3	151.50	10.67	3.07	1.80	0.59	36.50	53.07	59.07
T4	149.94	9.95	3.32	2.18	0.62	35.00	53.19	59.19
T5	147.32	10.15	3.12	2.14	0.90	35.26	54.13	60.13
T6	137.07	9.30	2.88	1.84	0.72	36.07	53.07	59.07
T7	145.75	9.76	3.00	2.24	0.58	34.83	53.88	59.88
T8	149.51	10.49	3.01	2.16	0.67	35.88	52.51	58.51
T9	149.13	10.14	3.12	2.41	0.66	36.35	51.63	57.63
T10	150.32	9.94	3.50	2.07	0.61	36.68	53.44	59.44
T11	141.44	9.33	3.19	2.38	0.87	35.03	52.38	58.38
T12	152.44	9.88	3.01	1.74	0.97	35.43	53.07	59.07
T13	151.13	8.97	3.13	2.15	0.50	35.81	52.63	58.63
T14	157.75	10.76	3.38	2.10	0.76	35.94	54.32	60.32
T15	161.07	10.87	3.51	2.12	0.60	36.14	52.44	58.44
T16 (P1)*	142.75	7.89	3.06	1.31	1.14	34.63	46.56	52.56
CD	16.62	2.77	0.49	0.60	0.34	1.68	2.41	2.41
SE	7.80	1.30	0.23	0.28	0.16	0.79	1.13	1.13

*P1: Parent 1 (*A.caillei*)

*P2: Parent 2 (*A.esculentus*)

Table 3. Continued ..

Treatments	First fruiting node	Length of fruit (cm)	Girth of fruit (cm)	Locules per pod	No. of fruits per plant	No.of ridges per pod	Crop duration (days)	Yield per plant (g)	Pollen sterility (%)
	9	10	11	12	13	14	15	16	17
T1	4.44	27.66	7.47	5.00	15.00	5.00	167.81	190.15	1.60
T2	6.00	19.81	8.13	5.94	12.01	5.94	166.94	179.93	14.25
T3	5.88	16.57	8.00	6.00	11.88	6.00	166.69	176.44	11.65
T4	5.63	16.78	7.93	6.07	11.32	6.07	166.51	176.02	13.50
T5	6.07	20.00	8.07	6.07	10.69	6.00	164.50	178.71	8.80
T6	6.01	17.69	7.86	5.82	11.00	5.82	165.63	176.57	6.65
T7	5.82	17.93	8.06	5.88	11.13	5.82	165.32	177.12	11.30
T8	6.01	20.20	8.07	5.94	11.62	5.94	166.57	179.90	6.35
T9	6.00	11.11	7.73	5.94	11.19	5.88	165.63	169.77	8.50
T10	5.69	18.66	7.80	6.00	11.19	6.00	165.69	177.64	9.85
T11	5.88	9.48	7.61	6.07	9.62	5.94	162.44	166.97	7.50
T12	5.63	19.83	7.65	5.88	10.51	5.88	163.63	177.98	6.10
T13	6.00	20.06	8.14	5.88	12.44	5.88	167.75	186.20	8.45
T14	5.82	18.33	7.93	5.88	10.75	5.88	164.32	176.49	9.35
T15	6.07	19.52	7.91	5.75	12.00	5.75	166.38	179.39	10.75
T16	5.94	16.87	8.38	6.12	12.06	6.00	171.88	177.32	1.95
CD	0.51	2.13	0.55	0.18	2.13	0.21	4.69	3.84	7.67
SE	0.24	1.00	0.26	0.08	1.00	0.10	2.20	1.80	3.60

Table 4. ANOVA (mean squares) for the different quantitative characters in the F_4 generation

Sl. No	Characters	Treatments	P1 vs Families	P2 vs Families	Error
		df = 15	df = 1	df = 1	df = 15
1	Plant Height (cm)	145.00**	543.71**	36.62**	60.92
2	Internodal length (cm)	2.15	5.33	4.00**	1.75
3	Number of primary branches	0.09	0.01	0.01	0.06
4	Length of epicalyx segment (cm)	0.15	0.04	0.60	0.08
5	Width of epicalyx segment (cm)	0.06	0.03	0.20	0.02
6	Petiole length (cm)	4.30**	28.27	1.11**	0.52
7	Days to flower	27.74**	183.15**	42.13**	1.29
8	Days to first harvest	27.74**	183.15**	42.13**	1.29
9	First fruiting node	0.30	2.10	0.00	0.06
10	Length of fruit (cm)	32.06**	101.30**	0.49	1.07
11	Girth of fruit (cm)	0.11	0.20	0.21	0.07
12	Locules per pod	0.13	0.87	0.03**	0.01
13	No. of fruits per plant	2.72*	14.07	0.67	1.10
14	No.of ridges per pod	0.11	0.83	0.01	0.01
15	Crop duration (days)	8.92**	39.60	4.99	4.84
16	Yield per plant (g)	56.77**	169.93*	0.06	3.17
17	Pollen sterility (%)	25.17**	62.09*	56.71*	13.29

* Significant at 5 % level

** Significant at 1 % level

Petiole length revealed high significant differences between the families and with the parent, P2. The mean values for the character ranged from 30.36 cm in T1 to 36.68 cm in T10.

High significant differences were present among the families and with both the parents for days to first flowering. The mean values for the character ranged from 39.5 in T1 to 54.32 in T14.

Days to first harvest revealed significant differences among the families and with the two parents. The maximum and minimum mean values for the character were recorded in T14 (60.32) and T1 (45.5) respectively.

Length of fruit varied significantly between the families and with the parent, P2. The means ranged from 9.48 cm in T11 to 27.66 cm in TI.

Significant differences were observed for number of locules per pod with the parent, P2. The mean values ranged from 5.00 in T1 to 6.12 in T16. T11 and T12 were on par with T1.

Number of fruits per plant varied significantly among the families. The maximum and minimum values for the character were recorded as 15 in T1 and 9.62 in T11 respectively.

Significant differences were observed for duration of the crop among the families. The mean values ranged from 162.44 days in T11 to 171.88 days in parent P2.

Yield per plant exhibited high significant differences among the families. Yield was maximum for parent, P2 (190.15 g), which was on par with T13 and minimum for T11 (166.97 g).

The differences in pollen sterility (%) among the families were highly significant. With both the parents, the differences were significant. The mean values for pollen sterility ranged from 1.6 in parent, P2 to 14.25 in T2. Parent P1 was on par with parent P2 in pollen sterility.

4.2 Genetic parameters in F_4 generation

The genetic parameters, viz., the phenotypic and genotypic coefficients of variation, heritability and genetic advance for each character under study in the F_4 generation were estimated and are presented in Table 5.

4.2.1 Phenotypic and genotypic coefficients of variation

The maximum value for phenotypic coefficient of variation was recorded for pollen sterility (51.39) followed by width of epicalyx segment (29.53), length of fruit (22.42) and length of epicalyx segment (16.86) (Fig 1).

The phenotypic coefficient of variation was minimum for duration of crop (1.58) followed by yield per plant (3.08), girth of fruit (3.73) and number of ridges per pod (4.33).

The maximum value for genotypic coefficient of variation was recorded for pollen sterility (28.56) followed by length of fruit (21.68), width of epicalyx segment (19.32) and length of epicalyx segment (9.67).

The genotypic coefficient of variation was minimum for duration of crop (0.86) followed by girth of fruit (1.75), yield per plant (2.9) and petiole length (3.85).

4.2.2 Heritability and genetic advance

Majority of the characters exhibited very high heritability, the minimum being 0.68 for first fruiting node. The heritability value was maximum for fruit length (93.5),followed by days to first flowering (91.1), days to first harvest (91.1),locules per pod (89.9), yield per plant (89.4) and number of ridges per pod (85.4)(Fig 2).

Maximum genetic advance was exhibited by yield per plant (10.08) followed by plant height (8.54) and length of fruit (7.84). The genetic advance was minimum for the character, number of primary branches (0.12) followed by girth of fruit (0.13), width of epicalyx segment(0.18) and length of epicalyx segment (0.23).

Table 5. Genetic parameters for the different quantitative characters in F_4 generation

Sl. No	Characters	PCV	GCV	Heritability	Genetic advance
1	Plant height (cm)	6.91	4.41	40.80	8.54
2	Internodal length (cm)	14.10	4.54	10.40	0.30
3	Number of primary branches	8.52	4.00	22.10	0.12
4	Length of epicalyx segment (cm)	16.86	9.67	32.90	0.23
5	Width of epicalyx segment (cm)	29.53	19.32	42.80	0.18
6	Petiole length (cm)	4.45	3.85	74.80	2.42
7	Days to flower	7.35	7.02	91.10	7.15
8	Days to first harvest	6.59	6.29	91.10	7.15
9	First fruiting node	7.36	6.08	0.68	0.60
10	Length of fruit (cm)	22.42	21.68	93.50	7.84
11	Girth of fruit (cm)	3.73	1.75	22.00	0.13
12	Locules per pod	4.49	4.26	89.90	0.49
13	Number of fruits per plant	12.01	7.80	42.20	1.20
14	Number of ridges per pod	4.33	4.00	85.40	0.45
15	Crop duration (days)	1.58	0.86	29.60	1.60
16	Yield per plant (g)	3.08	2.91	89.40	10.08
17	Pollen sterility (%)	51.39	28.56	30.90	2.79

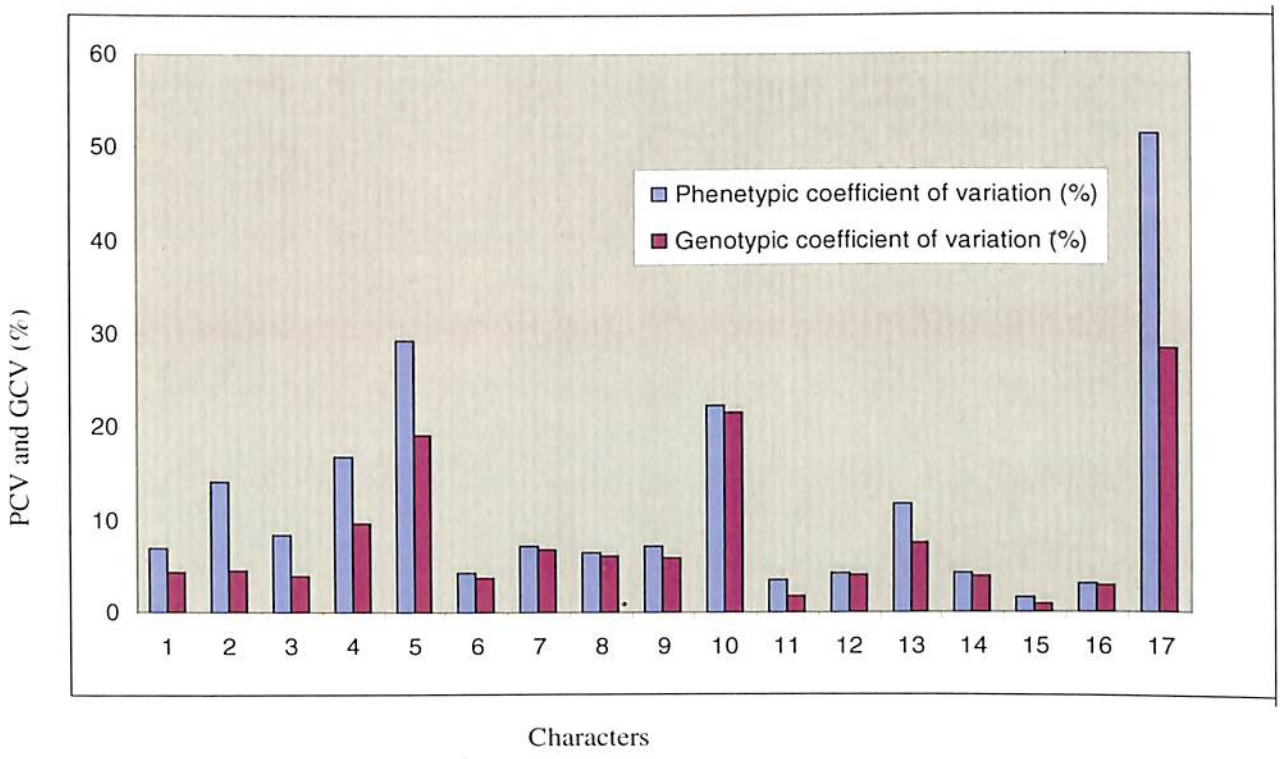


Fig.1. Phenotypic and genotypic coefficients of variation for characters in the F_4 generation

1. Plant height (cm)
2. Internodal length (cm)
3. No. of primary branches
4. Length of epicalyx segment (cm)
5. Width of epicalyx segment (cm)
6. Petiole length (cm)
7. Days to flower
8. Days to first harvest
9. First fruiting node
10. Length of fruit (cm)
11. Girth of fruit (cm)
12. Locules per pod
13. No. of fruits per plant
14. No.of ridges per pod
15. Crop duration (days)
16. Yield per plant (g)
17. Pollen sterility (%)

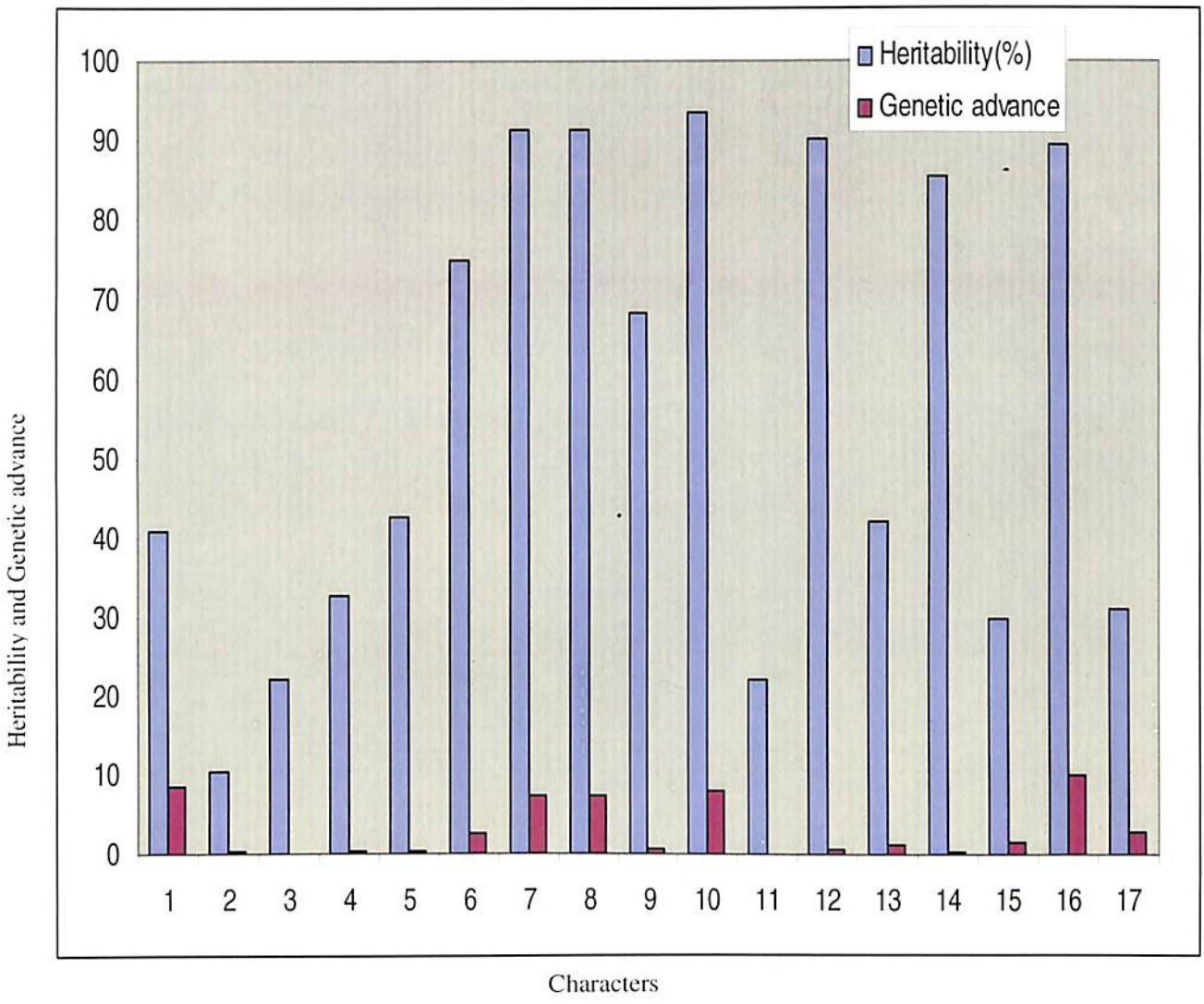


Fig. 2. Heritability and genetic advance for characters in the F_4 generation

1. Plant Height (cm)
2. Internodal length (cm)
3. No. of primary branches
4. Length of epicalyx segment (cm)
5. Width of epicalyx segment (cm)
6. Petiole length (cm)
7. Days to flower
8. Days to first harvest
9. First fruiting node
10. Length of fruit (cm)
11. Girth of fruit (cm)
12. Locules per pod
13. No. of fruits per plant
14. No.of ridges per pod
15. Crop duration (days)
16. Yield per plant (g)
17. Pollen sterility (%)

4.3 Correlation in F_4 generation

The data relating to the characters studied in the F_4 generation were subjected to correlation analysis and the results are presented in Table 6.

4.3.1 Phenotypic correlation

Plant height had significant positive phenotypic correlation with number of primary branches, petiole length, days to first flowering, days to first harvest, first, fruiting node, girth of fruit, locules per pod, number of ridges per pod, pollen sterility and significant negative correlation with internodal length, length of fruit, number of fruits per plant, duration of crop and yield per plant.

Internodal length had significant positive phenotypic correlation with number of primary branches, length of epicalyx segment, length of fruit, number of fruits per plant, duration of crop and yield per plant and highly significant negative correlation with width of epicalyx segment, petiole length, days to first flowering, days to first harvest, first fruiting node, girth of fruit, locules per pod, number of ridges per pod and pollen sterility.

Number of primary branches showed high positive phenotypic correlation with plant height, internodal length and length of epicalyx segment and highly significant negative correlation with width of epicalyx segment, first fruiting node, girth of fruit, number of ridges per pod and duration of crop.

Significant positive correlation was noticed for length of epicalyx segment with internodal length and pollen sterility and highly significant negative correlation with width of epicalyx segment, first fruiting node, girth of fruit, locules per pod and number of ridges per pod.

