PROGENY STUDIES OF INTERSPECIFIC CROSSES OF *Abelmoschus*

BY

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DECLARATION

I hereby declare that this thesis entitled "Progeny studies of interspecific crosses of Abelmoschus" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me, of any degree, diploma, associateship, fellowship or other similar title, of any University or Society.

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CERTIFICATE

Certified that this thesis entitled "Progeny studies of interspecific crosses of Abelmoschus" is a record of research work done independently by Kumari Renie Alex, under my guidance and supervision, and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

The utility of a disease resistant variety, needs no emphasis in a country like India where a sizeable area is under cultivation with different kinds of vegetables, constantly facing depredations of heavy pest and disease incidence. In view of the importance given to the vegetables and hazards involved in chemical control measures of insect vectors in these crops it has become imminent to seek for built-in protection by way of varietal resistance to the disease pathogen wherever possible.

Bhindi (Abelmoschus esculentus (L.) Moench) is one of the most important vegetable crops grown in the tropics. Due to its wide range of adaptability and ease of cultivation it is grown extensively in India. Bhindi is prone to a few diseases of which the yellow vein mosaic caused by virus inflicts heavy damage on the crop growth and yield of fruits. It occurs in a severe form all over the plains and lower hills of India. Inspite of the severity of the disease there are no effective control measures so far. Costa (1976) reported that there is practically no insecticide that will kill white flies (Bemisia tabaci) which transmit this disease, rapidly enough to prevent the transmission of this disease.

However, since the bhindi fruits are harvested once in two or three days, the use of insecticides have to be avoided owing to the residual toxicity problem. Hence the most logical and economic way to control this disease appears to be through varietal resistance.

Pusa Sawani, a tolerant cultivar, was developed using a resistance gene from the strain I.C.1542 (Singh et al., 1962). Since then Pusa sawani had stabilized okra cultivation in the 1960's and early 1970's. However, in recent years Pusa Sawani has been severely affected by yellow vein mosaic and a new stable resistant variety is an immediate felt necessity.

An attempt was made at the Department of Plant Breeding, College of Agriculture, Vellayani to transfer the yellow vein mosaic resistance found in A. manihot to the cultivated A. esculentus varieties viz., CO-1 and K.S-17. The present study involves the screening of the fifteen F_4 lines, derived from the above two crosses, for resistance to yellow vein mosaic and other desirable attributes.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

I. Breeding for resistance to yellow vein mosaic of bhindi.

1. History and nature of the disease

Yellow vein mosaic in bhindi was first reported by Kulkarni (1924) from the Bombay region. Uppal et al. (1940) established the viral nature of the disease and gave it its present name 'yellow vein mosaic'. Capoor and Varma (1950) described the symptomatology and host range. Yellow net work of veins is the prominent symptom. The affected plants show stunted growth, and fruits produced on such plants will be malformed, reduced in size, pale in colour, tough and fibrous. The host range of this virus is restricted to the family Malvaceae. The transmission of this virus by the whitefly (Bemisia tabaci) was also established by them. The virus is neither seed nor sap transmissible, but is readily transmitted through whiteflies and by grafting.

The virus-vector relationship was studied by Varma (1952, 1955). According to him a single whitefly can transmit the virus and the percentage of infestation increase with the increase in the number of insects per plant. One hundred per cent infection was obtained on using 10 flies/plant. A pre-acquisition feeding

period of four hours seemed to improve the efficiency of Bemisia tabaci to acquire the virus from the diseased plants, but longer period had no effect. The minimum acquisition feeding period is one hour, but six to eight hours of feeding in the diseased plants enables the vector to retain the virus throughout its life span of 15-24 days. The yellow vein mosaic virus is a persistent virus and undergoes a latent period of seven hours in the vector. White flies remain non-infective upto six hours after feeding on the source of the virus, but at the end of seven hours, 23.07 per cent becomes viruliferous. The minimum transmission feeding period is 30 minutes, but transmission upto six hours ensure 100 per cent transmission.

2. Effect of viral infection on the growth and yield of bhindi

The economic importance of the disease cannot be denied as it reduces the yield considerably and causes much loss to the grower (Capoor and Varma, 1950). The disease spreads rapidly from one infected field to another, as the affected fields act as foci of infection not only for the neighbouring plots, but for the entire area under bhindi. The disease occurs all over the plains and also in the lower hills of India. It is more prevalent during the rainy season

and in years of heavy infection, the crop fails badly (Singh et al., 1962).

The virus can infect at all stages of growth of the crop. The loss in yield depends on the stage of growth of the crop at which infection occurs (Sastry and Singh, 1974). They have reported a loss of 93.8 per cent in yield when the infection occurred 35 days after germination. Chelliah and Murugesan (1975) also reported that infection by the virus in 30 day old crop resulted in 88 per cent loss in yield.

Yellow vein mosaic virus, infecting bhindi plants at different stages of growth had adverse effect on plant height, number of branches, number and size of the fruits and seed yield (Sinha and Chakraborti, 1978). The highest loss of seeds was 86.13 per cent in plants producing symptoms on 33rd day of sowing and was lowest (32.55 per cent) in plants which showed symptoms on 75th day of sowing. There was no effect on the test weight and germination of seeds.

3. Sources of resistance

A suitable source of resistance is a pre-requisite in any resistance breeding programme. Resistant sources may be obtained from the cultivated varieties of the particular species, or from related species.

3 a. Search for resistance source within the species Abelmoschus esculentus

Varma and Mukherjee (1955) screened 43 varieties of bhindi in West Bengal and reported that pink types appeared to be resistant. A survey conducted at IARI employing over 100 cultivated species and hybrids of bhindi has revealed that all were susceptible (Nariani and Seth, 1958). One variety of Abelmoschus esculentus accessioned as I.C.1542 which consistently showed freedom from the disease under field conditions, was found to be a symptomless carrier of the virus (Singh et al., 1962).