Width of epicalyx segment showed significant positive phenotypic correlation with first fruiting node, locules per pod and number of ridges per pod while the correlation was negative and significant with length of epicalyx segment, length of fruit, number of fruits per plant, duration of crop, yield per plant and pollen sterility.

Table 6. Genotypic and phenotypic correlation coefficients for characters in F4 generation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1		0.236	0.314*	0.079	0.022	0.673**	0.588**	0.588**	0.591**	-0.23	0.156	0.478**	-0.527**	0.529**	-0.515**	-0.245	0.369*
2	-0.914**		0.325*	0.479**	-0.286	-0.099	-0.147	-0.147	-0.196	0.273	-0.557**	-0.457**	0.031	-0.398*	-0.009	0.188	-0.028
3	0.836**	1.674**		0.233	-0.085	0.098	-0.062	-0.062	-0.12	0.042	-0.284	-0.093	0.124	-0.033	0.109	-0.01	0.006
4	-0.194	0.833**	0.819**		-0.432*	-0.103	0.069	0.069	-0.034	-0.124	-0.416**	-0.248	-0.074	-0.23	-0.104	-0.074	0.062
5	0.028	-1.293**	-0.496**	-0.915**		0.1	-0.046	-0.046	0.206	-0.206	0.18	0.355*	-0.379*	0.275	-0.354*	-0.288	-0.403*
6	0.94	-1.179**	-0.032	-0.139	0.023		0.8**	0.8**	0.785**	-0.532**	0.151	0.713**	-0.57**	0.767**	-0.497**	-0.519**	0.362*
7	0.854**	-0.94**	-0.1	0.043	0.098	0.911**		1**	0.742**	-0.47	0.165	0.705**	-0.705**	0.772**	-0.663**	-0.493**	0.63**
8	0.854**	-0.94**	-0.1	0.043	0.098	0.91**	1**		0.742**	-0.47	0.165	0.705**	-0.705**	0.772**	-0.663**	-0.493**	0.63**
9	0.568**	-2.248**	-0.531**	-0.538**	0.336*	0.928**	0.846**	0.846**		-0.512**	0.423*	0.729**	-0.628**	0.738**	-0.561**	-0.48**	0.356*
10	-0.361*	1.056**	0.009	-0.125	-0.449*	-0.603**	-0.47	-0.47	-0.662**		0.072	-0.676**	0.617**	-0.614**	0.527**	0.919**	-0.2
11	0.612**	-0.923**	-0.403*	-0.931**	0.266	0.802**	0.623**	0.623**	1.159**	-0.189		0.373*	-0.041	0.319*	-0.048	0.1	0.225
12	0.606**	-1.595**	-0.244	-0.354*	0.609**	0.809**	0.773**	0.773**	0.951**	-0.704**	1.042**		-0.646**	0.97**	-0.513**	-0.639**	0.335*
13	-0.308*	2.045**	-0.183	0.094	-0.656**	-0.898**	-0.977**	-0.977**	-0.732**	0.943**	-0.047	-1.007**		-0.638**	0.97**	0.679**	-0.373*
14	0.696**	-1.579**	-0.336*	-0.4*	0.495**	0.868**	0.833**	0.833**	0.954**	-0.628**	1.17**	1.002**	-0.964**		-0.508**	-0.593**	0.424*
15	-0.424*	1.832**	-0.379*	-0.036	-0.655**	-0.987**	-1.083**	-1.083**	-0.727**	1.013**	0.481**	-1.048**	1.02**	-1.002**		0.61**	-0.399*
16	-0.337*	0.0769	0.055	-0.142	-0.588**	-0.568**	-0.517**	-0.517**	-0.573**	0.968**	0.086	-0.694**	1.085**	-0.613**	1.178**		-0.243
17	0.707**	-0.562**	0.112	0.697**	-0.503**	0.771**	0.963**	0.963**	0.635**	-0.388*	0.175	0.637**	-0.245	0.712**	-0.102	-0.325*	

** Significant at 1 % level

* Significant at 5 % level

1. Plant Height (cm)
2. Internodal length (cm)
3. No. of primary branches
4. Length of epicalyx segment (cm)
5. Width of epicalyx segment (cm)
6. Petiole length (cm)
7. Days to flower
8. Days to first harvest
9. First fruiting node
10. Length of fruit (cm)
11. Girth of fruit (cm)
12. Locules per pod
13. No. of fruits per plant
14. No.of ridges per pod
15. Crop duration (days)
16. Yield per plant (g)
17. Pollen sterility (%)

Petiole length recorded highly significant positive phenotypic correlation with plant height, days to first flowering, days to first harvest, first fruiting node, girth of fruit, locules per pod, number of ridges per pod and pollen sterility and highly significant negative correlation with length of fruit, number of fruits per plant, duration of crop and yield per plant.

Days to first flowering showed high positive phenotypic correlation with plant height, petiole length, days to first harvest, first fruiting node, girth of fruit, locules per pod, number of ridges per pod and pollen sterility and highly significant negative correlation with length of fruit, number of fruits per plant, duration of crop and yield per plant.

Days to first harvest showed high positive phenotypic correlation with plant height, petiole length, first fruiting node, girth of fruit, locules per pod, number of ridges per pod and pollen sterility and highly significant negative correlation with length of fruit, number of fruits per plant, duration of crop and yield per plant.

First fruiting node exhibited high positive phenotypic correlation with plant height, petiole length, days to first flowering, days to first harvest, girth of fruit, locules per pod, number of ridges per pod and pollen sterility and significant negative correlation with length of fruit, number of fruits per plant, duration of crop and yield per plant.

Length of fruit had high positive phenotypic correlation with number of fruits per plant, duration of crop and yield per plant and significant negative correlation with petiole length, days to first flowering, days to first harvest, first fruiting node, locules per pod, number of ridges per pod and pollen sterility.

Girth of fruit had high positive phenotypic correlation with first fruiting node, locules per pod, number of ridges per pod and duration of crop and significant negative correlation with internodal length and length of epicalyx segment.

Locules per pod showed significant positive phenotypic correlation with plant height, width of epicalyx segment, petiole length, days to first flowering, days to first

harvest, first fruiting node, girth of fruit, number of ridges per pod and pollen sterility and significant negative phenotypic correlation was presented for internodal length, length of fruit, number of fruits per plant, duration of crop and yield per plant.

Number of fruits per plant showed high positive phenotypic correlation with length of fruit, duration of crop and yield per plant. Significant negative correlation was observed with plant height, width of epicalyx segment, petiole length, days to first flowering, days to first harvest, first fruiting node, locules per pod and number of ridges per pod.

Number of ridges per pod had high positive phenotypic correlation with plant height, petiole length, days to first flowering, days to first harvest, first fruiting node, girth of fruit, locules per pod and pollen sterility and significant negative correlation with internodal length, length of fruit, number of fruits per plant, duration of crop and yield per plant.

Crop duration exhibited high positive phenotypic correlation with length of fruit, number of fruits per plant and yield per plant and significant negative correlation with plant height, width of epicalyx segment, petiole length, days to first flowering, days to first harvest, first fruiting node, locules per pod and number of ridges per pod.

Yield per plant was having high positive phenotypic correlation with length of fruit, number of fruits per plant and duration of crop while significant negative correlation was noticed with petiole length, days to first flowering, days to first harvest, first fruiting node locules per pod, number of ridges per pod and pollen sterility.

Pollen sterility had high positive phenotypic correlation with plant height, petiole length, days to first flowering, days to first harvest, first fruiting node, locules per pod and number of ridges per pod and significant negative correlation with width of epicalyx segment, number of fruits per plant and duration of crop.

4.3.2 Genotypic correlation

Plant height had significant positive genotypic correlation with number of primary branches, petiole length, days to first flowering, days to first harvest, first fruiting node, locules per pod, number of ridges per pod and pollen sterility and significant negative correlation with number of fruits per plant and duration of crop.

Internodal length had significant positive genotypic correlation with number of primary branches and length of epicalyx segment and highly significant negative correlation with plant height, girth of fruit, locules per pod and number of ridges per pod.

Number of primary branches showed high positive genotypic correlation with plant height and internodal length.

Significant positive correlation was noticed for length of epicalyx segment with internodal length and number of primary branches and highly significant negative correlation with width of epicalyx segment and girth of fruit.

Width of epicalyx segment showed significant positive genotypic correlation with locules per pod while the correlation was negative and significant with internodal length, number of primary branches, length of epicalyx segment, and number of fruits per plant, duration of crop and pollen sterility.

Petiole length recorded highly significant positive genotypic correlation with plant height, days to first flowering, days to first harvest, first fruiting node, locules per pod, number of ridges per pod and pollen sterility and highly significant negative correlation with internodal length, length of fruit, number of fruits per plant, duration of crop and yield per plant.

Days to first flowering showed high positive genotypic correlation with plant height, internodal length, petiole length, first fruiting node, locules per pod, number of ridges per pod and pollen sterility and highly significant negative correlation with length of fruit, number of fruits per plant, duration of crop and yield per plant.

Days to first harvest showed high positive genotypic correlation with plant height, petiole length, days to first flowering, first fruiting node, locules per pod, number of ridges per pod and pollen sterility and highly significant negative correlation with internodal length, length of fruit, number of fruits per plant, duration of crop and yield per plant.

First fruiting node exhibited high positive genotypic correlation with plant height, width of epicalyx segment, petiole length, days to first flowering, days to first harvest, girth of fruit, locules per pod, number of ridges per pod and pollen sterility and significant negative correlation with internodal length, number of primary branches, length of epicalyx segment, length of fruit, number of fruits per plant, duration of crop and yield per plant.

Length of fruit had high positive genotypic correlation with internodal length, number of fruits per plant, duration of crop and yield per plant and significant negative correlation with plant height, width of epicalyx segment, petiole length, days to first flowering, days to first harvest, first fruiting node, locules per pod and number of ridges per pod.

Girth of fruit had high positive genotypic correlation with plant height, petiole length, days to first flowering, days to first harvest, first fruiting node, locules per pod and number of ridges per pod and significant negative correlation with internodal length, number of primary branches and length of epicalyx segment.

Locules per pod showed significant positive genotypic correlation with plant height, width of epicalyx segment, petiole length, days to first flowering, days to first harvest, first fruiting node, girth of fruit, number of ridges per pod and pollen sterility and significant negative genotypic correlation was presented for internodal length, length of epicalyx segment, length of fruit, number of fruits per plant, duration of crop and yield per plant.

No. of fruits per plant had high positive genotypic correlation with internodal length, length of fruit, duration of crop and yield per plant and significant negative

correlation with plant height, width of epicalyx segment, petiole length, days to first flowering, days to first harvest, first fruiting node, locules per pod, number of ridges per pod and pollen sterility.

Number .of ridges per pod had high positive genotypic correlation with plant height, width of epicalyx segment, petiole length, days to first flowering, days to first harvest, first fruiting node, girth of fruit, locules per pod and pollen sterility and significant negative correlation with internodal length, number of primary branches, length of epicalyx segment, length of fruit, number of fruits per plant, duration of crop and yield per plant.

Crop duration had high positive genotypic correlation with internodal length, length of fruit, girth of fruit, number of fruits per plant and yield per plant and significant negative correlation with plant height, number of primary branches, width of epicalyx segment, petiole length, days to first flowering, days to first harvest, first fruiting node, locules per pod, number of ridges per pod and pollen sterility.

Yield per plant had high positive genotypic correlation with internodal length, length of fruit, number of fruits per plant and duration of crop and significant negative correlation with plant height, width of epicalyx segment, petiole length, days to first flowering, days to first harvest, first fruiting node, locules per pod and number of ridges per pod.

Pollen sterility had high positive genotypic correlation with plant height, length of epicalyx segment, petiole length, days to first flowering, days to first harvest, first fruiting node, locules per pod and number of ridges per pod and significant negative correlation with internodal length, width of epicalyx segment, length of fruit and duration of crop.

4.4 Reaction of parental species and F_4 segregants to YVMV

Field screening trial for resistance to YVMV showed that the parent *A.esculentus* as highly susceptible (CI=71.9) whereas the other parental species *A.*

caillei and all the 14 F_4 segregants were completely free of YVMV. Reaction of the parental species and F4 segregants to YVMV in the field screening studies is given in Table 7.

The symptoms of YVMV on susceptible *A. esculentus* var. Salkeerthi is shown in Plate 4. Grafting, diseased *A.esculentus* at 30 day old seedling stage, with selected segregants did not show any symptom of YVMV however symptoms were observed on newly emerged leaves of susceptible variety 'Salkeerthi'. It is clearly evident from both the field screening and graft inoculation studies that the segregants are highly resistant to YVMV. The reaction of desirable F_4 lines to YVMV in the graft inoculation studies is given in the Plate5 and Table 7.

4.5 Pollen fertility studies in the parents and F_4 segregants

The pollen fertility of parental lines and F_4 segregants was studied by staining with one per cent acetocarmine (Table 14). Pollen fertility in the parental species *A.esculentus* variety Salkeerthi was as high as 98.4 per cent (Plate 6a) and *A.caillei* variety Susthira recorded 98.05 per cent pollen stainability (Plate 6b). In the F_4 generation families, it ranged from 85.75 to 93.9 (Plate 6c). The desirable segregants like F_4-2 (Plate 6c (1)) was showing high amount of fertility compared to the other segregants like F_4-28 (Plate 6c (4)).

4.6 Selection of desirable lines from F_4 segregants

The F_4 generation plants showed considerably good amount of variability with respect to plant, leaf, flower and fruit characters. The F_4 generation plants were morphologically more similar to semi wild parent, *A. caillei*. However seven F_4 selections made viz., F_4-2, F_4-5, F_4-8, F_4-13, F_4-15, F_4-16, and F_4-20 were having more fruit length ranging from 17cm to 24cm, attractive fruit colour and desirable number of ridges per fruit. These selections also showed considerably good amount

Plate 4. *A.esculentus* showing typical symptoms of YVMV

5a. F_4-2 grafted with *A. esculentus*

5b. F_4-4 grafted with *A. esculentus*

5c. F_4-8 grafted with *A. esculentus*

Plate 5. Absence of YVMV symptoms in F_4 selections in the graft combination with diseased *A.esculentus*

Table 7. Reaction of parental species and F_4 segregants to YVMV in the field screening and graft transmission studies

Sl. No	Field screening			Graft transmission	
	Treatments	CI	Disease reaction	Treatments	Disease reaction
1	T1 (Male parent)*	71.9	HS	Sel-1 (F4-2)	HR
2	T16 (Female parent)*	0	HR	Sel-2 (F4-5)	HR
3	T2	0	HR	Sel-3 (F4-8)	HR
4	T3	0	HR	Sel-4 (F4-13)	HR
5	T4	0	HR	Sel-5 (F4-15)	HR
6	T5	0	HR	Sel-6 (F4-16)	HR
7	T6	0	HR	Sel-7 (F4-20)	HR
8	T7	0	HR		
9	T8	0	HR		
10	T9	0	HR		
11	T10	0	HR		
12	T11	0	HR		
13	T12	0	HR		
14	T13	0	HR		
15	T14	0	HR		
16	T15	0	HR		

Female Parent *: P1 (*A.caillei*)

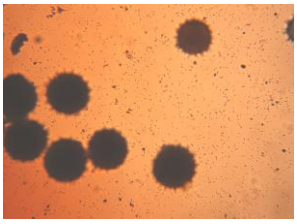
Male Parent *: P2 (*A.esculentus*)

HR - Highly Resistant

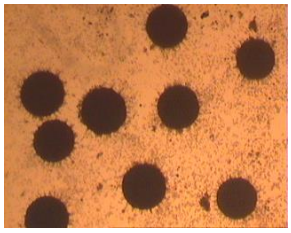
R - Resistant

MR- Moderately Resistant

HS - Highly Susceptible

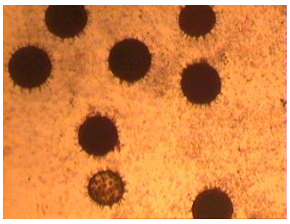


6a. Pollen grains of *A. esculentus*

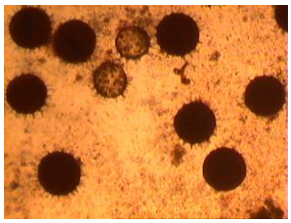


6b. Pollen grains of *A. caillei*

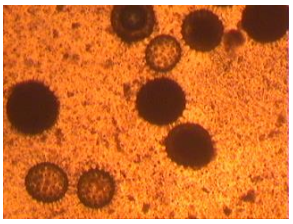
6c. Pollen grains of F_4 segregants



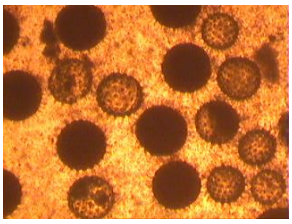
6c (1) Pollen grains of F_4-2



6c(2)Pollen grains of F_4-13



6c(3)Pollen grains of F_4-25



6c(4)Pollen grains of F_4-28

Plate 6. Pollen grains of parents and segregants in the F_4 generation showing fertile and sterile pollen grains

of fertility and resistance to YVMV (Table 8). Hence these selections (Plate 7) were sown in the field to raise F_5 generation families to advance the breeding programme.

4.7 Evaluation of F_5 families

4.7.1 Qualitative characters

Leaf margin was deeply fid in *A.esculentus* but that in *A.caillei* and most of the F_5 segregants were narrowly fid. Flower colour was yellow in both the parents and segregants. Flower size was medium in both the parental species where as segregants had large, medium and small sized flowers. Both parents and segregants had purple throat at base of corolla in the inside and colour of leaf vein was green with purple tinge. Colour of fruit was light green in *A.esculentus* whereas that in *A.caillei* was green. Segregants produced green, light green and dark green fruits. Pod pubescence was absent in both the parents but the segregants were slightly pubescent (Table 9). The variability expressed by the pods is shown in the Plate 8.

4.7.2 Quantitative characters

The mean values for the 17 characters relating to different treatments are given in Table 10. The data pertaining to the 18 characters studied in the F_5 generation was tabulated and subjected to analysis of variance and are presented in Table 11.

Plant height varied significantly among the different families and with the parent, P2. The mean values for plant height ranged from 46.33 cm in T4 to 101.33 cm in T3. T1 was on par with T4.

Length of epicalyx segment varied significantly with the wild parent, P1. The mean value for this character ranged from 1.43 cm in T9 to 2.73 cm in T6. T4 and T8 were at par.

Table 8. Details of quantitative and qualitative characters expressed by selections from F_4 generation in comparison with parents

Sl. No	Characters	Sel-1 (F_4-2)	Sel-2 (F_4-5)	Sel-3 (F_4-8)	Sel-4 (F_4-13	Sel-5 (F_4-15)	Sel-6 (F_4-16)	Sel-7 (F_4-20)	P1 *A.c**	P2 *A.e**
1	**Quantitative characters**									
	Plant Height (cm)	120	121.5	132	143	105.5	115.3	122.8	142.7	125.4
	Internodal length (cm)	8.5	9.4	14.4	8.5	8.6	6.1	12.1	7. 9	12.2
	No. of primary branches	3	3	4	3	4	1	3	3	3.2
	Length of epicalyx segment (cm)	2	1.8	1.7	2.5	2.1	2.1	2.1	1.3	2.3
	Width of epicalyx segment (cm)	0.5	0.9	0.8	0.8	0.7	0.3	0.6	1.1	0.5
	Petiole length (cm)	35	32	35	35.5	34.6	35	38.5	34.6	30.3
	Days to flower	49	55	55	54	55	50	54	46.5	39.5
	Days to first harvest	55	61	61	59	61	55	59	52.5	45.5
	First fruiting node	4	6	5	5	6	6	6	5.9	4.4
	Length of fruit (cm)	19.4	17	18.4	18.5	22	18.4	24	16.8	27.6
	Girth of fruit (cm)	7.2	8	7.6	8.3	7.8	7.8	8.5	8.4	7.5
	Locules per pod	5	5	6	5	5	6	5	6	5
	No. of fruits per plant	16	13	12	11	10	11	10	12	15
	No.of ridges per pod	5	5	6	5	5	5	6	6	5
	Crop duration (days)	182	179	179	163	178	170	163	171.88	167.8
	Yield per plant (g)	201.5	188	185.5	182.5	174.5	170.8	162.5	177.32	190.1
	YVMV reaction	HR	HR	HR	HR	HR	HR	HR	HR	HS
	Pollen fertility (%)	96.80	94.60	94.80	93.80	94.60	95.50	94.00	98.05	98.4
2	**Qualitative characters**									
	Pod pubescence	NP	NP	NP	NP	LP	LP	NP	NP	NP
	Leaf margin	DF	DF	NF	NF	NF	NF	NF	NF	DF
	Flower colour	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
	Flower size	Medium	Large	Large	Medium	Small	Medium	Medium	Medium	Medium
	Purple throat at base of corolla	Present	Present	Present	Present	Present	Present	Present	Present	Present
	Colour of leaf vein	GWPT	GWPT	GWPT	GWPT	GWPT	GWPT	GWPT	GWPT	GWPT
	Colour of fruit	G	G	DG	DG	LG	G	G	G	LG

G-Green
DG- Dark Green
LG- Light Green
HR- Highly Resistant
GWPT- Green with purple tinge
DF-Deeply fid
NP- Not pubescent
LP- Less pubescent
NF- Narrowly fid
HS-Highly susceptible
A.c- A. caillei
A.e- A. esculentus

Sel-1 (F_4-2)

Sel-2 (F_4-5)

Sel-3 (F_4-8)

Sel-4 (F_4-13)

Sel-5 (F_4-15)

Sel-7 (F_4-20)

Sel-6 (F_4-16)

Plate 7. Promising segregants from F_4 generation

Table 9. Comparison of qualitative characters of parental species and F_5 segregants

Sl.No.	Characters	*A.esculentus*	*A.caillei*	Segregants
1	Leaf margin	Deeply fid	Narrowly fid	Narrowly fid
2	Flower colour	Yellow	Yellow	Yellow
3	Flower size	Medium	Medium	Large, medium and Small
4	Purple throat at base of corolla	Present inside	Present inside	Present inside
5	Colour of leaf vein	Green with purple tinge	Green with purple tinge	Green with purple tinge
6	Colour of fruit	Light green	Green	Green, Light green and Dark green
7	Pod pubescence	Absent	Absent	Slightly pubescent

Plate 8a. Variability in fruit shape and size in the F_5 segregants

Plate 8b. L.S.of fruits of F_5 segregants

Table 10. Mean values for the different quantitative characters in F_5 generation

Treatments	Plant Height (cm)	Internodal length (cm)	No. of primary branches	Length of epicalyx segment (cm)	Width of epicalyx segment (cm)	Petiole length (cm)	Days to flower	Days to first harvest	First fruiting node
	1	2	3	4	5	6	7	8	9
T1 (P2)*	47.67	4	2.33	2.1	0.23	27.83	46.67	52	3.33
T2 (Sel-1)	61.67	3.83	3.33	2.23	0.67	25.5	58	63.67	5.67
T3 (Sel-2)	101.33	4.73	3	2.03	0.57	25.5	58	63.67	4
T4 (Sel-3)	46.33	4.33	2.67	1.9	0.5	20.5	55	60.67	4.33
T5 (Sel-4)	73.33	4.83	3.33	2.03	0.6	20.67	59.33	65.33	6.33
T6 (Sel-5)	75.67	4.47	3	2.73	0.47	25	60.67	67	5
T7 (Sel-6)	68.00	4	4.67	1.93	0.57	23.67	49.67	55.33	4.33
T8 (Sel-7)	71.33	3.67	2.67	1.87	0.57	19.17	52.33	57.67	5
T9 (P1)*	67.67	4.5	2.67	1.43	0.57	22.17	54.67	60.33	4
CD	26.20	1.87	1.95	0.64	0.25	10.24	6.53	6.72	2.88
SE	12.36	0.88	0.92	0.3	0.12	4.83	3.08	3.17	1.36

*P1: Parent 1 (*A.caillei*)

*P2:Parent 2(*A.esculentu*

Table 10. Continued

Treatments	Length of fruit (cm)	Girth of fruit (cm)	Locules per pod	No. of fruits per plant	No. of ridges per pod	Crop duration (days)	Yield per plant (g)	Pollen sterility (%)	Coefficient of infection
	10	11	12	13	14	15	16	17	18
T1	23.33	7.53	5.00	15.33	5.00	154.33	200.57	0.1	79.93
T2	19.33	9.33	5.00	13.33	5.00	145.00	177.00	4.20	2.19
T3	20.17	8.30	5.67	13.33	5.67	157.00	199.97	7.73	3.03
T4	17.13	9.00	5.00	10.33	5.00	161.00	160.00	10.20	3.91
T5	15.23	8.07	5.67	9.00	5.67	134.00	149.10	4.73	8.47
T6	17.17	8.43	5.33	8.33	5.33	165.00	161.50	6.20	14.01
T7	12.67	8.17	5.67	15.33	5.67	152.00	181.00	8.60	0.87
T8	19.83	9.13	5.67	8.67	5.67	156.00	182.50	12.47	2.29
T9	17.50	8.37	6.00	13.33	5.67	170.00	188.87	0.5	0.67
CD	5.94	1.38	1.55	7.34	1.48	1.31	41.42	1.40	1.55
SE	2.80	0.65	0.73	3.46	0.70	0.62	19.54	0.66	0.73

Table 11. ANOVA (mean squares) for the different quantitative characters in the F_5 generation

Sl. No	Characters	Treatments	P1 vs Families	P2 vs Families	Error
		df = 8	df = 1	df = 1	df = 8
1	Plant Height (cm)	799.00**	537.72**	11.49	229.00
2	Internodal length (cm)	0.49	0.07	0.05	1.17
	Number of primary branches	1.39	0.81	0.32	1.28
4	Length of epicalyx segment (cm)	0.35	0.00	0.44**	0.13
5	Width of epicalyx segment (cm)	0.45	0.11	0.00	0.025
6	Petiole length (cm)	24.89**	24.22**	0.46	35.07
7	Days to flower	65.23**	87.94**	2.12**	14.27
8	Days to first harvest	72.20**	96.16**	2.43*	15.16
9	First fruiting node	2.58*	2.58	0.89	2.77
10	Length of fruit (cm)	28.52**	34.91**	0.02	11.8
11	Girth of fruit (cm)	0.98	1.19	0.07	0.65
12	Locules per pod	0.41	0.18	0.31*	0.81
13	No. of fruits per plant	23.91**	16.80**	4.49**	18.02
14	No.of ridges per pod	0.31	0.18	0.06	0.74
15	Crop duration (days)	343.65**	2.13	288.00**	0.59
16	Yield per plant (g)	964.25**	744.36**	246.50**	572.96
17	Pollen sterility (%)	43.12**	51.26**	26.12**	0.65
18	Coefficient of infection	1895.50**	5251.69**	35.93**	0.81

* Significant at 5 % level

** Significant at 1 % level

The families exhibited highly significant variation from the parent P2 and among themselves for petiole length. The mean values for petiole length ranged from 19.17 cm in T8 to 27.83 cm in P2.

The variations among the families and with both the parents were highly significant for the character, days to first flowering. The mean values for this character ranged from 46.67 in P2 to 60.67 in T6.

Days to first harvest differed significantly among the different families and with both the parents. The mean values ranged from 52 in P2 to 67 in T6.

The differences between the mean values among the families were significant for first fruiting node. The mean values ranged from 3.33 in P2 to 6.33 in T5.

Length of fruit varied significantly among the different families and with the parent P2. The mean values for length of fruit ranged from 12.67 cm in T7 to 23.33 cm in T1.

Significant differences were observed for number of locules per pod with the wild parent, P1. The mean values ranged from 5 in T1, T2 and T4 to 6 in T9.

Highly significant differences among the families and with both the parents were observed for number of fruits per plant. The mean values for number of fruits ranged from 8.33 in T6 to 15.33 in T1 and T7.

Duration of crop varied significantly among the different families and with the wild parent, P1. Maximum duration was recorded for wild parent, P1 (170) and the minimum was recorded in T5 (134).

Significant differences among the families and with the two parents for yield/ plant were observed. Maximum yield was recorded for the parent, P2 (200.57). T3 was on par with P2 and minimum was observed for T5 (149.10g).

The families differed significantly among themselves and with the two parents for pollen sterility (%). Maximum sterility was recorded in T8 (12.47) and the minimum in the parent, P2 (0.10). P1 was on par with P2.

Significant differences among the families and the two parents were exhibited for coefficient of infection of yellow vein mosaic virus. The means ranged from 0.67 in wild parent, P1 to 79.93 in the parent, P2. T7 was on par with P1.

4.8 Genetic parameters in F_5 generation

All the characters studied in the F_5 generation were subjected to estimation of genetic parameters viz., phenotypic and genotypic coefficients of variation, heritability and genetic advance and the results are given in Table 12.

4.8.1 Phenotypic and genotypic coefficients of variation

The maximum value for phenotypic and genotypic coefficients of variation were observed for coefficient of infection of YVMV (177.26 and 177.15 respectively) followed by pollen sterility (60.56 and 59.2 respectively) (Fig 3).

The phenotypic coefficient of variation was minimum for duration of crop (6.92) followed by days to first harvest and days to first flowering (9.64 and 10.18 respectively). The genotypic coefficient of variation was minimum for petiole length (0.14)) followed by number of ridges per pod and first fruiting node (0.58 and 0.68 respectively).

4.8.2 Heritability and genetic advance

High heritability was recorded for all the 18 characters studied (Fig 4). Maximum heritability was noticed for coefficient of infection (99.9 per cent) followed by duration of crop (99.5 per cent) and number of fruits per plant (9.8 per cent). The heritability value was minimum for both petiole length and first fruiting node.

T able 12. Genetic parameters for the different quantitative characters in F_5 generation

Sl. No	Characters	PCV	GCV	Heritability (%)	Genetic advance
1	Plant Height (cm)	30.07	20.24	45.30	19.12
2	Internodal length (cm)	25.49	0.74	0.10	0.00
3	No. of primary branches	37.43	6.26	2.80	0.07
4	Length of epicalyx segment (cm)	22.52	13.37	35.30	0.33
5	Width of epicalyx segment (cm)	33.98	15.74	21.40	0.08
6	Petiole length (cm)	25.38	0.14	0.00	0.00
7	Days to flower	10.18	7.50	54.30	6.26
8	Days to first harvest	9.64	7.19	55.60	6.70
9	First fruiting node	35.72	0.68	0.00	0.00
10	Length of fruit (cm)	23.11	13.08	32.10	2.75
11	Girth of fruit (cm)	10.31	3.95	14.70	0.26
12	Locules per pod	16.64	0.58	0.10	0.00
13	No. of fruits per plant	37.61	11.78	9.80	0.90
14	No.of ridges per pod	15.98	0.58	0.10	0.00
15	Crop duration (days)	6.92	6.90	99.50	21.97
16	Yield per plant (g)	14.91	6.42	18.50	10.13
17	Pollen sterility (%)	60.56	59.20	95.60	7.58
18	Coefficient of infection	177.26	177.15	99.90	51.74

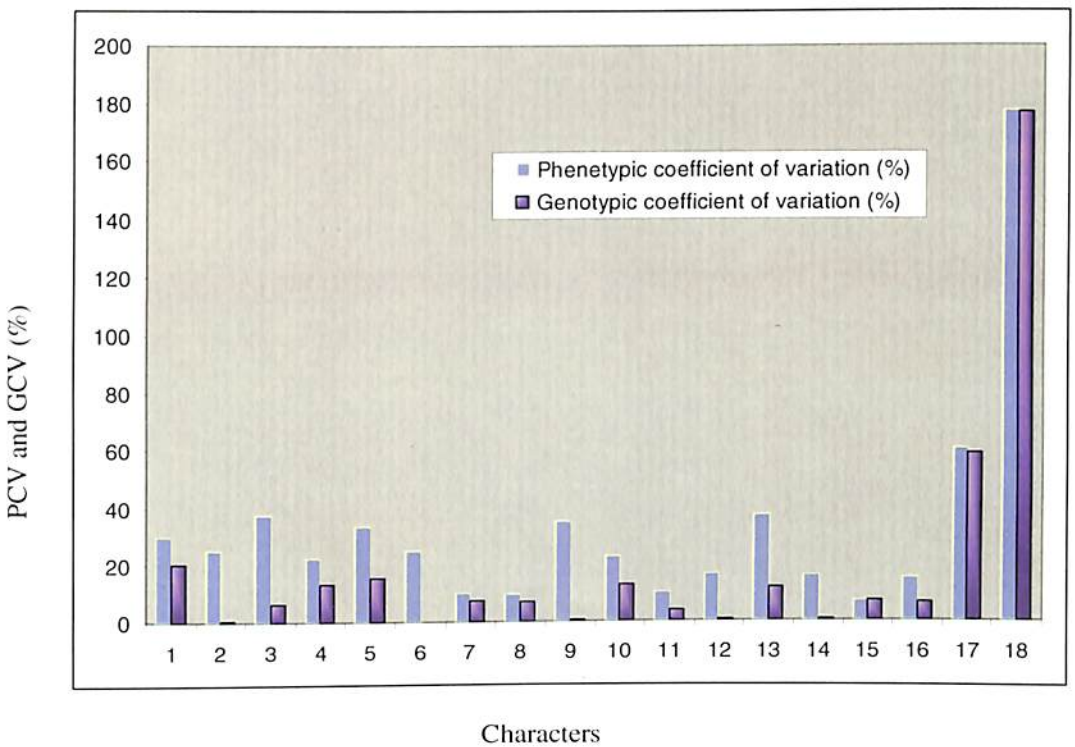


Fig.3. Phenotypic and genotypic coefficients of variation for characters in the F_5 generation

1. Plant Height (cm)
2. Internodal length (cm)
3. No. of primary branches
4. Length of epicalyx segment (cm)
5. Width of epicalyx segment (cm)
6. Petiole length (cm)
7. Days to flower
8. Days to first harvest
9. First fruiting node
10. Length of fruit (cm)
11. Girth of fruit (cm)
12. Locules per pod
13. No. of fruits per plant
14. No.of ridges per pod
15. Crop duration (days)
16. Yield per plant (g)
17. Pollen sterility (%)
18. Coefficient of infection to YVMV

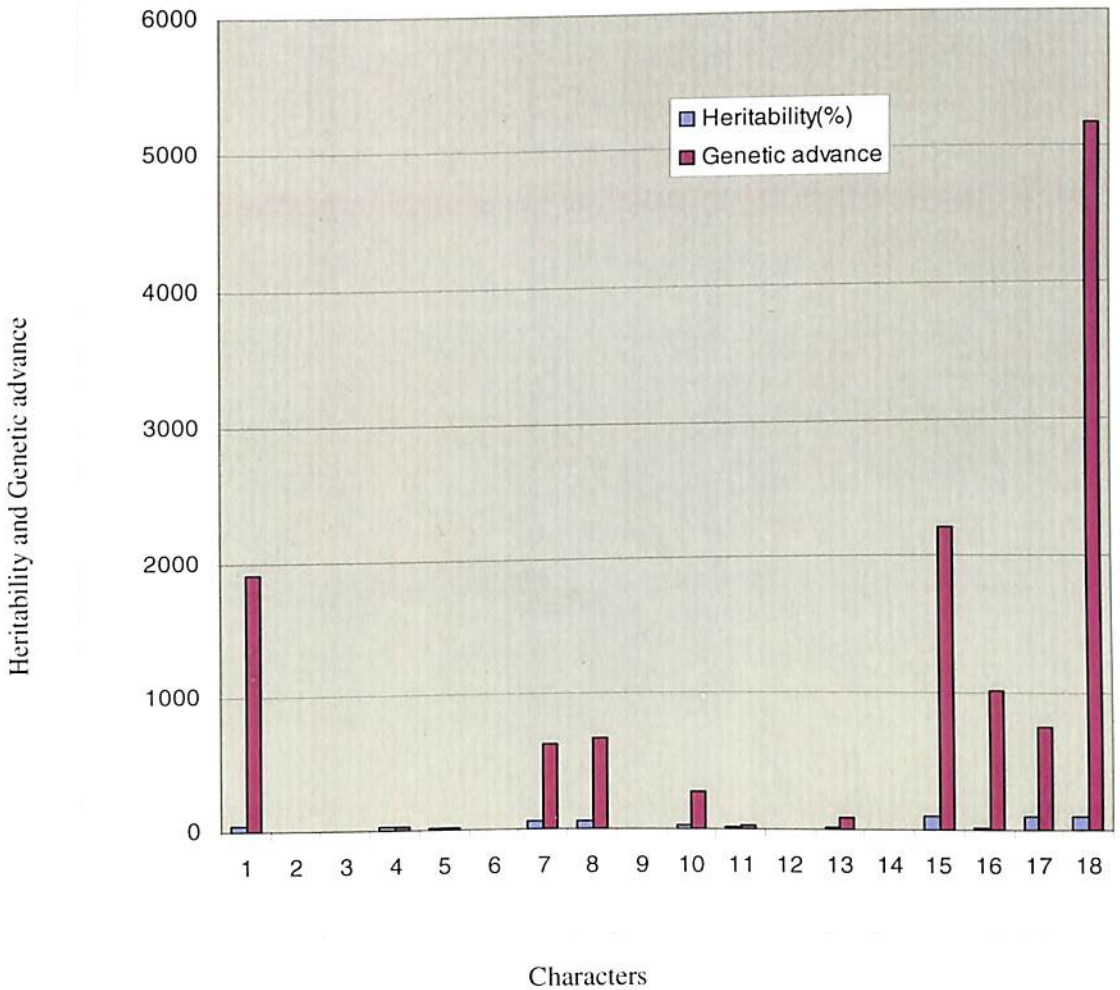


Fig. 4. Heritability and genetic advance for characters in the F_5 generation

1. Plant Height (cm)
2. Internodal length (cm)
3. No. of primary branches
4. Length of epicalyx segment (cm)
5. Width of epicalyx segment (cm)
6. Petiole length (cm)
7. Days to flower
8. Days to first harvest
9. First fruiting node
10. Length of fruit (cm)
11. Girth of fruit (cm)
12. Locules per pod
13. No. of fruits per plant
14. No.of ridges per pod
15. Crop duration (days)
16. Yield per plant (g)
17. Pollen sterility (%)
18. Coefficient of infection to YVMV

The highest genetic advance was estimated for the character, coefficient of infection (51.74 per cent) followed by duration of crop (21.97). Number of ridges per
pod, locules per pod, first fruiting node, petiole length and internodal length recorded minimum genetic advance.