Premnath (1970) reported that resistance to yellow vein mosaic was noticed among 267 indigenous collections of Hibiscus esculentus and the lines IHR-20-7 and IHR-15-1 showed high resistance. Three lines of Abelmoschus esculentus viz. I.C.1542, selection 1-1 and selection 2-2 were found to show field resistance to yellow vein mosaic under conditions of heavy natural infection in a screening trial conducted by Sandhu et al., 1974. Hibiscus esculentus types 15-1-7-4 and 3-1-1-2 were observed to be completely resistant to yellow vein mosaic by Rao et al. (1976) out of nine selections. The short day Hibiscus esculentus line Tae 316 showed tolerance to okra mosaic virus (Anon, 1976).

The field tolerant variety evolved at IARI - Pusa Sawani - from a cross between I.C.1542 and Pusa Makhmali, has lost its tolerance due to various genetic and agro-climatic factors (Singh and Thakur, 1979).

L-63 derived from a backcrossing programme involving the mosaic tolerant strain VT and the high yielding strain H10, was more resistant than the standard varieties and had fruits of better quality (Regunathan, 1980). Forty six strains of Abelmoschus esculentus were assessed for yield and virus infection under unsprayed field conditions by Chauhan et al. (1981). They found no strains showing resistance and the supposed to be resistant 'Pusa Sawani' had a mean infection rate of 75.8 per cent. Atiri (1983) reported from Nigeria some cultivars of Abelmoschus (Hibiscus) esculentus with high yield and resistance to the Hibiscus esculentus mosaic virus.

A high degree of symptomless carrier type of resistance to yellow vein mosaic virus was identified in the Abelmoschus (H.) esculentus variety E.C.31830 (=Asutemkolo) from Ghana (Sharman and Sharma, 1984). Salehuzzaman (1985) reported that an accession of Abelmoschus esculentus from Liberia remained unaffected by the yellow vein mosaic virus. Of five varieties of Abelmoschus (H.) esculentus screened

under field conditions, S.1-1 showed the lowest incidence of infection (24.36 per cent) and gave the highest yield (40.36 q/ha) as reported by Khan and Mukhopadhyay (1986).

3 b. Resistant sources from among the related wild species

Different species of Abelmoschus and Hibiscus were screened for their reaction to yellow vein mosaic virus by graft inoculation as well as by feeding viruliferous white flies (Nariani and Seth, 1958). Results of the inoculation showed that Abelmoschus manihot var. pungens, Abelmoschus crinitus, Hibiscus vitifolius and Hibiscus panduraeformis could not be infected by either method and this indicated that they were immune to infection. However, the other species of Abelmoschus and Hibiscus which were infected with the virus showed great variation in symptoms from the typical mosaic to mild forms. Some species like A. tuberculatus, A. manihot, A. angulosus, H. cannabinus and H. subdariffa carry the virus without showing symptoms such as veinal chlorosis, although numerous vein swellings on the under surface of leaves were noticed.

Sandhu et al. (1974) found that five wild species of Abelmoschus were showing field resistance to yellow vein mosaic under conditions of heavy natural infection. They

reported that Hibiscus manihot from Ghana, which was almost immune to yellow vein mosaic, could be considered as a good source to develop resistant lines.

Two forms of Abelmoschus manihot introduced from Africa and Japan, proved to be highly resistant to the yellow vein mosaic (Arumugam et al., 1975). However, the African accession was found to be a symptomless carrier as revealed in further studies by them. Singh et al. (1976) identified an accession from Ghana as being immune to the disease, from among a number of cultivars from West Africa. Singh and Thakur (1979) conclusively proved that Abelmoschus manihot Ssp. manihot is a symptomless carrier of yellow vein mosaic based on graft inoculation studies.

Chelliah and Srinivasan (1983) reported that resistance to yellow vein mosaic virus transmitted by Bemisia tabaci was found in Abelmoschus manihot and Abelmoschus manihot Ssp. tetraphyllus. The preliminary evaluation of bhindi types in the Department of Plant Breeding, College of Agriculture, Vellayani has revealed that a semi-wild species, Abelmoschus manihot was completely resistant to yellow vein mosaic disease while 20 other cultures in the germplasm were severely affected by the disease (Anon, 1983).

Sharman and Sharma (1984 a) found that Abelmoschus manihot Ssp. manihot from Ghana was resistant. Although, it proved to be a symptomless carrier of the virus in grafting tests, it was regarded as a good source for incorporating resistance into susceptible Abelmoschus esculentus cultivars. Madhusoodanan and Nazeer (1986) reported that the Guineen type of okra originated through natural hybridization between Abelmoschus esculentus and Abelmoschus manihot, was immune to yellow vein mosaic virus disease.

4. Genetics of Resistance

Inheritance studies in the crosses between Abelmoschus esculentus stocks I.C.1542 as the resistant parent and 'Pusa Makhmali', S-91 and S-72 as susceptible parents, suggested that two loci were involved, the presence of dominant alleles at both loci being necessary for causing susceptibility to the disease. The field resistant variety, I.C.1542, was assigned the genotype $yv_1yv_1yv_2yv_2$ and the susceptible parents $Yv_1Yv_1Yv_2Yv_2$ (Singh et al., 1962).

Segregation data from the F_1 and B C_1 to B.C_3 of Hibiscus esculentus 'Pusa Sawani' x Hibiscus manihot Ssp. manihot grown under conditions of natural epiphytotics of yellow vein mosaic showed that resistance was conditioned

by two complementary dominant genes, Hibiscus esculentus having the genotype $yu_1/yu_1/yu_2/yu_2$ and Hibiscus manihot Ssp. manihot the genotype $Yu_1/Yu_1/Yu_2/Yu_2$ (Thakur, 1976).

F_1 - F_3 segregation data from crosses involving two wild forms of A. (H.) manihot and susceptible varieties of A. (H.) esculentus revealed that resistance to this virus was conditioned by a single dominant gene, designated 'Y' (Arumugam and Muthukrishnan, 1980). Jambhale and Nerkar (1981 a) also reported that yellow vein mosaic resistance was controlled by a single dominant gene.

Sharma and Dhillon (1983) studied the genetics of resistance to yellow vein mosaic virus in interspecific crosses of okra and found that the resistance was controlled by two complementary genes. Limited inheritance studies by Sharman and Sharma (1984 b) revealed that tolerance to the virus was controlled by two dominant complementary genes or was under polygenic control.

Pillai (1984) suggested that resistance to the yellow vein mosaic virus was controlled by dominant nuclear gene(s). Mathews (1986) reported that resistance to the virus was governed by a single dominant gene.

5. Incorporation of resistance

Attempts were made to incorporate the resistance gene

from the wild species to the cultivated species, after the resistance to the yellow vein mosaic virus was located in the wild species of Abelmoschus. During the first half of this century, interspecific hybridization has been carried out in the genus Abelmoschus, with a view to understand the evolutionary stages in the origin of cultivated bhindi. Thus, Teshima (1933, cited by Skovsted) observed that Hibiscus esculentus and Hibiscus manihot crossed only when the former was used as the female parent. Skovsted (1935) reported that in the cross Hibiscus abelmoschus x Hibiscus manihot, empty seeds were obtained, where as in the reciprocal crosses seedless capsules were formed. With Hibiscus esculentus as female parent both Hibiscus abelmoschus and Hibiscus manihot produced viable seeds where as in one of the reciprocal combinations, Hibiscus abelmoschus x Hibiscus esculentus, only empty seeds were obtained. Ustinova (1937) reported that F_1 hybrids of the cross between Hibiscus esculentus and Hibiscus manihot were partially fertile.

Pal et al. (1952) studied five species of Abelmoschus viz. A. esculentus, A. ficulneus, A. manihot var. pungens and A. tuberculatus morphologically and in interspecific hybridization. The studies confirmed the view that these species constitute a distinct taxonomical unit and that

A. tuberculatus is more nearly related to A. esculentus than any other species and A. manihot follows it. A. manihot var. pungens appears to be a variety of A. manihot as adopted by Hochreutiner. A. ficulneus is, however, only distantly related. Where as the other four species readily crossed with each other and formed viable seeds, crosses with A. ficulneus resulted in only shrivelled or empty seeds. The various F_1 hybrids studied were sterile, fruits were either seedless or with few empty seeds. Back crosses and crossing of hybrids in various combinations failed to produce viable seeds. Joshi and Hardas (1956) based on cytogenetic studies in Abelmoschus esculentus x Abelmoschus tuberculatus hybrids, established that Abelmoschus esculentus originated through hybridization between a 29 chromosome species and a 36 chromosome species of Abelmoschus followed by chromosome doubling in the resulting hybrid. The former genome is homologous with that of Abelmoschus tuberculatus.

During the latter half of this century, crosses have been attempted amongst the different species of okra mainly for transferring genes for resistance to pests and diseases from suitable sources to the cultivated species. Attempts were made at IARI to transfer the true resistance of Abelmoschus manihot var. pungens and 'symptomless' type of

resistance of Abelmoschus tuberculatus. These species were crossed with Pusa Makhmali a variety of Abelmoschus esculentus. In the case of crosses with Abelmoschus tuberculatus, the F_1 hybrids were completely sterile and no viable seeds were obtained even from backcrossing (Pal et al., 1952).

Singh et al. (1962) observed that when the chromosomes of F_1 hybrids were doubled by colchicine treatment, the amphidiploid (Zn = 188) although seed fertile, was not free from yellow vein mosaic. It was also seen that the true resistance discovered in Abelmoschus manihot var. pungens could not be made use of owing to the sterility of the hybrids (2n = 134). Ovule and embryo culture were employed to raise viable hybrids in crosses involving Abelmoschus esculentus and two related species, viz. Abelmoschus moschatus and Abelmoschus ficulneus (Gadwal et al., 1968).

Kuwada (1974) observed that hybridization between Abelmoschus tuberculatus and Abelmoschus manihot was successful only when the former was used as the female parent, but the hybrid was completely sterile. Arumugam et al. (1975) found that in crosses between Hibiscus manihot and Hibiscus esculentus the F_1 seeds were viable although there was 90

per cent sterility in F_2. Singh *et al.* (1976) reported that the hybrids of an accession from Ghana, which was identified as being immune to yellow vein mosaic, with Indian okra, were only partially fertile while those between Ghanian accession and *Abelmoschus tetraphyllus* were completely sterile.

Hibiscus esculentus x *Hibiscus ficulneus* hybrids studied by Hossain and Chattopadhyay (1976) were self sterile, but produced many fruits without seeds or with only rudimentary seeds. The hybrids resembled their wild parent in several morphological characters and inherited its resistance to yellow vein mosaic. Nair and Kuriachen (1976) reported a spontaneous hybrid between *Hibiscus esculentus* and *Hibiscus tetraphyllus* which was highly pollen sterile and totally seed sterile in which selfing, open-pollination and backcrossing produced only fruits with empty seeds. Morphological characters of the hybrid between *Abelmoschus esculentus* and *Abelmoschus tetraphyllus* were intermediate in expression between those of the parents. The F_1 was resistant to virus and wilt diseases (Ugale *et al.*, 1976). They suggested that the factors governing the resistance to virus and wilt disease present in the B genome of *Abelmoschus tetraphyllus* can be incorporated into the cultivated *Abelmoschus esculentus* by backcrossing.

Arumugam and Muthukrishnan (1978 a) observed that all F_1s from four crosses involving two wild forms of Abelmoschus manihot and two susceptible cultivars of Abelmoschus esculentus namely 'Pusa Sawani' and 'Co-1' were resistant to the virus and that there was remarkable recovery of the cultivar build in the recombinants obtained from F_2 and F_3 segregants. Mamidwar et al. (1979) studied crosses of Abelmoschus esculentus with three wild forms and observed that the fruit set was highest when Abelmoschus esculentus was the female parent. The hybrids produced seedless fruits or fruits with shrivelled seeds. Jambhale and Nerkar (1981 b) crossed the wild species Abelmoschus manihot (2n = 66) and Abelmoschus manihot Ssp. manihot (2n = 194) reciprocally to susceptible Abelmoschus esculentus 'Pusa Sawani'. The hybrids were resistant and fertile.