4.9 Correlation in F_5 generation

The data relating to the characters studied in the F_5 generation were subjected to correlation analysis and the results are presented in Table 13.

4.9.1 Phenotypic correlation

Plant height had significant positive phenotypic correlation with internodal length, number of primary branches, width of epicalyx segment, days to first flowering, days to first harvest, first fruiting node, locules per pod and number of ridges per pod. Significant negative correlation was observed with petiole length, number of fruits per plant and coefficient of infection.

Internodal length had significant positive phenotypic correlation with width of epicalyx segment, days to first flowering, days to first harvest, locules per pod and number of ridges per pod and highly significant negative correlation with number of primary branches, length of epicalyx segment, first fruiting node, length of fruit, girth of fruit, number of fruits per plant, duration of crop, yield per plant, pollen sterility and coefficient of infection.

Number of primary branches showed high positive phenotypic correlation with length of epicalyx segment, width of epicalyx segment, petiole length, first fruiting node, length of fruit, locules per pod, number of fruits per plant, number of ridges per pod, duration of crop, pollen sterility and coefficient of infection and highly significant negative correlation with yield per plant.

Significant negative correlation was noticed for length of epicalyx segment with petiole length, days to first flowering, days to first harvest and first fruiting node

Table13. Genotypic and phenotypic correlation coefficients for characters in the F5 generation

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1		0.225	0.135	0.025	0.435**	0.047	0.21	0.221	0.031	-0.034	-0.141	0.426**	0.126	0.408**	0.003	0.223	0.197	-0.356*
2	4.901**		-0.026	0.067	0.053	0.181	0.348*	0.33*	0.156	0.064	-0.163	0.125	-0.039	0.101	0.011	-0.034	-0.03	-0.072
3	0.769**	-1.065**		-0.043	0.203	-0.247	0.019	0.035	0.268	-0.529**	-0.182	-0.04	0.242	-0.037	-0.215	-0.136	0.124	-0.158
4	0.234	-1.648**	0.784**		0.281*	0.366**	0.388**	0.392**	0.128	0.403**	0.08	-0.064	-0.356*	0.041	-0.121	-0.112	-0.059	0.139
5	0.459**	0.787**	2.412**	-0.029		-0.263	0.278	0.262	0.162	-0.454**	0.226	0.346*	0.184	0.342*	-0.18	-0.169	0.259	-0.626**
6	-0.749**	*******	141.876**	21.753**	-43.60**		-0.162	-0.177	-0.315*	0.481**	-0.067	0.194	-0.085	0.224	0.033	0.108	-0.283*	0.303*
7	0.805**	4.63**	-0.038	0.426**	1.037**	-3.693**		0.996**	0.475**	-0.079	0.25	0.05	-0.392**	0.074	-0.099	-0.326*	0.057	-0.544**
8	0.781**	5.278**	-0.011	0.459**	1.022**	-0.613**	1.002**		0.499**	-0.103	0.209	0.047	-0.401**	0.066	-0.097	-0.344*	0.054	-0.538**
9	6.758**	-78.94**	2.282**	11.085**	32.985**	*******	15.15**	14.252**		-0.202	0.003	-0.104	-0.364**	-0.106	-0.36*	-0.508**	0.091	-0.27
10	-0.191	-8.419**	2.617**	-0.399**	0.651**	-1.221**	-0.424**	-0.439**	-13.43**		0.094	0.099	-0.194	0.114	0.121	0.416**	-0.232	0.389**
11	0.121	-5.893**	1.13**	-0.184	1.781**	-88.66**	0.619**	0.629**	30.824**	-0.368*		0.022	-0.2	0.082	0.043	0.171	0.367**	-0.45**
12	3.738**	18.518**	18.257**	-10.03**	0.177	*******	1.048**	1.108**	99.537**	-11.73**	-6.2**		-0.133	0.799**	0.062	0.113	0.044	-0.18
13	-0.796**	-6.223**	0.524**	-0.246	-1.669**	198.35**	-1.195**	-1.178**	-23.459**	1.555**	-1.197**	3.71**		-0.152	0.04	0.569**	-0.264	0.277
14	4.582**	17.826**	22.061**	-8.173**	-0.177	********	0.782**	0.94**	138.891**	-11.52**	-7.597**	*********	2.247**		-0.004	0.098	0.092	-0.163
15	-0.032	-0.389**	-1.377**	-0.203	-0.421**	3.956**	-0.122	-0.115	-19.755**	0.207	0.099	1.684**	0.061	-0.164		0.236	0.081	-0.051
16	0.092	-7.571**	-0.679**	-0.713**	-0.725**	89.179**	-0.983**	-0.99**	-20.876**	0.975**	-1.596**	-0.427**	1.285**	-1.702**	0.54**		-0.108	0.269
17	0.238	-3.743**	0.742**	-0.025	0.581**	-59.78**	0.1	0.087	4.665**	-0.396**	0.975**	1.825**	-0.973**	3.167**	0.081	-0.424**		-0.548**
18	0.539**	-2.92*	-1.005**	0.233	-1.353**	55.005**	-0.737**	-0.719**	-14.969**	0.674**	-1.184**	-5.234**	0.876**	-4.527**	-0.053	0.613**	-0.565**	

* Significant at 5 % level

** Significant at 1 % level

1. Plant Height (cm)
2. Internodal length (cm)
3. No. of primary branches
4. Length of epicalyx segment (cm)
5. Width of epicalyx segment (cm)
6. Petiole length (cm)
7. Days to flower
8. Days to first harvest
9. First fruiting node
10. Length of fruit (cm)
11. Girth of fruit (cm)
12. Locules per pod
13. No. of fruits per plant
14. No.of ridges per pod
15. Crop duration (days)
16. Yield per plant (g)
17. Pollen sterility (%)
18. Coefficient of infection to YVMV

and highly significant negative correlation with locules per pod, number of ridges per pod and yield per plant.

Width of epicalyx segment showed significant positive phenotypic correlation with plant height, days to first flowering, days to first harvest, first fruiting node, girth of fruit and pollen sterility while the correlation was negative and significant with length of epicalyx segment, petiole length, length of fruit, number of fruits per plant, duration of crop, yield per plant and coefficient of infection.

Petiole length recorded highly significant positive phenotypic correlation with length of epicalyx segment, locules per pod, duration of crop, yield per plant, pollen sterility and coefficient of infection and highly significant negative correlation with days to first flowering, days to first harvest, length of fruit and girth of fruit.

Days to first flowering showed high positive phenotypic correlation with internodal length, length of epicalyx segment, days to first harvest, first fruiting node, girth of fruit, locules per pod and number of ridges per pod and highly significant negative correlation with petiole length, length of fruit, number of fruits per plant, yield per plant and coefficient of infection.

Days to first harvest showed high positive phenotypic correlation with internodal length, length of epicalyx segment, days to first flowering, first fruiting node, girth of fruit, locules per pod and number of ridges per pod and highly significant negative correlation with length of fruit, number of fruits per plant, yield per plant and coefficient of infection.

First fruiting node exhibited high positive phenotypic correlation with days to first flowering, days to first harvest, length of fruit, girth of fruit, locules per pod, number of ridges per pod and pollen sterility and significant negative correlation with petiole length, number of fruits per plant, duration of crop, yield per plant and coefficient of infection.

Length of fruit had high positive phenotypic correlation with length of epicalyx segment, petiole length, number of fruits per plant, yield per plant and

coefficient of infection and significant negative correlation with width of epicalyx segment, girth of fruit, locules per pod, number of ridges per pod and pollen sterility.

Girth of fruit had high positive phenotypic correlation with pollen sterility and significant negative correlation with locules per pod, number of fruits per plant, number of ridges per pod, yield per plant and coefficient of infection.

Locules per pod showed significant positive phenotypic correlation with plant height, width of epicalyx segment, number of fruits per plant, duration of crop and pollen sterility and significant negative phenotypic correlation was presented for yield per plant and coefficient of infection.

No. of fruits per plant had high positive phenotypic correlation with number of ridges per pod, yield per plant and coefficient of infection and significant negative correlation with length of epicalyx segment, days to first flowering, days to first harvest, first fruiting node and pollen sterility.

Number .of ridges per pod had high positive phenotypic correlation with plant height, width of epicalyx segment, locules per pod, pollen sterility and coefficient of infection and significant negative correlation with yield per plant.

Crop duration had high positive phenotypic correlation with yield per plant and significant negative correlation with first fruiting node.

Yield per plant had high positive phenotypic correlation with length of fruit, number of fruits per plant and coefficient of infection and significant negative correlation with days to first flowering, days to first harvest, first fruiting node and pollen sterility.

Pollen sterility had high positive phenotypic correlation with girth of fruit and significant negative correlation with petiole length and coefficient of infection to YVMV.

Coefficient of infection of YVMV showed high positive phenotypic correlation with petiole length and length of fruit and highly significant negative

correlation with plant height, width of epicalyx segment, days to first flowering, days to first harvest, girth of fruit and pollen sterility.

4.9.2 Genotypic correlation

Plant height had significant positive genotypic correlation with width of epicalyx segment, locules per pod and number of ridges per pod and significant negative correlation with coefficient of infection.

Internodal length had significant positive genotypic correlation with plant height, days to first flowering and days to first harvest. Number of primary branches showed high positive genotypic correlation with plant height and highly significant negative correlation with internodal length and length of fruit.

Significant negative correlation was noticed for length of epicalyx segment with number of primary branches, petiole length, days to first flowering, days to first harvest and length of fruit and highly significant negative correlation with internodal length, width of epicalyx segment and number of fruits per plant.

Width of epicalyx segment showed significant positive genotypic correlation with plant height, internodal length, number of primary branches, locules per pod and number of ridges per pod while the correlation was negative and significant with length of fruit and coefficient of infection.

Petiole length recorded highly significant positive genotypic correlation with number of primary branches, length of epicalyx segment and length of fruit and highly significant negative correlation with plant height, width of epicalyx segment, days to first flowering, first fruiting node and pollen sterility.

Days to first flowering showed high positive genotypic correlation with plant height, internodal length, length of epicalyx segment, width of epicalyx segment, days to first harvest and first fruiting node and highly significant negative correlation with petiole length, number of fruits per plant, duration of crop and coefficient of infection.

Days to first harvest showed high positive genotypic correlation with plant height, internodal length, length of epicalyx segment, width of epicalyx segment and first fruiting node and highly significant negative correlation with petiole length, number of fruits per plant, duration of crop and coefficient of infection.

First fruiting node exhibited high positive genotypic correlation with plant height, number of primary branches, length of epicalyx segment, width of epicalyx segment, days to first flowering and days to first harvest and significant negative correlation with internodal length, number of fruits per plant, duration of crop and yield per plant.

Length of fruit had high positive genotypic correlation with number of primary branches, first fruiting node, yield per plant and coefficient of infection and significant negative correlation with internodal length, width of epicalyx segment, petiole length, days to first flowering and days to first harvest.

Girth of fruit had high positive genotypic correlation with width of epicalyx segment, days to first flowering, days to first harvest, first fruiting node and pollen sterility and significant negative correlation with internodal length, petiole length, length of fruit and coefficient of infection.

Locules per pod showed significant positive genotypic correlation with plant height, internodal length, number of primary branches, petiole length, days to first flowering, days to first harvest, first fruiting node and number of ridges per pod and significant negative genotypic correlation was presented for length of epicalyx segment, length of fruit and girth of fruit.

No. of fruits per plant had high positive genotypic correlation with number of primary branches, length of fruit, locules per pod and yield per plant and significant negative correlation with plant height, internodal length, width of epicalyx segment, days to first flowering, days to first harvest, first fruiting node and girth of fruit.

Number of ridges per pod had high positive genotypic correlation with plant height, internodal length, number of primary branches, days to

first flowering, days to first harvest, first fruiting node and number of fruits per plant and significant negative correlation with length of epicalyx segment, length of fruit and girth of fruit.

Crop duration had high positive genotypic correlation with number of primary branches, petiole length and locules per pod and significant negative correlation with internodal length, width of epicalyx segment and first fruiting node.

Yield per plant had high positive genotypic correlation with petiole length, length of fruit, number of fruits per plant and duration of crop and significant negative correlation with internodal length, number of primary branches, length of epicalyx segment, width of epicalyx segment, days to first flowering, days to first harvest, first fruiting node, girth of fruit, locules per pod and number of ridges per pod.

Pollen sterility had high positive genotypic correlation with number of primary branches, width of epicalyx segment, petiole length, first fruiting node, girth of fruit, locules per pod and number of ridges per pod and significant negative correlation with internodal length, length of fruit, number of fruits per plant, yield per plant and coefficient of infection.

Coefficient of infection of YVMV showed high positive genotypic correlation with number of primary branches, petiole length, length of fruit, number of fruits per plant, number of ridges per pod and yield per plant and highly significant negative correlation with plant height, internodal length, width of epicalyx segment, days to first flowering, days to first harvest, first fruiting node, girth of fruit, locules per pod and pollen sterility.

4.10 Reaction of parental species and F_5 segregants to YVMV

4.10.1 Field screening

The parental species and the segregants were screened for YVMV resistance (Table14). *A.esculentus* variety Salkeerthi expressed coefficient of infection of 79.93 where as *A.caillei* variety Susthira showed a very low coefficient of 0.67. The

segregants showed coefficient of infection ranging from 0.87 to 14.01 (Highly resistant to moderately resistant).

4.10.2 Artificial inoculation of YVMV by approach grafting

Grafting diseased *A.esculentus* with selected F_5 segregants at 30 day old seedling stage did not show symptoms of YVMV, however symptoms were observed on the newly emerging leaves of susceptible variety Salkeerthi. The reaction of desirable F_5 lines to YVMV in the graft inoculation studies is given in the Plate 9. The F_5 lines viz., F_5-1, F_5-3, F_5-7, F_5-9, F_5-20 and F_5-26 did not show any symptom of YVM disease in artificial inoculation studies (Table 14).

4.11 Pollen fertility studies in the parents and F_5 segregants

The pollen fertility of parental lines and F_5 segregants was studied by staining with one per cent acetocarmine (Table 15). Pollen fertility in the parental species *A.esculentus* variety Salkeerthi was as high as 99.9 per cent (Plate 10a) *and A.caillei* variety Susthira recorded 99.5 per cent pollen stainability (Plate 10b). In the F_5 generation families it ranged from 87.53 to 95.8 per cent (Plate 10c). . It is also noted that pollen stainability was more in F_5 segregants as compared to the F_4 segregants. viz., Plate 10c (3).