Meshram and Dhapake (1981) reported that the hybrid between Abelmoschus esculentus and Abelmoschus tetraphyllus was spreading in habit, dwarf in stature and highly male sterile. Dhillon and Sharma (1982) reported successful interspecific crosses between two cultivars of Abelmoschus esculentus susceptible to yellow vein mosaic and one resistant cultivar Abelmoschus manihot. The hybrids showed resistance to the virus. Martin (1982) reported that F_1 hybrids

between a West African okra species and Abelmoschus esculentus were quite sterile, although in some cases a few germinable seeds were produced. Backcrosses, on the other hand were more fertile than the F_1 hybrids and fertility was almost complete in B.C.2. He observed some evidence of cytoplasmic interaction with chromosomes in the production of sterile backcross hybrids.

Jambhale and Nerkar (1983) found that the hybrid between Abelmoschus esculentus and Abelmoschus tetraphyllus was completely seed sterile and attempts to backcross the F_1 to Pusa Sawani met with failure. Backcrossing the induced amphidiploid to Pusa Sawani could not be carried beyond B.C.2 due to sterility. However, a resistant segregant from F_2 generation had improved seed fertility (71.67 per cent) and desirable traits. The F_5 lines derived from this plant had fixation of morphological traits of Pusa Sawani and resistance to yellow vein mosaic. Sharman and Sharma (1984) identified a plant carrying the symptomless carrier type of resistance to yellow vein mosaic virus, in the open pollinated F_2 of Pusa Sawani x E.C.31830. This plant was crossed with the F_1 of Pusa Reshmi x E.C.31830. Following controlled pollination, this second cross was advanced to the F_8. This was found to be superior to Pusa Sawani and other varieties,

with regard to fruit number per plant, fruit length, shelf life, and yield and field tolerance to the virus with a disease score of 1.5 - 2 compared to 3.8 - 4.5 in Pusa Sawani on a 0-5 scale. Pillai (1984) obtained hybrids with complete resistance to yellow vein mosaic virus by crossing Abelmoschus manihot with four susceptible cultivars of Abelmoschus esculentus, viz. A.E.87, Pusa Sawani, Co-1 and Kilichundan selection-17. But none of them outyielded the highest yielding parent (K.S-17). For further improvement of the resistant hybrids, selection for better recombinants with resistance to yellow vein mosaic disease and higher yield among the segregating populations in the backcrossing or selfing series was suggested. Mathews (1986) evaluated the F_2 population of the crosses Co-1 x Abelmoschus manihot and K.S-17 x Abelmoschus manihot and observed yellow vein mosaic resistant types.

Cherian (1985) observed that when the F_1 of Abelmoschus manihot Ssp. tetraphyllus and Abelmoschus esculentus, which had low pollen fertility were irradiated with gamma rays, there was considerable enhancement in pollen fertility and changes in discrete characters, but they had seedless fruits and fruits with incompletely filled seeds.

Nerkar and Jambhale (1985) observed during the transfer

of resistance to yellow vein mosaic from related species, viz. Abelmoschus tetraphyllus, Abelmoschus manihot and Abelmoschus manihot Ssp. manihot into cultivated okra Abelmoschus esculentus cv. Pusa Sawani, that transfer of resistance from Abelmoschus manihot was successful by two backcrosses followed by selection in the selfed generations, while that from Abelmoschus manihot Ssp. manihot was successful by growing straight generations. Nine yellow vein mosaic resistant lines (in the B.C.2F5, B.C2F6 and F8 generations) were selected having fixation for agronomic traits and consumer qualities of the cultivar Pusa Sawani and also its high yield. Jambhale and Nerkar (1986) reported that 'Parbhani Kranti' an Abelmoschus esculentus variety derived from backcrosses of Abelmoschus manihot to the okra Pusa Sawani carries resistance to yellow vein mosaic derived from Abelmoschus manihot. It outyielded Pusa Sawani in trials at three sites over three years and produced dark green, slender fruits of 8-9 cm length.

6. Mechanism of resistance

Ramiah (1970) reported higher quantities of glutamic acid, aspartic acid, glycine and isoleucine in the leaves of yellow vein mosaic susceptible plants. Ramiah et al. (1973 a) found that due to virus infection there were increases

in catalase and peroxidase activity. Catalase activity increased even in mildly infected leaves, while peroxidase activity increased only in the moderately and severely infected leaves. Polyphenol oxidase activity decreased due to virus infection. Ascorbic acid oxidase activity decreased in the initial stages of infection, but in very severely infected leaves, the enzyme activity increased. Dechlorophyllation in the infected plants has been attributed to increases in the ascorbic acid oxidase enzyme activity.

Ramiah et al. (1973 b) reported accumulation of potassium and reduction in calcium content in bhindi leaves due to infection by the virus. They also observed an increase in the iron content in infected leaves. They suggested that the veinal and interveinal chlorosis observed was probably due to the accumulation of insoluble form of iron in diseased leaves. Magnesium and sulphur also accumulated in the infected leaves.

Potty and Wilson (1973) observed that the inoculated plants showed lower contents of total sugars. However, crude fibre and carbohydrate was recorded higher than in healthy plants. Total nitrogen was also high in inoculated plants. C.N ratio of inoculated plants was narrower than in the healthy plants. They suggested that the higher percentage of

total carbohydrate which resulted from higher levels of crude fibre in the infected plants could be due to the reduced activity of enzymes responsible for the breakdown of cellulose materials.

Arumugam and Muthukrishnan (1978 b) reported that the resistant types had lower contents of total nitrogen, ammoniacal nitrogen and nitrite nitrogen and higher contents of amide nitrogen and nitrate nitrogen than susceptible types. The resistant parents and F_1 derived from these were found to contain some unidentified aminoacids which were absent in susceptible cultivars (Arumugam and Muthukrishnan, 1978 c). The aminoacids, viz. isoleucine, glycine, aspartic acid and glutamic acid were found to be associated with resistance while tryptophan, asparagine and alanine aid the host plant to succumb to the disease. They suggested that the unidentified aminoacid present in the resistant wild parents and inherited by F_1 progenies might play a greater role in conferring resistance to yellow vein mosaic of bhindi. Arumugham and Muthukrishnan (1978 d) reported that all the fractions of sugars were higher in the resistant parents and F_1 hybrids, than in susceptible plants.