4.12 Selection of desirable lines from F_5 segregants

Some of the F_5 segregants expressed characters much similar to the cultivated species *A. esculentus* line Salkeerthi such as five number of ridges per pod, longer fruit length, reduced width of epicalyx segment, fruit yield etc. The segregants such as F_5-1, F_5-3, F_5-7, F_5-9, F_5-20 and F_5-26 (Plate 11) were selected based on its promising fruit characters tending towards *A. esculentus*. Their fruit length ranged from 17- 21.5cm. They were also having more number of fruits per plant and high

9a. F_5-1 grafted with *A.e**

9b. F_5-3 grafted with*A.e**

9c. F_5-7 grafted with *A.e**

9d. F_5-9 grafted with *A.e**

9e. F_5-20 grafted with *A.e* *

9f. F_5-26 grafted with *A.e**

**A.e – Abelmoschus esculentus*

Plate 9. Absence of YVMV symptoms in F_5 selections in the graft combination with diseased *A.esculentus*

Table 14. Reaction of parental species and F_5 segregants to YVMV in the field screening and graft transmission studies

Sl. No	Field screening			Graft transmission	
	Treatments	CI	Disease reaction	Treatments	Disease reaction
1	T1 (Male parent)*	79.93	HS	Sel-1 (F_5-1)	HR
2	T9 (Female parent)*	0.67	HR	Sel-2 (F_5-3)	HR
3	T2	2.19	HR	Sel-3 (F_5-7)	HR
4	T3	3.03	HR	Sel-4 (F_5-9)	HR
5	T4	3.91	HR	Sel-5 (F_5-20)	HR
6	T5	8.47	MR	Sel-6 (F_5-26)	HR
7	T6	14.01	MR		
8	T7	0.87	HR		
9	T8	2.29	HR		

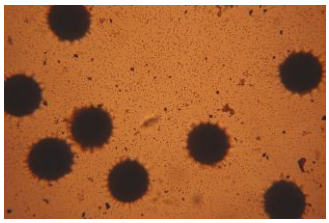
Female Parent *: P1 (*A.caillei*)

Male Parent *: P2 (*A.esculentus*)

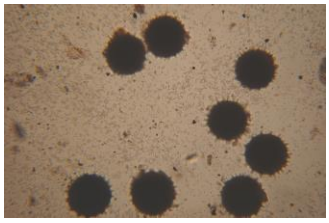
HR - Highly Resistant

MR- Moderately Resistant

HS - Highly Susceptible

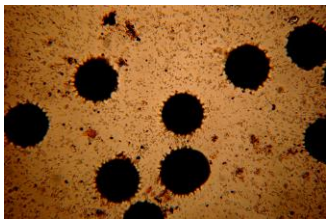


10a. Pollen grains of *A. esculentus*

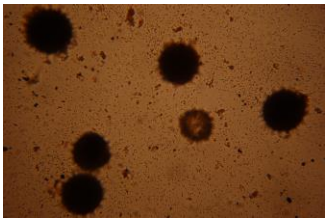


10b. Pollen grains of *A. caillei*

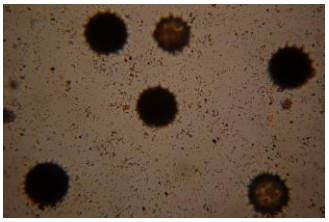
10c. Pollen grains of F_5 segregants



10c (1)Pollen grains of F_5-1



10c (2) Pollen grains of F_5-3



10c (3) Pollen grains of F_5-7

Plate 10. Pollen grains of parents and segregants in the F_5 generation showing fertile and sterile pollen grains

Table 15. Estimation of pollen fertility in parents and F_4 segregants

F_4 families / parents	Pollen stainability (%)	F_5 families / parents	Pollen stainability (%)
P1	98.05	P1	99.5
P2	98.4	P2	99.9
T2	85.75	T2	95.8
T3	88.35	T3	92.27
T4	86.5	T4	89.8
T5	91.2	T5	95.27
T6	93.35	T6	93.8
T7	88.7	T7	91.4
T8	93.65	T8	87.53
T9	91.5		
T10	90.15		
T11	92.5		
T12	93.9		
T13	91.55		
T14	90.65		
T15	89.25		

Sel-1 (F_5-1)

Sel-2 (F_5-3)

Sel-3 (F_5-7)

Sel-4 (F_5-9)

Sel-5 (F_5-20)

Sel-6 (F_5-26)

Plate 11. Promising segregants from F_5 generation

Table 16. Details of the quantitative and qualitative characters expressed by the selections in F_5 generation in comparison with parents

Sl. No	Characters	Sel-1 (F_5-1)	Sel-2 (F_5-3)	Sel-3 (F_5-7)	Sel-4 (F_5-9)	Sel-5 (F_5-20)	Sel-6 (F_5-26)	P1 *A.c**	P2 *A.e**
1	Quantitative Characters								
	Plant Height (cm)	85	97	72	55	90	82	67.7	47.7
	Internodal length (cm)	3.5	3.7	3	3.5	4	4	4.5	4
	No. of primary branches	3	2	4	2	3	3	2.7	2.3
	Length of epicalyx segment (cm)	2	1.8	2.6	2.5	2	1	1.4	2.1
	Width of epicalyx segment (cm)	0.9	0.6	0.5	0.5	0.4	0.1	0.57	0.2
	Petiole length (cm)	30	21	31	25	20	19.5	22.1	27.8
	Days to flower	52	40	47	48	52	46	54.6	46.7
	Days to first harvest	57	46	52	53	58	51	60.3	52
	First fruiting node	4	2	1	3	6	4	4	3
	Length of fruit (cm)	17	17.5	20.5	23	21.5	17	17.5	23.3
	Girth of fruit (cm)	8.3	8.4	8.1	9.5	8.5	7.5	8.4	7.5
	Locules per pod	5	5	5	5	5	5	6	5
	No. of fruits per plant	25	22	15	9	11	10	13.3	15.3
	No.of ridges per pod	5	5	5	5	5	5	6	5
	Crop duration (days)	154	151	149	160	153	155	170	154.3
	Yield per plant (g)	282.5	262.8	223	192.5	182.5	172.5	188.9	200.6
	Pollen fertility (%)	97.90	96.50	99.00	97.50	97.00	98.50	99.5	99.9
	YVMV reaction	HR	HR	HR	HR	HR	HR	HR	HS
2	Qualitative characters								
	Pod pubescence	NP	NP	LP	NP	LP	NP	NP	NP
	Leaf margin	DF	DF	DF	NF	NF	DF	NF	DF
	Flower colour	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow	Yellow
	Flower size	Medium	Large	Large	Medium	Small	Medium	Medium	Medium
	Purple throat at base of corolla	Present	Present	Present	Present	Present	Present	Present	Present
	Colour of leaf vein	GWPT	GWPT	GWPT	GWPT	GWPT	GWPT	GWPT	GWPT
	Colour of fruit	DG	G	DG	DG	LG	G	G	LG

G-Green DG- Dark Green LG- Light Green

HR- Highly Resistant GWPT- Green with purple tinge DF-Deeply fid

NP- Not pubescent LP- Less pubescent NF- Narrowly fid

HS-Highly susceptible *A.c- A. caillei* *A.e- A. esculentus*

yield (Table 16). These selections also showed considerably good amount of pollen fertility and resistance to YVMV. So these selections can be further advanced to develop YVMV resistant varieties combined with other desirable traits.

Discussion

5. DISCUSSION

The present study aimed at evaluating the genetic variability in the F_4 and F_5 generations of the cross *A.caillei* variety Susthira x *A.esculentus* variety Salkeerthi and also to identify disease resistant high yielding segregants from these generations. In interspecific hybridization programmes, progenies developed from the crosses are expected to exhibit a broad spectrum of genetic variability, there by offering great scope for isolating desirable segregants in the advanced generations. The results obtained are discussed in the following section.

5.1 Evaluation of F_4 families

Majority of the characters studied in the F_4 generation exhibited wide range of variability between the different families (Table 3).

In general, the segregants showed prominent *A.caillei* characters such as winged epicalyx segments, fruit length, more ridges per pod, broad leaves, days to flower etc., rather than expressing recombinants resembling *A.esculentus* variety Salkeerthi. This might be due to the one sided segregation as explained by Kalloo (1988) in several segregating generations of interspecific crosses. The possible reasons for this phenomenon is due to reduced pairing of chromosome, restricted recombination, linkage, gametic and zygotic elimination.

5.2 Genetic parameters in F_4 generation

5.2.1 Variability

An estimate of the magnitude of variability present in a population is of great importance as it provides basis for effective selection. The observed variability in a population is the total variation arising due to the genotypic and environmental effects. But only the genotypic component of total variability contributes to gain under selection. So knowledge of the nature and magnitude of genetic variation

governing inheritance of quantitative characters like yield and its components is essential (Allard, 1960). In okra great variability in qualitative and quantitative characters had been observed by many workers like Vashista *et al.* (1982); Hamon and Charrier (1983); Hamon *et al.* (1991) and Ariyo (1993).

Length of fruit, number of fruits per plant, plant height, petiole length, days to flower, days to first harvest, crop duration, yield per plant and pollen sterility exhibited considerable variability. Murthy and Bavaji (1980) also reported considerable variability for length and number of fruits and yield per plant. Vashista *et al.* (1982) observed significant difference for yield and agronomic characters. Jeyapandi and Balakrishnan (1992) observed highest variability for yield per plant followed by plant height. Bhindu *et al.* (1997) observed wide range of variation for most of the traits including fruit length, days to first flower, plant height and fruit weight per plant. Significant variation among six parental strains and their 30 F_1 hybrids was reported by Rajani and Manju (1997) for days to flower, fruits per plant, length of fruit, yield per plant and plant height. Yassin and Anbu (1997) observed wide variability for plant height, fruits and yield per plant but not for girth of fruits.

Significant variability was observed for all characters studied in F_2M_2 and F_3M_3 families by John (1997) and John *et al.* (1999) and in F_4M_4 and F_5M_5 families by Philip (1998). Twenty two okra genotypes exhibited wide variation for plant height, days to first flower, fruits per plant and yield (Hazra and Basu, 2000). Philip *et al.* (2000) observed significant variation for fruits per plant. Gandhi *et al.* (2001) observed significant variability for plant height, fruits per plant, length of fruits and yield per plant.

Variation was low for ridges per fruit, first fruiting node, number of primary branches and length and width of epicalyx segments. Hazra and Basu (2000) also reported low variation for ridges on fruits and first flowering node.

5.2.2 Coefficient of variation

Variability is also expressed as the coefficient of variation. Phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) are better indices for comparison of characters with different units of measurements. The GCV provides a valid basis for comparing and assessing the range of genetic diversity for quantitative characters and PCV measures the extent of total variation. GCV is a better tool to understand useful variability as it is free from the environmental component affecting variability. In the present study GCV and PCV for all characters are presented in Fig 2.

The magnitude of PCV was higher than GCV for all the treatments suggesting the role of environmental variance. Duration of crop, days to first flowering and number of ridges per fruit recorded low values for genotypic and phenotypic coefficients of variation. The low variability noticed for these characters indicate the difficulty in improving these characters by selection. Balachandran (1984) and Sheela (1994) observed very low genotypic coefficient of variation for days to flowering but Rao (1972) observed high genetic variability for the character. John (1997) reported low degree of genetic variability for all the above characters.

GCV and PCV were high for pollen sterility, length of fruit, length and width of epicalyx segments, number of fruits per plant and days to first flowering .According to Balachandran (1984) number and yield of fruits had high PCV and GCV. High PCV was observed for fruits per plant (Lakshmi *et al*. 1996). GCV was high for fruits per plant, fruit length and plant height while low for fruit girth (Bindhu *et al.*,1997). Rajani and Manju (1999) reported that PCV and GCV were low for fruit girth. Philip (1998) noticed high PCV and GCV for YVM disease index. GCV was moderate for plant height (Hazra and Basu, 2000). Dhankar and Dhankar (2002) noticed high PCV and GCV for branches, number of fruits and plant height.

Sindhumole (2003) observed high PCV and GCV for most of the traits including yield and its major components. However GCV was moderate for fruit

girth, ridges and seeds per fruit and leaf axil bearing first flower but low for plant duration and YVM incidence at 30 days after sowing.

5.2.3 Heritability and Genetic Advance

While evaluating more than one character, their interrelations also have to be worked out. The parameters like heritability and genetic advance are unavoidable. The phenotypic variance which is due to genotypic variance is expressed in heritability. The magnitude of improvement through selection programme is detected by genetic advance. High heritability together with high genetic advance is an important requirement for selection programme.

Selection acts on genetic differences and gains from selection for a specific character depend largely on the heritability of the character (Allard, 1960). Heritable variation may be efficiently used with greater degree of accuracy when heritability is studied on conjunction with genetic advance (Majumdar *et al.*, 1974).

High heritability along with high genetic advance was shown by height of the plant and yield per plant. This indicates the presence of additive genes and shows that these characters can be improved by selection. Such results were also obtained by Mishra and Chhonkar (1979), Murthy and Bavaji (1980), Reddy *et al*. (1985) and Ariyo (1990).

High heritability was observed for days to first flowering, first fruiting node and medium for plant height, number of fruits per plant and fruit yield per plant which indicates that the environment plays a little role in inheriting these traits to progenies. In comparison with other characters, moderate genetic advance was noticed for these characters which indicate additive gene effects to provide a rapid genetic improvement. This result is in accordance to the findings of Singh and Singh (2006).

Dakahe *et al*. (2007) reported that the estimates of heritability (bs) were of high magnitude for green fruits per plant, plant height and days to maturity indicating

the major role of genotype and ultimately less environmental influence. Similar results were reported by Thaker *et al*. (1981) for plant height and fruit yield per plant and Jeyapandi and Balakrishnan (1992) for fruit yield, plant height and days to maturity.

5.3 Correlation in F_4 generation

Information regarding association of characters like growth, earliness, yield and its component characters is very useful for plant breeder in developing commercial variety or hybrid. Many of these characters are interrelated in desirable and undesirable direction. Correlation studies measure the mutual relationships between various characters and help in determining the component characters on which selection can be based. The efficiency of selection mainly depends upon the direction and magnitude of correlation between the different characters studied. Correlation analysis provides reliable information on nature, extent and direction of selection. The phenotypic and genotypic correlation coefficients were worked out among the different characters to gather information on the association of the characters.

The results on correlation indicated similar trend in genotypic and phenotypic correlation (Table 5). It was noted that days to flower and first fruiting node were negatively correlated with fruit yield per plant. These results are in conformity with the findings of Korla and Rasthogi (1978) and Patel and Dalal (1994).Alex (1988) and John (1997) reported significant negative correlation for days to first flowering with length of fruit.

Significant positive phenotypic and genotypic correlation with yield was shown by fruit length and fruits per plant indicating that an improvement of these characters will produce a simultaneous improvement in yield. This had also been reported by Chacko (1996); Antur (1999) and Bhalekar *et al*. (2005)

The positive correlation of number of fruits per plant with yield has been stressed by Arumugham and Muthukrishnan (1981). Balachandran (1984) suggested the importance of fruit number per plant as a selection criterion for increasing yield. Ariyo (1992) and Sheela (1994) also observed strong positive association between number of fruits per plant and weight of fruits per plant. Singh and Singh (2006) reported the same with fruit yield and girth of fruit.

Nodes at first flowering had positive and significant correlation with days to first flowering. This result is in accordance with the findings of Singh and Singh (2006).

5.4 Evaluation of F_5 families

Most of the characters studied in the F5 generation exhibited significant variation among the families. The cultivated parent had the lowest mean value for first fruiting node. Segregants resembled the wild parent with respect to this character. This result is in accordance with the findings of Sheela (1994) and John (1997).

Some of the F5 segregants showed characters similar to the cultivated species *A. esculentus* line Salkeerthi such as less number of ridges per pod, longer fruit length, reduced width of epicalyx segment etc. This shows that the one sided segregation as expressed in the F_4 generation is getting broken in the F_5 generation.

Total yield per pant was positively and significantly correlated with number of fruits per plant. The yield was also positively and significantly correlated with fruit length. Similar results had been reported by Kohle and Chavan (1967), Mahajan and Sharma (1979), Vashista *et al.*(1982), Sivagamasundhari *et al.* (1992),Sheela (1994), Das and Mishra (1995), Dhankar and Dhankar (2002) and Dakahe *et al.* (2007).

Total yield had negative and significant association with number of locules per fruit as observed by Sood *et al.* (1995) and days to flowering according to Majumdar *et al.* (1974) in okra.

Fruit length had positive association with number of primary branches per plant. This result is in accordance with the findings of Singh and Singh (2006).

5.5 Genetic parameters in F_5 generation

High phenotypic and genotypic coefficients of variation were exhibited by incidence of YVMV. Kaul *et al.* (1979) and Alex (1988) observed high genotypic coefficient of variation for incidence of YVMV, but Mathews (1986) and John (1997) reported low phenotypic and genotypic coefficient of variation for YVMV incidence.

Days to first flowering, girth of fruit and duration of the crop exhibited low phenotypic coefficient of variation. John (1997) also observed low genotypic and phenotypic coefficients of variation for these characters.

Number of branches per plant recorded comparatively low heritability and low genetic advance indicating high environmental influence on this trait. John (1997) noticed high heritability and high genetic advance for this character.

Duration of the crop and days to first flowering recorded high heritability but low genetic advance. Sheela (1994) also observed high heritability but low genetic advance for days to flowering and John (1997) reported moderately high to high heritability for crop duration.

5.6 Correlation in F_5 generation

The magnitude and direction of association among the 18 characters studied in the F_5 generation were assessed by means of correlation analysis (Table 13).

Significant negative association was observed between number of branches, fruit length, yield per plant and locules per pod. Arumugham and Muthukrishnan (1979) reported that there was significant association between number of branches, YVMV disease reaction, plant height, days to flowering, fruit length , fruit girth and number of fruits per plant.

Number of fruits per plant is positively correlated with yield. The same result was also obtained by Arumugham and Muthukrishnan (1981). Balachandran (1984)

and Mishra and Singh (1985) suggested the importance of fruit number per fruit as a selection criterion for increasing yield.

There was significant negative association between YVMV disease reaction and days to flowering. Mathews (1986) reported that significant negative association between the intensity of mosaic incidence and days to flowering.

Days to first flowering was negatively correlated with number of fruits per plant. This is in accordance with the findings of Alex (1988).

Yield per plant was positively correlated with length of fruit, petiole length, number of fruits per plant and duration of crop. Significant positive association of fruit yield per plant with number of fruits per plant has been reported by several workers (Mahajan and Sharma, 1979; Elangovan *et al.* 1980; Vashista *et al.* 1982; Mathews 1986; Alex, 1988; Ariyo, 1992; Sheela, 1994 and John, 1997).

Nodes at first flowering had positive and significant correlation with days to first flowering. This result is in accordance with the findings of Sriramachandramurthy and Bavagi (1980), Parthap *et al.* (1979) Singh and Singh (2006).

5.7 Screening for YVMV resistance in the F_4 and F_5 segregants

In the field screening trials the *A. esculentus* line Salkeerthi was highly susceptible to YVMV (CI=79.93) where as *A. caillei* variety Susthira was highly resistant (CI=0.67). This observation is in accordance with the findings of Sureshbabu *et al*. (2002). In F_5, most of the segregants were highly resistant and some were moderately resistant (CI=0.87 to 14.01) to YVMV. This result is in agreement with Cheriyan (1986) and Philip (1988). The occurrence of individuals having gradation in the level of resistance to YVMV in the F_5 segregants shows that the genetic mechanism of resistance to this disease may be polygenic. Similar type of gene action for resistance to YVMV has been reported by Charrier, 1984. The occurrence of highly YVMV resistant advanced generation lines (F_5) clearly shows

that the flow of desirable genes from the semi-wild species *A. caillei* to the cultivated species *A. esculentus* has been successful. Thaker *et al*.(1981), Jambhale and Nerkar(1983), Sureshbabu and Dutta (1990) and Philip (1988) have reported similar type of gene introgression in okra.

5.8 Pollen fertility studies in parents and segregants

The pollen fertility studies in the parental species showed that they were almost 100 per cent fertile obviously due to their regular chromosome behavior during meiosis. Pollen stainability in the F_4 segregants varied from 85.75 to 93.9 per cent. The desirable selections from F_4 families viz., F_4-2, F_4-5, F_4-8, F_4-13, F_4-15, F_4-16, and F_4-20 showed pollen fertility in the range of 93.8 to 96.8 per cent. In the case of F_5 families pollen fertility ranged from 87.53 to 95.8 per cent. The promising lines selected from F_5 families viz., F_5-1, F_5-3, F_5-7, F_5-9, F_5-20 and F_5-26 showed pollen fertility in the range of 96.5 to 99 per cent.