II. Studies on resistance to shoot and fruit borer (Earias vitella F.)

The shoot and fruit borer (Earias vitella F.) is

one of the most serious pests of this crop which causes considerable loss to tender shoots, buds and fruits. Dahanukar (1970) screened 24 varieties of okra against this pest and concluded that varieties with more hair density on fruits showed more fruit infestation. Patil (1975) made the same observation. However, screening trials of okra varieties under the AICVIP at Rahuri, revealed that there was no shoot and fruit borer incidence in a wild species Abelmoschus manihot (Anon, 1977).

Teli and Dalaya (1981) screened 20 okra varieties and 7 F_1s for resistance to fruit and shoot borer. In natural screening, A.E-79, A.E-52, Sel-1-1 x A.E-79 and A.E-69 were found to be promising and less susceptible to the attack of fruit and shoot borer. It was found that more number of eggs were laid on fruits having maximum hair density. The larval entry was easier in soft-skinned, smooth surfaced and dense haired varieties. Mote (1982) evaluated 10 Hibiscus esculentus varieties for resistance to Earias vitella. A.E-79, A.E-72, A.E-57, A.E-3 and wonderful pink, all with dense and long hairs, had the best resistance with the least number of eggs laid and least entry of larvae into fruits, as well as the lowest infestation in the field. Sel.6-2 and Sel.2-2 had moderate resistance with high yield potential.

III. Genetic variability and correlation studies in bhindi

1. Phenotypic and genotypic variability, heritability and genetic advance for yield and its components.

Rao (1972) reported that plant height and days to flower showed high genotypic coefficient of variation of 19.34 and 10.44 respectively coupled with both high values of heritability (71.52 per cent and 99.82 per cent) and expected genetic advance (78.96 and 50.8). Ngah and Graham (1973) observed highest heritability for fruit length (84 per cent) and lowest for fruit weight (48 per cent). Heritability for plant height was 79 per cent. Singh et al. (1974) reported high heritability values and estimates of genetic advance for fruit diameter and fruit length.

High genotypic coefficient of variation was observed for yield per plant, number of fruits per plant, weight of fruit and length to girth ratio of the fruit. Heritability estimates were found to be highest for weight of the fruit (69.56 per cent) and lowest for plant height (34.79 per cent) (Majumdar et al., 1974). Ramu (1976) reported high narrow sense heritability for pod number per plant and yield per plant. High additive and nonadditive components of genetic variation were also observed for number of pods per plant and yield per plant.

Lal et al. (1977) found that the highest heritability value was recorded by days to flower (91.9 per cent) followed by fruit thickness (91.7 per cent), internode length (88.4 per cent) and fruit length (82.5 per cent). The lowest heritability was recorded by yield per plant (30.5 per cent). Highest genetic advance was recorded by internode length (739.2) and lowest by fruit yield and fruit thickness (234.7 and 230.8). Rao et al. (1977) reported that the estimate of heritability and genetic advance were highest for number of fruits per plant and that this character was under the control of additive genes.

Singh and Singh (1978) observed that broad sense heritability estimates and expected genetic advance were greatest for days to flowering, yield per plant and number of fruits per plant. Heritability estimates were high for number of fruits, fruit length and fruit diameter (Mahajan and Sharma, 1979). Meshra and Chhonkar (1979) reported high estimates of heritability, genetic advance and genotypic coefficient of variation for number of branches per plant, pods per plant and seeds per pod, pod length, plant height and percentage of plants infected with yellow vein mosaic virus. Partap et al. (1980) observed high heritability for all characters except yield per plant (19.09 per cent),

number of fruits per plant (32.56 per cent) and plant height (39.45 per cent).

Appreciable variability was noticed for pod length, fruit number and yield (Murthy and Bavaji, 1980). Highest heritability was noticed for pod length (99.6 per cent). Highest genetic advance was also noticed for pod length (61.86). Arumugam and Muthukrishnan (1980) reported that heritability for resistance ranged from 69-95 per cent and that additive variance was higher than dominant variance. Palaniveluchamy et al. (1982) observed that heritability and genetic advance were of lower magnitude for all the characters studied, nearly half of the characters exhibiting negative estimates. Highest heritability was recorded for plant height (25.03 per cent). Maksoud et al. (1984) noted high broad and narrow sense heritability values for earliness of flowering, fruits per plant and fruit weight.

Plant height exhibited the greatest variability and node of first fruit set the least (Korla and Sharma, 1984). All the traits studied, viz. plant height, node of first fruit set, number of fruits per plant and yield per plant, had a low to moderate coefficient of variability and moderate to high heritability and genetic advance. Palve et al. (1985) recorded a good amount of variability, high magnitude of

heritability and appreciable genetic advance for yield, number of fruits per plant, fruit length and days to flower. Highest heritability and genetic advance was observed for fruit length (98 per cent and 52.18 respectively) and lowest for days to flower (43 per cent and 15.97).

Reddy et al. (1985) reported high heritability for plant height and number of branches. Sheela (1986) recorded the meximum genotypic coefficient of variation for number of branches (27.88) and the minimum value for girth of fruit (2.58). Yellow vein mosaic intensity and fruiting phase showed high heritability values (85.98 and 80.5 per cent respectively) and the maximum genetic advance was noted for yellow vein mosaic intensity (108.93). Mathews (1986) observed high heritability and genetic advance for weight of fruits per plant, days to flowering and number of leaves per plant.

Yadav (1986) reported that plant height registered the highest value for genotypic coefficient of variation (48.086) and pod length exhibited the lowest value (14.215). The highest heritability was recorded for number of seeds per pod (99.894 per cent) and highest genetic advance for yield per plant (112.08).

2. Correlation studies on yield and its components and path coefficient analysis.

Fruit yield per plant was found to be positively

correlated with number of flowers per plant, number of branches per plant, stem diameter, plant height, number of leaves per plant, number of fruits per branch, fruit number per plant and fruit weight. Yield was primarily dependent on fruit weight, number of fruits per plant and number of flowers per plant (Singh et al., 1974).

Majumdar et al. (1974) found that yield was positively correlated with number of fruits per plant, weight of fruit, length to girth ratio of fruit and plant height, while its association with days to flower was negative. Path coefficient analysis revealed that the weight of fruit had maximum direct contribution to yield. The plant height also had a positive direct effect.

Yield per plant was significantly correlated with pod and node number and plant height, pod number with node number and height, and node number with height, and seed number with pod ridge number per plant. An increase in yield of 0.1580, 0.406 and 0.305 g/plant was associated with unit increase in plant height (cm), node number and pod number respectively (Ramu, 1976). He observed that pod number per plant had the greatest maximum direct effect on yield.

All the characters studied, viz. number of fruits, number of branches, height of main shoot, fruit length and

weight of fruit had positive significant correlation with yield (Roy and Chhonkar, 1976), whereas only two characters - number of fruits and number of branches per plant had significant positive partial correlation with yield. Data on correlation among five traits in the F_2 of the cross H.C.583 x N.P-6 revealed that selection on the basis of plant height, stem thickness, number of days to flowering, fibre weight and fibre length would result in forms with high yield and early maturity (Patil et al., 1978). Singh and Singh (1978) found that yield was positively correlated with fruits per plant, branches per plant, plant height and fruit length.

Rao and Kulkarni (1978) reported high significant positive correlation between height and number of pods per plant. The direct effect of height was greater than days to flowering, being positive in the former and negative in the latter. Ajmal et al. (1979) observed that fruit yield was positively correlated with fruit number and length of nodes. Number of days to first flowering made the greatest direct contribution to yield, followed by node number and fruit number.

A strong negative correlation between disease resistance and values for a hybrid index was noticed (Arumugam and Muthukrishnan, 1979) but there was no association between disease reaction and eight yield components and associated

traits. Kaul et al. (1979) reported that primary branches per plant followed by pod yield per plant had the greatest direct effect on seed yield and that seed yield was positively correlated with pod yield.

Yield has a positive and significant association with plant height, number of fruits per plant and fruit length (Mahajan and Sharma, 1979). Partap et al. (1979) observed that fruit number per plant and fruit weight made a direct positive contribution to yield, while fruit length and fruit number per branch made the highest indirect contribution to yield via fruit number per plant. Singh and Singh (1979) found that fruit yield was significantly and positively correlated with number of fruits per plant, number of branches per plant, fruit length and plant height. Plant height, followed by internode length and fruit number per plant had the greatest direct effect on fruit yield.

Elangovan et al. (1980) found strong association for yield with number of branches, earliness, number of fruits per plant, fruit width and fruit length. Murthy and Bavaji (1980) reported that fruit number followed by days to flowering had a high direct effect on yield. Arumugam and Muthukrishnan (1981) observed that fruit yield was highly correlated with number, length and seed content of fruit

and to a lesser degree, with plant height and days to flowering.

Maksoud et al. (1984) found positive correlation between plant height and each of fruit weight and fruit length. They also observed that later flowering was positively correlated with more fruits per plant and larger fruits. The number of pods per plant, pod weight, pod length, 1000 seed weight, plant height and number of nodes per plant had high positive genotypic correlations with yield per plant, while yellow vein mosaic, seeds per pod and branches per plant showed negative associations with yield per plant (Meshra and Singh, 1985). Based on path coefficient analysis, pod weight and pods per plant were found to be the most important variables.

Palve et al. (1985) observed that yield was significantly and positively correlated with number of fruits. Reddy et al. (1985) found that plant height had direct as well as indirect effect on yield per plant and number of branches per plant had an indirect effect on yield through fruits per plant and fruit length. Sheela (1986) reported that number of fruits per plant, number of branches, length, girth and weight of a single fruit, total number of flowers, fruiting phase, number of seeds per fruit and girth of stem

were the important characters contributing to yield. Mathews (1986) found that the major yield contributing characters were number of flowers per plant, number of fruits per plant, height of plant and earliness in flowering.

Plant height, number of pods per plant and pod length had positive and strong correlation with yield (Yadav, 1986).

MATERIALS AND METHODS

MATERIALS AND METHODS

The present study was conducted at the Department of Plant Breeding, College of Agriculture, Vellayani during 1987 kharif as a continuation of the work done by Mathews (1986) to isolate lines resistant to yellow vein mosaic of bhindi, resulting from the crosses of Abelmoschus esculentus var. Co-1 x Abelmoschus manihot (1) and A. esculentus var. K.S.-17 x A. manihot (2).

A. Materials

The F_2 plants in the above project were selfed and seeds collected to raise the F_3. The F_3 generation was grown and plants showing resistance to yellow vein mosaic and having good yield characteristics were selected and selfed to produce the F_4 seeds. In this study, fifteen F_4 progenies were evaluated for resistance to yellow vein mosaic and desirable characteristics in interspecific crosses of Abelmoschus.

B. Methods

1. Fifteen F_4 lines were raised and evaluated for selecting the best plants showing resistance to yellow vein mosaic and desirable yield attributes.

2. Selfing of the selected F_4 plants for obtaining F_5 seeds.

Technique of selfing

Selfing was effected by tying the tip of the mature flower buds, early in the morning prior to anthesis.

The evaluation trial was laid out in Randomized Block Design with three replications during June-October 1987. There were 16 treatments including the control K.S-17 as given below.

Sl. No.	Treatments	Ten F_4 lines derived from the cross number 1 (CO.1 x A. manihot)	Sl. No.	Treatments	Five F_4 lines derived from the cross number 2 (K.S-17 x A.manihot)
1	1-1		11	2-1	
2	1-2		12	2-2	
3	1-3		13	2-3	
4	1-4		14	2-5	
5	1-5		15	2-6	
6	1-6		16	K.S-17 (control)	
7	1-7				
8	1-8				
9	1-9				
10	1-10				

A population strength of thirty plants per plot was maintained. The planting was done at a spacing of 60 x 45 cm.

Unsprayed field condition was provided for natural incidence of yellow vein mosaic as suggested by Chauhan et al. (1981). The highly susceptible variety Kilichundan was grown interspersed with the treatments as well as on either ends of each replication as border rows to counter the border effect and to enhance yellow vein mosaic incidence. All agronomic practices except insecticidal sprays were followed as per the package of practices recommendations of the Kerala Agricultural University (Anon., 1986).