Pollen fertility studies in the segregating generations showed that still some amount of sterility exist in the segregating generations. This is obviously due to the cytological irregularities during meiosis as reported by Pal *et al*. (1952); Stebbins (1958) and Arumugham *et al*. (1975). It was also observed that the level of pollen fertility was increased in the F_5 families in comparison with that in the F_4 families. This indicated that the degree of sterility is decreasing in the succeeding generation and provide scope for securing fully fertile advanced generation lines combined with desirable traits. Similar results have been reported by Jambhale and Nerkar(1983); Suresh babu and Dutta (1990).

5.9 Selection of desirable segregants in F_4 and F_5 generation

In the present study F_4 and F_5 segregants raised out of the cross *A. caillei* x *A. esculentus* were evaluated in an attempt to develop YVMV resistant genotypes combining desirable agronomic traits. Among F_4 families, seven selections viz., F_4-2,

F_4-5, F_4-8, F_4-13, F_4-15, F_4-16, and F_4-20 were made. Further advancing the generation and raising the F_5 families promising selections viz., F_5-1, F_5-3, F_5-7, F_5-9, F_5-20 and F_5-26 were made. The prominent features of these F_4 and F_5 selections were that they expressed high level of resistance to YVMV (CI=0.87 to 14.01), high pollen fertility (87.53 to 95.8 per cent in F_4 and 93.8 to 96.8 per cent in F_5) and prominent morphological characters of *A. esculentus*. This clearly shows that breeding programme of developing YVMV resistant okra genotypes with desirable qualitative and quantitative traits has proceeded in the right direction. Further advancing these selections made from F_5 families will definitely result in development of high yielding and YVMV resistant okra varieties in the near future.

Summary

6. SUMMARY

Okra has captured a prominent position among the vegetables due to its year round cultivation, export potential and high nutritive value. However many of the okra cultivars now in vogue are highly susceptible to YVMV disease which reduces the yield considerably. Hence it is essential to evolve varieties resistant to YVMV disease. The present investigation was undertaken in the Department of Olericulture, College of Horticulture, Thrissur, during 2007-2008. The main objective of the study was to identify the promising segregants in F_4 and F_5 generations of the cross *Abelmoschus caillei* variety Susthira x *Abelmoschus esculentus* variety Salkeerthi and to select the high yielding YVMV resistant lines from those segregating populations and also to study the variability.

The F_4 plants were raised in the field along with their parents and were further advanced to F_5 generation. The morphological traits of parents and the segregants were compared. The evaluation of YVMV resistance in the parents and the segregants was made by field screening and artificial inoculation by grafting technique. The disease incidence and disease severity were assessed for all the genotypes.

Evaluation of the F_4 families

Significant variability was present for most of the characters studied in the F_4 families. Delayed flowering and fruiting at higher nodes compared to the cultivated parent were noted in majority of the families. The families in general showed higher pollen sterility compared to the parents.

The phenotypic and genotypic coefficients of variation were maximum for length of fruits, length and width of epicalyx segments and pollen sterility suggesting the suitability of these traits for selection.

High heritability was observed for most of the characters studied. Days to first flowering, length of fruit and yield per plant recorded high heritability and genetic advance indicating effective yield improvement through selection of these characters.

Yield of fruits per plant was significantly and positively correlated with number of fruits per plant, length of fruit and crop duration. All these characters have significant positive correlation among themselves, which indicates ample scope for yield improvement through selection for these characters.

Selection of promising segregants from F_4 population

The F_4 generation plants showed good amount of variability with respect to plant, leaf, flower and fruit characters. The F_4 generation plants were morphologically more similar to semi wild parent *A. caillei*. However seven selections F_4-2, F_4-5, F_4-8, F_4-13, F_4-15, F_4-16, and F_4-20 having more fruit length ranging from 17cm to 24cm and desirable number of ridges per fruit could be selected. These selections showed considerably good amount of fertility and resistance to YVMV. Hence these selections were raised in the field to advance to F_5 generation.

Evaluation of F_5 families

All the families in the F_5 generation exhibited significant variation for the different characters studied.

An increase in the pollen fertility was noted in the F_5 generation. The fruiting phase and duration of all the F_5 families were longer than the cultivated parent. The plant height of the progenies in the F_5 population excelled both the parents.

Incidence of YVM disease was much lower in the families compared to the cultivated parent. The PCV and GCV were maximum for incidence of YVMV disease whereas duration of the plant and petiole length exhibited low variation.

High heritability and genetic advance were noted for crop duration, coefficient of infection of YVMV and plant height. Number of primary branches per plant recorded comparatively low heritability and genetic advance suggesting the predominant role of environment on the expression of this character.

Fruit yield per plant recorded significant positive correlation with number of fruits per plant and crop duration thereby indicating the plant and fruit characters that should be considered while selection for yield improvement.

Pollen fertility studies

The pollen fertility studies revealed that the parents *Abelmoschus caillei* variety Susthira and *Abelmoschus esculentus* variety Salkeerthi had higher fertility per cent compared to the segregants (98.05 and 98.4 in the F_4 generation and 99.5 and 99.9 in the F_5 generation respectively). The fertility per cent of the segregants ranged from 85.75 to 93.90 in the F_4 and 87.53 to 95.8 in the F_5 generations. The high level of pollen fertility in the parents must be attributed to their regular chromosome pairing during meiosis. An increase in fertility per cent was noticed in the F_5 generation as compared to the F_4 generation attributed to their more stable meiosis.

Screening for resistance to YVMV

The parental species and the segregants were screened for YVMV resistance. In the F_4 generation, field screening trial for resistance to YVMV showed that the parent *A.esculentus* as susceptible (CI=71.9), while the other parental species *A. caillei* and all the 14 F_4 segregants were completely free of YVMV.

In the F_5 generation, *Abelmoschus esculentus* variety Salkeerthi showed severe infection of YVMV with a CI of 79.93 whereas *Abelmoschus caillei* variety Susthira showed very mild infection of 0.67 only. F_5 segregants showed CI of 0.87 to 14.01.

Artificial inoculation of YVMV by grafting, diseased *A.esculentus* with selected F_4 and F_5 segregants at 30 day old seedlings did not show any symptom of YVMV however symptoms were observed on newly emerged leaves of susceptible variety 'Salkeerthi'. It is clearly evident from both the field screening and graft inoculation studies that the segregants are highly resistant to YVMV.

Selection of promising segregants from the F_5 population

Six segregants viz., F_5-1, F_5-3, F_5-7, F_5-9, F_5-20 and F_5-26 showed characters such as less number of ridges per pod, longer fruit length, reduced width of epicalyx segment etc similar to the cultivated species *A. esculentus* line Salkeerthi. Their fruit lengths ranged from 17-21.5cm and were having green pods with five ribs. They were also having more number of fruits per plant and high yield. These selections also showed considerably good amount of fertility and resistance to YVMV.

In F_5 generation, majority of the lines exhibited increase in the mean values for the economically important characters and combined high yield with resistance to YVMV disease. The best lines of segregants thus selected from this study can be advanced to further generations to obtain stability for the characters under consideration so that the resultant lines can be released as high yielding YVMV disease resistant varieties.

References

REFERENCES

Alex, R.1988. Progeny studies of interspecific crosses of *Abelmoschus* sp. MSc (Ag) thesis, Kerala Agricultural University, Thrissur, 112p.

Ali, M., Hossain, M.Z. and Sarker, N.C. 2000. Inheritance of Yellow Vein Mosaic Virus (YVMV) tolerance cultivar of okra (*Abelmoschus esculentus* (L.) Moench). *Euphytica* 3 (3) : 205-209

Allard, R.W. 1960. *Principles of Plant Breeding*. John Wiley and sons, New York, 432p.

Amjad, M., Sultan, M., Arjum, M.A., Ayyub, C.M. and Mushtaq, M. 2001. Comparitive study on the performance of some exotic okra cultivars. *Int. J. Agric. Biol*. 3 : 423-425

Antur, S.S. 1999. Variability, correlation, path analysis and genetic diversity in okra. MSc (Ag) thesis BSKKV, Dapoli, 113p

Ariyo, O.J. 1990. Variation and heritability of fifteen characters in okra (*Abelmoschus esculentus* (L.) Moench). *J. Trop. Agric.* 67 (3) : 213-216

Ariyo, O.J. 1992. Factor analysis of vegetative and yield traits in okra (*Abelmoschus esculentus* (L.) Moench) *Indian J. Agric. Sci*. 62 : 83-84

Ariyo, O.J. 1993. Genetic diversity in West African okra (*Abelmoschus caillei*) Steveis multivariate analysis of morphological and agronomic characteristics. *Genet. Resour. Crop Evolution* 40 (1) : 25-32

Ariyo, O.J., Akenova, M.E. and Fatokun, C.A. 1987. Plant character correlation and path analysis of pod yield in okra (*Abelmoschus esculentus* (L.) Moench). *Euphytica* 36 : 677-686

Arumugham, R. and Muthukrishnan, C.R. 1978. Nitrogenous compounds in relation to resistance to yellow vein mosaic disease of okra. *Prog. Hort.* 10(2) : 17-21

Arumugham, R. and Muthukrishnan, C.R. 1979. Evaluation of interspecific hybrid progenies of bhindi. *Madras Agric. J.* 65 : 315-319

Arumugham, R. and Muthukrishnan, C.R. 1981. Association of metric traits in Bhindi. *S. Indian Hort*. 29 (1) : 1-3

Arumugham, R., Chelliah, S. and Muthukrishnan, C.R. 1975. *Abelmoschus manihot* - a source of resistance to bhindi yellow vein mosaic. *Madras Agric. J.* 62(5) : 310-312

Atiri, G.I. and Ibidapo, B. 1989. Effect of combined and single infections of mosaic and leaf curl viruses of okra (*Abelmoschus esculentus)* growth and yield. *J. Agric. Sci.* 112 : 413-418

Atiri, G.I. 1983. Identification of resistance to okra mosaic virus in locally grown okra varieties. *Ann. Appl. Biol*. 102 :132-133

Balachandran, P.V. 1984. Estimation of heterosis in bhindi (*Abelmoschus esculentus* (L.) Moench). MSc (Hort.) thesis, Kerala Agricultural University, Thrissur, 83p.

Balakrishnan, S. and Balakrishnan, R. 1990. Association and path analysis in bhindi (*Abelmoschus esculentus* (L.) Moench). *S. Indian Hort*. 38 (5) : 274-275

*Bates, D.M. 1968. Notes on the cultivated malvaceae *Abelmoschus*. *Baileya* 16 : 99-112

Bhagat, A.P., Yadav, B.P. and Prasad, Y. 2001. Rate of dissemination of okra YVMV disease in three cultivars of okra. *Indian phytopath*. 54 : 488-489

Bhalekar, S.G., Nimbalkar, C.A. and Desai, U.T. 2005. Correlation and path analysis studies in okra. *J. Maharashtra Agric. Univ*. 30 (1) : 109-112

Bhargava, Y.R. 1989. Interspecific hybrid incompatibility in okra. *Plant cell incompatibility Newsl*. 21 : 7-10

Bhindu, K.K. 1993. Genetic divergence in bhindi (*Abelmoschus esculentus* (L.) Moench). M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, 92p.

Bhindu, K.K., Manju, P. and Sreekumar, S.G. 1997. Genetic variability in bhindi (*Abelmoschus esculentus* (L.) Moench).*S. Indian Hort*. 45 : 286-288

Blennerhasset, R.M. and El- Zeftawi, B.M.1986. Productivity and growth of six cultivars. *Aust. J. Exp. Agric*. 26 : 625-629

*Candolle, A.P.De 1883. *Origin Des Plantus Cultivees*. Paris, 150p.

Chacko, R.S. 1996. Genetic improvement and cytogenetical studies in Thamaravenda (*Abelmoschus* manihot). MSc(Hort.) thesis, Kerala Agricultural University, Thrissur, 77p.

Chandran, M. and Rajamony, L. 1997. Interspecific cross compatibility in *Abelmoschus*. *Proc. 9th Kerala Sci. Congr*; January 1997, Thiruvanandapuram, Kerala. pp. 186.

Chandran, M., Rajamony, L., Mohanakumaran, N. and Rajmohan, K.1996. Embryos of interspecific crosses of *Abelmoschus* rescued invitro. *Proc. 2nd int. crop Sci. Congr*. November 17-24, 1996, New Delhi. pp. 165-166

*Charrier, A. 1984. Genetic resources of *Abelmoschus* (Okra) Report : *AGPC/ BPGR / 84/194* (Rome). p. 10-20

Chedda, H.R. and Fatokun, C.A. 1982. Numerical analysis of variation patterns in okra (*Abelmoschus esculentus*(L.) Moench). *Bot. Gaz*. 143 : 253—261

Chelliah, S. and Murukesan, S. 1976. Estimation of loss due to yellow vein mosaic disease in bhindi. *Annamalai Univ. Agric. Res*. P. 167-170

Chelliah, S. and Sreenivasan, K. 1983. Resistance in bhindi, brinjal and tomato to major insect and mite pests. In: *National seminar on breeding crop plants for resistance to pest and diseases*. May 25-27, 1983, Coimbatore, Tamilnadu, pp. 312-314

Cheriyan, D. 1986. Radiation induced variability in Interspecific hybrids involving okra, (*Abelmoschus esculentus* (L.) Moench) and *A. manihot*. MSc (Hort.) thesis, Kerala Agricultural University, Thrissur, 95p.

*Chevalier, A. 1940. L' origine, la culture et les usages decing Hibiscus de la section *Abelmoschus*. *Rev. Bot. Appl*. 20 : 319-328

Chizaki, Y. 1934. Breeding of new interspecific hybrid between *Abelmoschus esculentus* (L.) Moench and *Abelmoschus manihot*. *Proc. Crop Sci. Soc. Japan* 6 : 164-172

Dakahe, K., Patil, H.E. and Patil, S.D. 2007. Genetic variability and correlation studies in okra. *Asian J. Hort*. 2(1) : 201-203

Damarany, A.M. and Farag, I.A. 1994. An evaluation of growth, yield and quality of some okra cultivars and strains under Assiut conditions. *Assiut J. Agric. Sci*. 25 (4) : 57-70

Das, G.B. and Mishra, P.K. 1995. Variation and character association of fruit yield and its components in okra (*Abelmoschus esculentus* (L.) Moench). *Curr. Agric. Res*. 8 : 123- 127

Datar, V.V. and Mayee, C.D. 1981. Assessment of losses in tomato yields due to early blight. *Indian phytopath*. 34: 191-195

Deo, C., Singh, K. P. and Panda, P. K. 2000. Screening of okra parental lines and their F1s for resistance against yellow vein mosaic virus. *Veg. Sci*. 27(1) : 78-79

Dhall, R. K., Arora, S. K. and Rani, M. 2000. Correlation and path analysis in advanced generations of okra okra (*Abelmoschus esculentus* (L.) Moench). *Indian J. Hort*. 57 : 342 – 346

Dhankar, B.S. and Dhankar, S.K. 2002. Genetic variability, correlation and path analysis in okra (*Abelmoschus esculentus* (L.) Moench).*Veg. Sci*. 29 : 63-65

Dhankar, S.K., Saharan. B. S. and Dhankhar, B.S. 1996. Screening of okra genotypes for resistance to yellow vein mosaic disease. *Annu. Biol. (Ludhiana)* 12(1) : 90-92

Dhillon, T. S. and Sharma, B. R. 1982. Interspecific hybridization in okra. *Indian J. Genet. Pl. Breed*. 36 : 247-256

Dobzhansky, T. 1951. *Genetics and the Origin of Species erd Edn*. Columbia Univ. Press., New York, 364p.

Dutta, O.P. 1984. Breeding okra for resistance to yellow vein mosaic virus and enation leaf curl virus. *A. Rep*. Indian Institute of Horticultural Research, Bangalore, India. p. 43

Dutta, O.P. 1991. Okra germplasm utilization at IIHR, Bangalore . *Int. workshop okra genet. resour*. NBPGR, New Delhi. p. 114-116

*Dutta, P.C. and Nang, A. 1968. A few strains of (*Abelmoschus esculentus* (L.) Moench). Their Karyological study in relation to phylogeny and organ development. *Beitr. Biol. Pflanzen*. 45 :113-126

Dutta, P.J. 1999. Performance of lady's finger varieties under typical North Bank Plains Zone conditions of Assam. *J. Agric. Sci. Soc. N.E. India* 12 :128-130

El Macksoud, M.A., Helal, R.M. and Mohammed , M.H. 1984. Heritability estimates and correlation studies on six economic characters in okra. *Ann. Agric. Sci. Ain Shains Univ*. 29 : 439-452

El Macksoud, M.A., Helal, R.M. and Mohammed , M.H. 1986. Studies on an intervarietal cross and hybrid vigour in okra. *Ann. Agric. Sci*. 29 : 431-438

Elangovan, M., Muthukrishnan, C.R. and Irulappan, I. 1980. A study of correlation analysis in bhindi (*Abelmoschus esculentus*(L.) Moench). *S. Indian Hort.* 28 : 28-30

Fageria, M.S., Arya, P.S., Kholi, U.K. and Kumar, J. 1992. Correlation studies of yield traits of okra (*Abelmoschus esculentus*(L.) Moench) var Pusa Sawani. *J. Res. APAU* 14 : 255-257

Fatokun, C.A. 1987. Wide hybridization in okra. *Theoretical and Applied Genetics* 74 : 483-486

Fugro, P. A. and Rajput, J. C. 1999. Breeding okra for yellow vein mosaic virus resistance. *J. Mycol. Pl. Pathol*. 29(1) : 25-28

Gadwal, V.R., Joshi, A.B. and Iyer, R.D.1968. Interspecific hybrids of *Abelmoschus* through ovule and embryo culture. *Indian J. Genet.Pl. Breed*. 28 : 269-274

Gandhi, H.T., Yadav, M.D. and Navale, P.A. 2001. Studies on variability in okra (*Abelmoschus esculentus*(L.) Moench). *J. Maharashtra Agric. Univ*. 26 : 146-148

Gill, A.S., Verma, M.M., Dhaliwal, H.S. and Sandhu, T.S. 1983. Interspecific transfer of resistance to mungbean yellow mosaic virus from *Vigna mungo* to *Vigna radiata*. *Curr. Sci*. 52 : 31-33

Gondane, S.U., Bhatia, G.L. and Parthap, P.S. 1995. Correlation studies of yield components in okra (*Abelmoschus esculentus*(L.) Moench). *Haryana J. hort. Sci*. 24 : 151-156

Gondane, S.U. and Lal. G. 1994. Genetic studies in okra (*Abelmoschus esculentus*(L.) Moench). *Ann. Pl. Physiol*. 8 : 96-98

Goswami, B. K. and Bhagavathy, K.N. 1992. Natural incidence of yellow vein mosaic virus disease in bhindi in relation to different dates of sowing. *J. Assam Sci. Soc*. 34(2) : 19-24

Grubben, G.J.H. 1977. Okra In: *Tropical vegetables and their genetic resources*. IBPGR, Rome, pp 111-114

Hamon , S. and Charrier, A. 1983. Large variation of okra collected in Benin and Togo. *Plant Genetic resources Newsl*. 56 : 52-58

Hamon , S., Charrier, A., Koechlin, J. and Stoten, D.H. 1991. Potential improvement of okra (*Abelmoschus* spp.) through the study of its genetic resources. *Plant Genet. resour. Newsl*. 86 : 9-15

Hazra, P. and Basu, P. 2000. Genetic variability, correlation and path analysis in okra. *Ann. Agric. Res*. 21 : 452-453

Horvath, J. 1984. Virus resistance of species and varieties of peppers: incompatible host virus reaction. *Kertgazdasag* 16 : 93-95

Hossain, M. and Chattopathyay, T.K. 1976. Morphological features and resistance to yellow vein mosaic virus disease of F1 interspecific hybrids of *Abelmoschus* sp. *Plant Sci*. 8 : 49-51

Hussein, H.A. 1994. Variation, heritability and response to selection in okra. *Assiut J. Agric. Sci*. 25 : 193-202

Indurani, C. 1999. Studies on the development of F1 hybrids in okra (*Abelmoschus esculentus*(L.) Moench) with high yield and resistance to YVMV. MSc (Hort.) thesis, Tamilnadu Agricultural University, Coimbatore, p141

Jain, J.P. 1982. *Statistical Techniques in Quantitative Genetics*. Tata Mc Graw Hill Publishing Company, New Delhi, 103p.