Observations recorded

The following observations were recorded from ten plants selected at random from each treatment in each replication and the mean worked out.

1. Height of the plant

Height of the plant was measured from the ground level to the tip using a metre scale at final harvest and expressed in centimetres.

2. Number of branches per plant

The total number of primary branches were counted at final harvest and recorded.

3. Leaf area

The fully expanded fifth leaf from the top was selected and length of the midrib was measured in centimetres using a scale. The leaf area was calculated using the formula given by Asif (1977).

$Y = 115x - 1050$ $\quad$ y = leaf area in cm^2

x = midrib length in cm

4. Days to flowering

The number of days taken from sowing to the opening of the first flower was recorded.

5. Number of fruits per plant

The total number of fruits produced by each observational plant were counted at every harvest and recorded.

6. Fruiting phase

The number of days from the first harvest to the last harvest were recorded in each plant.

7. First fruiting node

The number of the node from which the first fruit was produced was noted and recorded.

8. Number of flowers per plant

The total number of flowers produced per plant was counted and recorded every day.

9. Weight of fruits per plant

The fruits produced by each plant at each harvest were periodically weighed and the total yield per plant was calculated after the final harvest and expressed in grams.

10. Weight of single fruit

From each plant, the weight of five fruits were taken individually, the mean worked out and the weight expressed in grams.

11. Percentage fruit set

The ratio of the total number of fruits to the total number of flowers produced per plant was worked out and expressed as percentage.

12. Length of fruit

The length of five fruits from each plant was measured from the base to the tip using a foot scale and the mean length expressed in centimetres.

13. Girth of fruit

The fruits used for recording length were also used for recording girth. The girth of the fruits was measured at the broadest part of the fruit using a twine and the mean girth expressed in centimetres.

14. Number of seeds per fruit

The number of seeds in five fruits from each plant were counted and the mean worked out.

15. Yellow vein mosaic scoring

The rating scale by Arumugam et al. (1975) was used for scoring yellow vein mosaic disease intensity. The scoring was done according to the characteristic symptoms appearing on the leaves or fruits of each observational plant.

16. Shoot and fruit borer incidence

Observations on fruit infestation by the borer (Earias vitella F.) was recorded at each picking by counting the healthy and infested fruits and percentage of infestation worked out.

Table 1. Yellow vein mosaic disease rating scale (Arumugam et al., 1975)

Symptoms	Grade	Rating scale
i. No visible symptoms characteristic of the disease	Highly Resistant	1
ii. Very mild symptoms, basal half of primary veins green, mild yellowing of anterior primary veins, secondary veins and veinlets. Infection is also seen late in the season under field conditions.	Resistant	2
iii. Veins and veinlets turn completely yellow. Interveinal areas green and normal.	Moderately resistant	3
iv. Pronounced yellowing of veins and veinlets, 50% of the leaf lamina turn yellow, fruits exhibit slight yellowing.	Susceptible	4
v. Petiole, veins, veinlets and interveinal areas turn yellow in colour; leaves start drying from the margin. Fruits turn yellow in colour.	Highly susceptible	5

C. Statistical analysis

The data collected from this experiment were subjected to statistical analysis.

I. Analysis of variance

The v = 16 treatments were replicated r = 3 times. The data were subjected to the following analysis of variance.

Anova

Source	d.f.	Sum of squares (S.S)	Mean sum of squares (M.S.S)	F
Replication	r-1 = 2	SSB	MSB	
Treatments	v-1 = 15	SSV	MSV	$\frac{MSV}{MSE}$
Error	(v-1) (r-1) = 30	SSE	MSE	
Total	vr-1 = 47	SST		

The treatments were tested against MSE.

II. Estimation of phenotypic variance, genotypic variance and genetic parameters.

1. Phenotypic variance

$V(P) = V(G) + V(E)$ V(G) = Genotypic variance

V(E) = Error variance

2. Genotypic variance

$$V(G) = \frac{\text{Mean Square (Treatment)} - \text{Mean Square (Error)}}{\text{replication}}$$

The genetic parameters were worked out as per the method suggested by Allard (1960) and Jain (1982).

(a) Phenotypic coefficient of variation (P.C.V)

$$\frac{\sqrt{V(P)}}{\bar{X}} \times 100$$

V(P) = Phenotypic variance

$\bar{X}$ = Mean of the character

(b) Genotypic coefficient of variation (G.C.V)

$$\frac{\sqrt{V(G)}}{\bar{X}} \times 100$$

V(G) = Genotypic variance

(c) Heritability in the broad sense (H^2)

$$H^2 = \frac{V(G)}{V(P)} \times 100$$

(d) Expected genetic advance under selection

$$G.A = K.H^2 \sqrt{V(P)}$$

K = Selection differential expressed in phenotypic standard deviation, whose value is 2.06 for 5 per cent selection in large samples.

III. Test for correlation coefficients

Correlation coefficients were worked out among pairs of characters under study and their significance tested (Fisher and Yates, 1965).

Genotypic correlation coefficient (rg) (Al-jibouri et al., 1958)

$$= \frac{CoVg\ 12}{\sqrt{Vg1 \times Vg2}}$$

CoVg 12 = Genotypic covariance of traits 1 & 2

Vg1 = Genotypic variance of trait 1

Vg2 = Genotypic variance of trait 2

Phenotypic correlation coefficient (rp)

$$\frac{CoVp\ 12}{\sqrt{Vp1 \times Vp2}}$$

CoVp 12 = Phenotypic covariance of traits 1 & 2

Vp1 = Phenotypic variance of trait 1

Vp2 = Phenotypic variance of trait 2

IV. Path coefficient analysis

Path coefficient analysis (Wright, 1921) was employed for evaluating the association between yield and component characters. Methods evolved by Wright (1921) and later elaborated by Dewey and Lu (1959) were used to partition the direct as well as indirect effects of various characters on yield. Path coefficients were obtained by the simultaneous solution of the following equations.

$$r_{1y} = p_{1y} + r_{12}\, p_{2y} + \ldots\ldots\ldots\ldots\ldots + r_{1k}\, p_{ky}$$

$$r'_{ky} = r_{k1}\, p_{1y} + r_{k2}\, p_{2y} + \ldots\ldots\ldots\ldots + r(k-1),\ {}_{k}p(k-1),\ y + p_{ky}$$

Where r_{1y} to r_{ky} denote the genotypic correlation coefficient between causal factors 1 to k and dependent variable (y): r_{12} to $r_{k-1,\ k}$ denote the correlation coefficient among all possible combinations of causal factors and p_{1y} to p_{ky} denote the direct effects of characters 1 to k on yield (y).