Jaiprakashnarayan, N.P and Mulge, R. 2004. Correlation and path analysis in okra (*Abelmoschus esculentus* (L.) Moench). *Indian J. Hort*. 61(3) : 232-235

Jambhale, N.D. and Nerkar, Y.S. 1982. An induced amphidiploid of *Abelmoschus*. *Indian J. Genet. Pl. Breed*. 42 (3) :372-375

Jambhale, N.D. and Nerkar, Y.S. 1983. Interspecific transfer of resistance to yellow vein mosaic virus disease in okra. *J. Maharashtra. Agric. Univ*. 8 : 197

Jambhale, N.D. and Nerkar, Y.S. 1985. An unstable gene controlling developmental variation in okra. *Theor. Appl. Genet*. 71(1) : 122-125

Jambhale, N.D. and Nerkar, Y.S. 1986. Parbhani Kranti , an yellow vein mosaic resistant okra. *Hort. Sci*. 21 : 1470-1471

Jeyapandi, A. and Balakrishnan, R. 1990. Correlation analysis in bhindi. *S. Indian Hort*. 38 : 83-85

Jeyapandi, A. and Balakrishnan, R. 1992. Genetic variability in okra. *Indian J. Hort.* 49 (2) : 197-199

John, S. 1997. Genetic analysis of segregating generations of segregating generations of irradiated interspecific hybrids in okra (*Abelmoschus esculentus* (L.) Moench) MSc (Ag) thesis, Kerala Agricultural University, Thrissur, 161p.

John, S., Manju, P., Gopimony, R. and Saraswathy. P. 1999. Variability studies in F3 generation of irradiated interspecific hybrids in okra (*Abelmoschus esculentus* (L.) Moench). *S. Indian Hort*. 47 : 210-212

Jose, J. and Usha, R. 2003. Bhindi yellow vein mosaic disease in India caused by association of a DNA beta satellite with a begomo virus. *Virol.* 305 : 310-317

Joshi, A.B and Hardas, M.W. 1956. Alloploid nature of okra, (*Abelmoschus esculentus* (L.) Moench). *Nature* 178 : 1190-1191

Joshi, A.B., Gadwal, V.R. and Hardas, M.W. 1974. Okra evolutionary studies in world crops diversity and changes in the Indian subcontinent Hutchinson, J. B. (Ed Cambridge) pp 99-105

Joshi, A.B., Singh, H.B. and Joshi, B.S. 1960. Why not grow Pusa Sawani? *Indian Fmg*. 10 : 6-7

Kale, P.B., Dod, V.N. and Tapar, R.R. 1989. Variability and correlation studies in okra. *PKV Res. J.* 13 : 1-5

Kale, P.B., Dod, V.N. and Gonge, V.S. 1986. Importance of vegetables and its prospects for improvement in India. *Vegetable crops in India*. (eds. Bose, T.K. and Som, M.G.). Nayaprakash, 206, Bidhan Sarani, Culkutta, India. pp.5-7

Kalloo, G. 1988. *Distant Hybridization in Vegetable Crop Species*. *Vegetable Breeding Vol. 11*, CRC press Inc. Florida, 148p.

Kalloo, G. and Banerjee, M.K. 1990. Transfer of Tomato leaf curl resistance from *Lycopersicon hirsutum f. glabratum to L. esculentum. Pl. Breed*. 105 (2) : 156-159

Kapoor, S.P. and Varma, P.M. 1950. Yellow vein mosaic of *Abelmoschus esculentus* L. *Indian J. Agric. Sci*. 20 : 217-230

Kaul, T., Lal, G. and Peter, K.V. 1979. Correlation and path coefficient analysis of components of earliness, pod yield and seed yield in okra. *Indian J. Agric. Sci*. 48 : 459-463

Kaul, T., Lal, G. AND Peter, K.V. 1979. Correlation and path coefficient analysis of components of earliness, pod yield and seed yield in okra. *Indian J. Agric. Sci*. 48 : 459- 463

KAU[Kerala Agricultural University]. 2007. KAU home page [online]. Available: http://www.kau.edu/varieties.htm. [06 June.2007]

Khan, M.A.1983. Studies on Yellow Vein Mosaic Disease of bhindi (*Abelmoschus esculentus*(L.) Moench) Ph.D. thesis, B.C.K.V. 247p.

Kohle, A.K. and Chavan, V.M. 1967. Development of fruit yielding capacity and influence of fruit maturity on the reproductive and vegetative behavior in okra (*Abelmoschus esculentus*(L.) Moench). *Indian. J. Agric. Sci*. 37 : 155-166

Kondaiah, G.M., Kulkarni, U.G. and Nerkar, Y.S. 1990. The evolution of West African cultivated Guinean okra. Further Evidence. *J. Maharashtra Agric. Univ*. 15(1) :65 - 68

Korla, B.N. and Rasthogi, K.B. 1978. Correlation and path coefficient analysis and their implication in selection for high fruit yield in bhindi (*Abelmoschus esculentus*(L.) Moench).*Haryana. J. Hort. Sci*. 7 : 83- 85

Korla, B.N. and Sharma,P.P. 1987. Genetic variability in okra. *Haryana J. hort. Sci*. 16 : 165-169

Korla, B.N., Sharma, P.P. and Rasthogi, K.B. 1984. Regression studies in bhindi (*Abelmoschus esculentus*(L.) Moench). *S. Indian Hort.* 32 : 270-274

Kousalya, V. 2005. Introgression of yellow vein mosaic virus resistance from *Abelmoschus caillei* (A.Cher.)Steveis into (*Abelmoschus esculentus* (L.) Moench. MSc (Hort.) thesis, Kerala Agricultural University, Thrissur, 67p.

Kulkarni, G.S. 1924. Mosaic and other related diseases of crops in Bombay presidency. *Poona Agric. Coll. Mag*. 16(1) : 6-12

Kumbhani, R.P., Godhani, P.R. and Fougat, R.S. 1993. Hybrid vigour in eight parent diallel crosses in okra (*Abelmoschus esculentus*(L.) Moench). *GAU Res. J*. 18(2) : 13-18

Kuwada, H. 1961. Studies on the interspecific crossing between *Abelmoschus esculentus*(L.) Moench and *Abelmoschus manihot* (L.) Medikis and the various hybrids and polyploids derived from the above two species. *Fac. Agic Kahgawa Univ. Mem.* 8 : 91

Kuwada, H. 1966. The new amphidiploid plant named *Abelmoschus tuber- esculentus* obtained from progeny of the reciprocal crossing between *A. tuberculatus* and *Abelmoschus esculentus . Jap. J. Breed.* 16 (1) : 21-30

Lakshmi, G.V., Ravishankar, C. and Prasad, O.M. 1996. Variability, correlation and path coefficient analysis in okra (*Abelmoschus esculentus*(L.) Moench). *Andhra Agric. J.* 43 : 16-20

Lal, G., Singh, D.K. and Jain, S.K. 2001. Response of okra (*Abelmoschus esculentus*(L.) Moench) cultivars to varying sowing dates under Tarai foot hills of Himalayas. *Adv. Hort. For.* 8 : 129-137

Langaroodi, H.M. and Kazerani, N. 1999. Study on the yield of okra cultivars. *Seed Pl.* 15 : 68-69

Madhusoodanan, K.J. and Nazeer, M.A. 1986. Origin of Guineen type of okra (*Abelmoschus*) and its nature of resistance to yellow vein mosaic virus disease. *Cytologia* 51 : 753-756

Mahajan, Y.P and Sharma, B.R. 1979. Parent offspring correlations and heritability of some characters in okra. *Sci. Hortic.* 10 : 135-139

Majumdar, M.K., Chatterjee, S.D., Bose, P. and Bhattacharya, D.1974. Variability interrelationship and path coefficient analysis for some quantitative characters in okra (*Abelmoschus esculentus*(L.) Moench). *Indian agric*. 18 : 13-20

Mamidwar, R.B., Nerkar, Y.S and Jambhale, N.D. 1980. Cytogenetics of interspecific hybrids in the genus *Abelmoschus*. *Indian J.Hered*. 11(2) : 35-40

Mandal, M. and Dana, I. 1994. Phenotypic stability of okra (*Abelmoschus esculentus*(L.) Moench). *Env. Biol*. 12 : 396-398

Manjuchandran, M 1996. Embryo rescue in the Interspecific crosses of *Abelmoschus* M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, 82p.

Markose, B.L. and Peter, K.V. 1990. *Review of Research on Vegetables and Tuber crops-Okra*. Directorate of Extension, Kerala Agricultural University, Thrissur, p109.

Martin, F.W. 1982. A second edible okra species and its hybrids with common okra. *Ann. Bot*. 50(2) : 277-283

*Masters, M.T. 1875. In: *Flora of British India* (Ed. Hooker, J.D.) Ashford Kent.1 : 320-348

Mathews , S.K., Vahab, M.A., Devadas ,V.S. and Cherian, A. 1993. Evaluation of selected varieties of okra for yield and resistance to yellow vein mosaic. *J. Trop. Agric*. 31(2) : 215-218

Mathews, H. 1986. Evaluation of the F2 generation of interspecific hybrids of *Abelmoschus* with reference to yellow vein mosaic resistance and yield. . MSc (Ag) thesis, Kerala Agricultural University, Thrissur, 112p.

Mazumder, N., Barthakur, U. and Chowdhury, D. 1996. Incidence of yellow vein mosaic of okra in relation to cultivar and vector population under different sowing dates. *Indian J. Virology*. 12(2) : 137-141

Medikus, F.K.1787. Ueber einige Kunstliche Gosch Lechter aus der Malven familie, denn der klasse der Monadelphien. *Mannheion* 45-46

Meghwal, P.R. and Khandelwal, R.C. 1994. Studies on coefficients of variation and heritable components of some quantitative characters in okra (*Abelmoschus esculentus*(L.) Moench). *Prog. Hort.* 26 : 57-61

Mehram, L.D. and Dhapke, D.K. 1981. Cytogenetical studies on the interspecific hybrid between (*Abelmoschus esculentus*(L.) Moench) x *Abelmoschus tetraphyllus. Proc. 4th Int. Congr*. SABRAO p.4-8

Mishra, R.S and Chhonkar, V.S. 1979. Genetic divergence in okra. *Indian J. Agric. Sci.* 49 (4) : 247-249

Mishra, R.S. and Singh, D.N. 1985. Correlation and path coefficient analysis in okra. *S. Indian Hort.* 33 : 360-366

Mishra, R.S. and Singh, D.N. 1992. Interrelationships in some quantitative traits in okra. *Indian J.Agric. Res*. 3 : 6-8

Mishra, R.S. Rath, U.K. and Sahu, G.S. 1990. Association of biometric characters in okra. *Orissa J.Agric. Res*. 3(1) : 6-8

Murthy, N.S. and Bavaji, J.N. 1980. Correlation and path coefficient analysis in bhindi. *S. Indian Hort*. 28(4): 35-38

Nair, P.G. and Kuriachan, P. 1976. A spontaneous hybrid between *Abelmoschus tuberculatus and Abelmoschus esculentus*(L.) Moench. *New Botanist* 3: 48-53

Nandi, A. 1990. Performance of some okra varieties in the north eastern ghat zone of Orissa. *Envt. Ecol*. 8 : 471-473

Naraini, T.K. and Seth, M.L. 1958. Reaction of *Abelmoschus* and *Hibiscus* sp. to yellow vein mosaic virus. *Phytopathology*. 11 : 137-143

Nath, P.S., Bhattacharya, P., Mallik, S.C. and Pandit, M.K. 1999. Studies on the incidence of bhindi yellow vein mosaic virus on some selected popular varieties under field conditions. *Veg. Sci*. 26(2) : 157-159

Nerkar, Y.S. and Jambhale, N.D. 1985. Transfer of resistance to yellow vein mosaic from related species into okra (*Abelmoschus esculentus* (L.) Moench)). *Indian J. Genet*. 45(2) : 268-270

Nerkar,Y.S. 1991. The use of related species in transferring disease and pest resistance genes to okra (*Abelmoschus esculentus* (L.) Moench). *Indian J. Agric. Res*. 31(3) : 141-148

Nirmaladevi, S. 1982. Induction of variability in *Abelmoschus manihot* var. Ghana by irradiation. . M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, 85p.

Padda, D.S. 1968. Resistance to virus diseases in some vegetable crops. *Punjab hort. J*. 8(1) : 249-252

Pal, B.P., Singh, H.B. and Swarup, V. 1952. Taxonomic relationships and breeding possibilities of species related to okra (*Abelmoschus esculentus* (L.) Moench). *Bot. Gaz.* 113 : 455-464

Pal, S.S., Dhaliwal, H.S. and Brains, S.S. 1991. Inheritance of reistance to yellow vein mosaic virus in some *Vigna* species. *Pl. Breed*. 106(2) : 168-171

Palaniveluchamy , K., Muthukrishnan, C.R. and Irulappan, I. 1982 Studies in heritability and genetic advance in bhindi. *Madras agric.* J. 69 : 597- 599

Palaniveluchamy , K., Muthukrishnan, C.R. and Irulappan, I. 1983. Variability studies in certain intervarietal cross of bhindi (*Abelmoschus esculentus* (L.) Moench). *Madras Agric. J.* 70 : 102-103

Panda, P.K. and Singh, K.P. 1997. Genetic variability, heritability and genetic advance for pod yield and its contributing traits in okra hybrids. *Madras Agric. J.* 84 : 136-138

Parthap , P.S., Dhankar, B.S. and Gautam, R.B. 1982. Genetics of earliness and quality in okra (*Abelmoschus esculentus* (L.) Moench). *Haryana Agric. Univ.J. Res*. 12 : 433-437

Parthap , P.S., Dhankar, B.S., Pandita, M.L. 1979. Inter-relationship and path analysis studies in okra (*Abelmoschus esculentus* (L.) Moench). *Haryana Agric. Univ.J. Res*. 9 :317-321

Parthap , P.S., Dhankar, B.S., Pandita, M.L. and Dubi, B.S. 1980. Genetic divergence in parents and their hybrids in okra. *Genet. Agraria* 34 : 323-330

Patel, J.N. and Dalal, K.C. 1992. Variability in okra. *GAU Res. J.* 19 : 57-61

Patel, J.N. and Dalal, K.C. 1994. Selection criteria for improving yield in okra. *GAU Res. J.* 18 : 132-134

Patel, S.S., Kulkarni, V.G. and Nerkar, Y.S. 1993. Association studies in okra (*Abelmoschus esculentus* (L.) Moench). *GAU Res. J.* 19 : 162-163

Patil, Y.B. 1995. Studies on genetic divergence, heterosis and combining ability in okra (*Abelmoschus esculentus* (L.) Moench). Ph.D. (Hort.) thesis, University of Agricultural Sciences, Dharwad, 134 p.

Philip, A.M.C. 1998. Genetic evaluation of F4 and F5 generations of irradiated interspecific hybrids in okra. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 85p.

Philip, A.M.C. and Manju, P. 2002. Correlation studies in F5 generation of irradiated interspecific hybrids in okra (*Abelmoschus esculentus* (L.) Moench)) . *Proc. 14th Kerala Congr. January 29-31, 2002*, (Ed. Das, M.R.), Science Technology and Environment Committee, Government of Kerala, Kochi, pp 271-273

Philip, A.M.C., Manju, P. and Rajagopalan, B. 2000. Variability in F5 generation of irradiated interspecific hybrids in okra (*Abelmoschus esculentus* (L.) Moench). *J. Trop. Agric.* 38 :87-89

Pillai, U.P.R. 1984. Evaluation of Interspecific hybrids of bhindi with reference to yellow vein mosaic resistance and heterosis. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 120p.

Prabha, P. 1986. Cross compatibility between (*Abelmoschus esculentus*(L.) Moench) and *Abelmoschus manihot* and hybrid sterility. M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 105p.

Pradeepkumar, T., Suma,B. Jyothibhaskar and K.N. Satheesan. 2008. *Management of Horticultural crops. Horticultural Science Series-11 Part-1*. (eds. Peter, K.V) New India Publishing Agency, New Delhi. pp. 141-142

Pun , K.B. and Doraisami, S. 1999. Effect of age of okra plants on susceptibility to okra yellow vein mosaic virus. *Indian J. Virol*. 15(1) : 57-58

Pun, K.B., Sabitha, D. and Doraiswami, S. 2000. Influence of weather factors on the incidence of okra yellow vein mosaic virus disease. *J. Agric. Sci. Soc. N.E. India*. 13 : 91-96

Pushparajan, G. 1986. Cytotaxonomic studies on South Indian Malvaceae. Ph.D. thesis, Kerala Agricultural University, Thrissur, 185p.

Raghupathy, N., Veeraragavathatham , D. and Thamburaj, S. 2000. Reaction of okra (*Abelmoschus esculentus* (L.) Moench) cultures to bhindi yellow vein mosaic virus (BYVMV) disease. *S. Indian Hort*. 48 : 1-6

Rajani, B. and Manju, P. 1997. Variability studies in okra (*Abelmoschus esculentus*(L.) Moench). *S. Indian Hort*. 45 : 61-62

Rajani, B. and Manju, P. 1999. Gene action in okra (*Abelmoschus esculentus* (L.) Moench). *S. Indian Hort*. 47: 193-195

Ram, H.H. 1998. *Vegetable Breeding – Principles and Practices*. Lalyani publishers Mew Delhi, 121p.

Rameshpathak, R. and Syamal, M.M. 1997. Line x tester analysis for heterobeltiosis for yield and its components in okra. *Punjab Veg. Grower*. 32 : 20-23

Rao, T.S. and Kulkarni, R.S. 1977. Genetic variation in bhindi. *Haryana Agric. Univ. J. Res*. 7 : 58-59

Rao, T.S. and Ramu, P.M. 1981. Genetic parametres and heterosis in 6x 6 diallel cross of bhindi (*Abelmoschus esculentus* (L.) Moench) *J. Res. APAU* 3 : 78-82

Rao, T.S. 1972. Note on the natural variability for some qualitative and quantitative characters in okra. *Indian J. Agric. Sci*. 42 :437-438

Rao, T.S., Ramu, P.M. and Kulkarni, R.S. 1977. Genetic variability and path coefficient analysis in bhindi. *Punjab Hort*. J. 18 : 78-83

Rattan, R.S. and Bindal, A. 2000. Development of okra hybrids resistant to yellow vein mosaic virus. *Veg. Sci*. 27 (2) : 121-125

Ravisankar, J. 2002. Development of yellow vein mosaic virus infection on growth and yield of okra crop. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrissur, 82p.

Reddy, K.R., Singh, R.P. and Rai, A.K. 1985. Variability and association analysis in okra. *Madras Agric. J*. 72(8) : 478-480

Sadashiva, A.T. 1988. Genetics of resistance to yellow vein mosaic virus, yield and yield components in okra (*Abelmoschus esculentus*(L.) Moench). Ph.D. (Hort.) thesis, *Univ. Agric. Sci*. Bangalore, 147p.

Sandhu , G.S., Sharma, B.R., Singh, B. and Bhalla, J.S. 1974. Sources of resistance to jassids and whitefly of okra germplasm. *Crop Improv. Newsl*. p: 77-81

Sangar, R.B.S. 1997. Field reaction of bhindi varieties to yellow vein mosaic virus. *Indian J. Virol*. 13 :131-134

Sastry, K.S. and Singh, S.J. 1974. Effect of yellow vein mosaic virus infection on growth and yield of okra crop. *Indian Phytopath*. 27 : 295-297

Sharma, B. R. and Arora , S.K. 1993. Improvement of okra . *Advances in Horticulture Vol. 5. Vegetable Crops Part 1*. (eds. Chadha, K.L. and Kalloo, G.) Malhothra Publishing House, New Delhi. pp. 343-364

Sharma, B. R. and Dhillon, T.S. 1983. Genetics of resistance to of yellow vein mosaic virus in interspecific crosses of okra (*Abelmoschus* spp.) *Genetica Agraria* 37 : 267-275

Sharma, B. R. and Sharma, O. P. 1984. Breeding for resistance to yellow vein mosaic virus in okra. *Indian J. Agric. Sci*. 54(10) : 917-920

Sharma, B.R. 1982 . Punjab Padmini- a new variety of okra. *Prog. Fmg*. 18 : 15-16

Sheela, M.N. 1994. Induction of genetic recombination in interspecific crosses of *Abelmoschus* . Ph.D. thesis, Kerala Agricultural University, Thrissur, 151p.

Sheela, M.N. 1986. Evaluation of bhindi hybrids for yield and its components. MSc(Ag) thesis, Kerala Agricultural University, Thrissur, 75p.

Shukla, A.K. 1990. Correlation and path analysis in bhindi . *Prog. Hort*. 22 : 156-159

Siemonsuma, J.S. 1982. West African okra- morphological and cytological indications for the existence of natural amphidiploid of (*Abelmoschus esculentus* (L.) Moench) and *Abelmoschus manihot* (L.) Medikar. *Euphytica*. 31(1) : 241-252

Sindhu, S. 1993. Interspecific cross- compatibility in the genus *Abelmoschus*. . M.Sc. (Ag.) thesis, Kerala Agricultural University, Thrissur, 59p.

Sindhumole, P. 2003. Genetic analysis for yield and resistance of Yellow Vein Mosaic in okra (*Abelmoschus esculentus* (L.) Moench). Ph.D. thesis, Kerala Agricultural University, Thrissur, 167 p.

Singh, A.K. and Singh, K.P.2000. Screening for incidence of YVMV in okra (*Abelmoschus esculentus* (L.) Moench) treated with gamma rays and EMS. *Veg.Sci*. 27 (1) : 72-75

Singh, B.N., Chakravarthi, S.C. and Kapoor, G.O. 1938. An interspecific hybrid between *Abelmoschus ficulneus* and *Abelmoschus esculentus*. *J . Hered*. 29 : 37-41

Singh, D.K., Lal, G. and Rai, P.N. 1993. Performance of okra cultivars under Tarai conditions of UP. *Ann. Agric. Res*. 14(4) : 429-433

Singh, H.B., Joshi, B.S., Khanna, P.O. and Gupta, P.S.1962. Breeding for field resistance to YVMV in bhindi. *Indian J. Genet. Pl. Breed*. 22 : 137-144

Singh, I.P. 2000. Study of the production efficiency of okra varieties under western Uttar Pradesh condition. *Bhartiya Krishi Anusandhan Patrika* 15 : 34 -38

Singh, K.P., Panda, P.K. and Deo, C. 2000. Screening of okra parental lines and their F1s for resistance against YVMV. *Veg . Sci*. 27(1) :78-79

Singh, S.P. 1986. Estimation of genetic variances of yield and other characters in okra. *Indian Aricst*. 30 : 245-248

Singh, S.P. and Singh, J.P. 2006. Selection criteria for increased yield in okra (*Abelmoschus esculentus*). *Int. J. Pl. Sci*.1(2) : 209-210

Singh, S.P., Srivastava, J.P. and Singh, H.N. 1975. Heterosis in bhindi (*Abelmoschus esculentus* (L.) Moench). *Prog. Hort*. 7(2) : 5-15

Sinha, S.N. and Chakrabarthy, A.K. 1978. Effect of YVMV infection on okra seed production. *Seed Res*. 6 : 67-70

Sivagamasundhari, J., Irulappan, R., Arumugham, R. and Jayasankar, S. 1992. Combining ability in okra (*Abelmoschus esculentus* (L.) Moench).*S. Indian Hort*. 40 : 21-27

Skovsted, A. 1935. Chromosome numbers in the family Malvaceae. *Indian J. Genet*.31 : 263-296

Sood, S. 1999. Varietal performance of okra (*Abelmoschus esculentus* (L.) Moench)under humid sub- temperate conditions of Himachal Pradesh. *S. Indian Hort*. 47 : 198-199

Sood, S., Arya, P.S. and Singh, Y. 1995. Genetics variability and correlation studies in okra (*Abelmoschus esculentus*). *Sci. Cult*. 35 : 318-319

Soubanbabu, S. and Sharma, B.R. 1983. Relative efficiency of different mating systems for improvement of okra. *SABRAO J. Breed. Genet*. 15 : 125-137

Sriramachandramurthy, N. and Bavaji, J.N. 1980. Correlation and path coefficient analysis in bhindi(*Abelmoschus esculentus*).*S. Indian Hort*. 28: 35-38

*Stebbins, G.L. 1958. Longevity, habit and release of genetic variability in the higher plants. Cold Spring Harb. *Sym. Quart. Biol*. 23 : 365- 378

*Stebbins, G.L., Jr., 1950. *Variation and Evolution in Plants*. Columbia Univ. Press., New York, 643p.

Sujatha, V.S.1983. Morphology of *Abelmoschus* sp. and crossability among them. MSc (Ag) thesis, IARI, New Delhi, 112p

Sureshbabu , K.V. and Dutta, O.P. 1990. Cytogenetic studies of the F1 hybrid (*Abelmoschus esculentus* (L.) Moench) x *Abelmoschus tetraphyllus* and its amphiploid. *Agric. Res. J. Kerala* 28 : 22-25

Sureshbabu , K.V., Gopalakrishnan, T.R., Mathew, S.K. and Rajan, S. 2002. Crop improvement in yellow vein mosaic resistant underexploited okra type of Kerala. *Proc. Int. Conf. on vegetable*. November 11-14, Bangalore. pp 382-383

Sureshbabu , K.V., Gopalakrishnan, T.R. and Mathew, S.K. 2004.Genetic variability, correlation studies, path analysis and reaction to YVMV. In: *Proc. 1st Indian Hort. Congr*. November 6-9, 2004, New Delhi. pp 85-86

Sureshbabu, K.V. 1987. Cytological studies in okra(*Abelmoschus esculentus* (L.) Moench). Ph.D. thesis, *Univ. Agric. Sci.* Bangalore, 147p.

Swami, AV.S.R. and Khanna, V.K. 1991. Pollen grain germination and pollen tube growth following Interspecific pollinations in *Cicer*. *SABRAO* 23 : 137-145

Teshima, T.K.1933. Genetic and Cytological studies in an interspecific hybrid of *Hibiscus esculentus* and *Hibiscus manihot*. *J.Fec. Agric. Hokkoido. Univ*. 34 : 1-155

Thaker, D.N., Tikka, B.S., Patel, K.K. and Ukani, S.J.1981. Analysis of parameters of variability in okra. *Indian J. Hort*. 38 (3) : 232-235

Thakur, M.R. 1976. Inheritance of yellow vein mosaic in a cross of okra species (*Abelmoschus esculentus* (L.) Moench) x *Abelmoschus manihot*. *SABRAO J*. 8 : 69-73

Thakur, M.R. and Arora, S.K. 1988. Punjab-7- A virus resistant variety of okra *Prog.Fmg*. 24 : 13-14

Thamburaj, S. and Kamalanathan, S. 1973. Studies on growth and productivity in bhindi. *Madras agric*. J. 1659-1666

Thangam,M. and Veeraragavathatham, D. 2006. Reaction of segregating populations for tomato leaf curl virus (TLCV) resistance by artificial screening in tomato. *Veg. Sci*. 33(1) : 98-100

Ugale, S.D., Patil, R.C. and Khuspe, S.S. 1976. Cytogenetic studies in the cross between *Abelmoschus esculentus* (L.) Moench and *Abelmoschus tetraphyllus*. *J. Maharashtra Agric. Univ*.1 (2-6) : 106-110

Uppal, B.N., Varma, P.M. and Capoor, S.P. 1940. Yellow Vein Mosaic of Bhindi. *Curr. Sci*. 9 : 27-28

Ustinova, E.I. 1937. A description of the interspecific hybrid of *Hybiscus esculentus and H. manihot*. *Genetica* 6 : 58-60

Vashista , R.N., Pandita, M.L. and Bhutani, R. D. 1982. Variability studies in okra (*Abelmoschus esculentus* (L.) Moench) under dry farming conditions. *Haryana. J. Hort. Sci*. 11 : 117-121

Vavilov, N.I. 1951. The origin, variation, immunity and breeding of cultivated plants. *Chron. Bot.* 13:1649-1650

Veeraragavathatham, D. and Irulappan, I. 1990. Combining ability analysis in certain okra (*Abelmoschus esculentus* (L.) Moench). *S. Indian Hort*. 39(4) : 193-199

Vijay, O.P. and Manohar. M.S. 1990. Studies on genetic variability, correlation and path analysis in okra (*Abelmoschus esculentus* (L.) Moench). *Indian J. Hort.* 47 : 97-103

*Waalkes, Van J.B. 1966. Malesian Malvaceae revised. *Blumea* 14 :1-251

Yadav, D.S. 1986. V ariability and interrelations between yield and its components in okra (*Abelmoschus esculentus* (L.) Moench). *Indian J. Hort*. 43 : 274-277

Yassin, G.M. and Anbu, S. 1997. Variability studies in bhindi. *S. Indian Hort*. 45 : 13-15

* Originals not seen

Appendices

Appendix.1. Mean weather data at Vellanikkara during the period of January 2007to March 2008

Source : Department of Agricultural Meteorology, KAU, Vellanikkara.

Months	Max. Temperature (^{0} C)		Min. Temperature (^{0} C)		RH (%)		Rainfall (mm)		Rainy days		Sunshine (hr.)		Wind speed (km/hr.)	
	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008	2007	2008
January	32.5	32.3	22.0	21.7	54	59	0.0	0	0	0	268.5	292.9	9.2	7
February	34.0	33.6	22.2	22.9	55	61	0.0	29.7	0	3	275.5	236.9	4.9	4.5
March	36.0	33.2	24.4	23.4	63	64	0.0	205.3	0	7	254.4	212.5	4.3	4.8
April	35.1	-	25.0	-	69	-	61.0	-	4	-	230	-	4.3	-
May	32.8	-	24.6	-	76	-	240.5	-	10	-	205.1	-	3.7	-
June	30.1	-	23.5	-	84	-	826.5	-	23	-	105.5	-	3.8	-
July	28.4	-	22.9	-	88	-	1131.9	-	28	-	22.1	-	3.2	-
August	29.0	-	22.8	-	84	-	549.7	-	19	-	100.5	-	2.7	-
September	29.4	-	22.9	-	86	-	765.9	-	23	-	75.1	-	3.0	-
October	30.5	-	22.5	-	79	-	383.8	-	14	-	135.2	-	3.2	-
November	31.7	-	21.6	-	67	-	24.8	-	3	-	239.2	-	4.5	-
December	31.6	-	22.7	-	56	-	8.7	-	1	-	207.1	-	8.6	-

IDENTIFICATION OF PROMISING SEGREGANTS IN F_4 AND F_5 GENERATIONS OF THE CROSS *Abelmoschus caillei* (A.Cher.) Steveis x *A.esculentus* (L.)Moench

By

JASEENA. P

ABSTRACT OF THE THESIS

Submitted in partial fulfillment of the requirement for the degree of

Master of Science in Horticulture

Faculty of Agriculture
Kerala Agricultural University

Department of Olericulture
COLLEGE OF HORTICULTURE
VELLANIKKARA, THRISSUR-680656
KERALA, INDIA

2008

ABSTRACT

Yellow Vein Mosaic (YVM) is a devastating disease infecting okra (*Abelmoschus esculentus* (L.)Moench), which affects all stages of crop growth, causing 50 to 90 per cent crop loss. The best way to tackle this disease is the use of resistant varieties. Hence a study was undertaken in the Department of Olericulture, College of Horticulture, Kerala Agricultural University, Vellanikkara, Thrissur during 2007-2008 for the evaluation of the F_4 and F_5 generations of the cross between *Abelmoschus caillei* variety Susthira (a semi wild yellow vein mosaic resistant variety) and *Abelmoschus esculentus* variety Salkeerthi (a high yielding widely adapted, but Yellow Vein Mosaic Virus (YVMV) susceptible variety), obtained from the earlier studies with the objective of identifying high yielding and YVM disease resistant lines from the segregating generations.

Okra germplasm consisting of 14 F_4 selections along with their parents was evaluated simultaneously for YVMV resistance and yield traits in RBD with two replications during April to September 2007. The F_4 segregants were morphologically more similar to semi wild parent *Abelmoschus caillei* and were highly resistant to YVMV. However, seven F_4 selections viz., F_4-2, F_4-5, F_4-8, F_4-13, F_4-15, F_4-16, and F_4-20 having more fruit length and desirable number of ridges per fruit were selected. These selections also showed considerably good amount of pollen fertility. So these selections were further advanced to F_5 generation and were also subjected to detailed testing programmes for reaction to YVMV and yield traits. The F_5 generation plants in general exhibited high level of resistance to YVMV throughout the crop phase.

During the evaluation of yield traits in the F_4 generation, significant variation among the genotypes was observed for the traits, plant height, petiole length, days to first flowering, days to first harvest, length of fruit, number of fruits per plant, crop duration, yield per plant and pollen sterility.

The maximum values for both PCV and GCV were noticed for pollen sterility, number of fruits per plant, length of fruits, internodal length and length and width of epicalyx segments.

Most of the traits possessed high heritability especially for days to first flowering, length of fruit, locules per pod and yield per plant. High genetic advance could be noticed for majority of the traits, the highest being for yield per plant and plant height.

Correlation analysis indicated that most of the character combinations had higher genotypic coefficients of correlation than phenotypic though both had the same direction. Fruit yield displayed positive genotypic association with length of fruit and number of fruits per plant. Among the 17 component traits which had high association with fruit yield the maximum positive and negative direct effects were exerted by number of fruits per plant and days to first flowering respectively.

During the evaluation of yield traits in the F_5 generation, significant variation among the genotypes was observed for the traits plant height, petiole length, days to first flowering, days to first harvest, first fruiting node, length of fruit, number of fruits per plant, crop duration, yield per plant and pollen sterility.

The maximum values for both PCV and GCV were noticed for coefficient of infection of YVMV, pollen sterility, number of fruits per plant, length of fruits, internodal length and length and width of epicalyx segment.

Correlation analysis indicated that most of the character combinations had higher genotypic coefficients of correlation than phenotypic though both had the same direction. Fruit yield displayed positive genotypic association with length of fruit and number of fruits per plant.

Most of the traits possessed high heritability especially for coefficient of infection of YVMV, pollen sterility, crop duration and days to first flowering. High genetic advance could be noticed for majority of the traits, the highest being for CI of YVMV, crop duration, yield per plant and plant height. High variation noted for

/YVMV disease incidence offers more scope for selection based on disease incidence, in the process of selection for high yielding disease resistant lines.

Some of the F_5 segregants showed characters similar to the cultivated species *A. esculentus* variety Salkeerthi such as less number of ridges per pod, longer fruit length, reduced width of epicalyx segment etc. The segregants such as F_5-1, F_5-3, F_5-7, F_5-9, F_5-20 and F5-26 were selected based on its promising fruit characters tending towards *A.esculentus*. These selections also showed considerably good amount of pollen fertility and high level of resistance to YVMV. So these selections can be further advanced to develop YVMV resistance varieties with desirable plant and fruit characters in the future.