The above equations can be written in the matrix form as shown below.

$$\begin{Bmatrix} r_{1y} \\ \\ \\ r_{ky} \end{Bmatrix} = \begin{Bmatrix} 1 & r_{12} & r_{13} & \ldots\ldots & r_{1k} \\ r_{21} & 1 & r_{23} & \ldots\ldots & r_{2k} \\ & & \ldots\ldots\ldots\ldots\ldots & & \\ r_{k1} & r_{k2} & r_{k3} & \ldots\ldots & 1 \end{Bmatrix} \begin{Bmatrix} p_{1y} \\ p_{2y} \\ \\ p_{ky} \end{Bmatrix}$$

A C B

$A = CB$

Hence $B = C^{-1} A$

C^{-1} = is the inverse matrix of C

Let C^{-1} =

$$\begin{matrix} C_{11} & C_{12} & \cdots\cdots\cdots & C_{1k} \\ C_{21} & C_{22} & \cdots\cdots\cdots & C_{2k} \\ \cdots\cdots & \cdots\cdots & \cdots\cdots & \cdots\cdots \\ C_{k1} & C_{k2} & \cdots\cdots\cdots & C_{kk} \end{matrix}$$

Path coefficients were obtained as

$$p_{1y} = \sum_{i=1}^{K} C_{1i} \; r_{iy}$$

$$p_{2y} = \sum_{i=1}^{K} C_{2i} \; r_{iy} \text{ etc.}$$

The residual factor (λ) which measures the contribution of the rest of the characters was obtained as

$$R = \sqrt{1-(p_{1y} \; r_{1y} + p_{2y} \; r_{2y} + \cdots\cdots p_{ky} \; r_{ky})}$$

Indirect effects of different characters on yield were obtained as follows. Indirect effect on the i^{th} character on yield through j^{th} character = $p_{iy} \; r_{ij}$

RESULTS

The data generated from this evaluation trial were subjected to analysis of variance. Phenotypic and genotypic variances, heritability in the broadsense, genetic advance and correlation were computed for the sixteen characters under study. The results on the various aspects are presented below.

I. Analysis of variance

The analysis of variance was done separately for each character. The analysis of variance pertaining to the different characters showed that the genotypes differed significantly for almost all the characters. The mean values of the treatments for each character is presented in Table 2. The anova of each character is given separately in Tables 3 to 18.

1. Height of plant

The results are presented in Tables 2 and 3. There was significant difference among the treatments for this character. The maximum height was exhibited by treatment 2 (113.03) followed by treatment 13 (107.83). The lowest value for this trait was observed for treatment 14 (55.66).

able 2 Mean values of sixteen characters in the sixteen treatments

		T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9	T_{10}	T_{11}	T_{12}	T_{13}	T_{14}	T_{15}	T_{16}	CD at 5% level of significance
	Height of plant (cm)	68 00	3 03	79 43	90 23	59 10	104 67	83 70	68 16	87 00	97 53	86 53	77 66	107 83	55 66	90 70	73 76	8 18
2	Number of branches/ plant	0 07	53	0 37	0 70	0 0	53	0 20	0 23	1 23	1 43	1 3	1 77	1 92	0 20	1 66	3 70	0 63
3	Leaf area (cm^2)	293 33	594 66	476 00	564 33	4 8 33	529 66	311 00	315 00	537 33	522 00	734 66	464 33	704 00	492 33	656 00	330 00	
4	D ys to flowering	68 73	45 03	69 3	50 90	66 36	4 50	57 66	69 63	41 53	47 50	53 26	46 47	51 25	66 66	50 53	41 86	11 95
5	Number of fruits per plant	5 33	4 0	5 13	6 63	5 30	80	6 63	4 77	4 47	5 93	4 17	4 56	8 73	4 50	3 03	9 17	2 82
6	Fruiting phase	57 83	40 00	56 06	5 53	5 50	48 60	51 43	53 40	48 06	51 36	37 50	44 53	48 38	45 73	27 90	6 93	8 76
7	First fruiting node	6 30	7 23	7 70	7 27	5 90	7 00	6 30	7 23	6 50	6 73	80	6 63	6 88	6 66	6 37	5 56	
8	Number of flowers	8 00	7 13	6 93	7 76	7 0	7 6	10 70	6 26	7 13	9 6	5 76	6 36	11 42	7 66	4 46	12 50	3 59
9	Weight of fruit /plant (yie d) (g)	98 67	148 90	2 4 46	248 0	95 32	193 92	275 61	187 83	156 13	223 83	136 15	160 05	293 13	55 42	103 30	35 91	107 54
0	Weight of single fruit (g)	37 60	27 73	42 12	36 0	38 08	36 98	4 43	38 93	30 00	33 03	26 58	32 18	30 95	33 13	24 38	36 66	7 23
1	Percentage of fruit set	68 5 55 84)	53 53 (47 00)	73 84 (59 2)	7 08 (57 44)	68 93 (56 09)	58 23 (49 71)	64 07 (53 15)	76 06 (60 68)	55 53 (48 5)	63 80 (52 98)	54 90 (47 81)	66 7 (54)	70 33 (56 97)	57 2 (49 12)	48 96 (44 38)	75 34 (60 20)	
2	Length of fruit (cm)	15 52	4 69	4 7	20 03	4 82	17 59	13 90	3 69	6 88	7 01	15 68	17 01	17 50	13 53	1 92	20 69	3 3
13	Girth of fruit (cm)	8 72	5 32	8 55	6 82	8 67	6 72	9 17	9 2	5 64	6 06	42	5 40	6 14	6 89	5 23	6 50	1 37
4	Number of seeds per fruit	80 56	49 17	83 76	74 70	73 70	4 93	55 20	79 40	46 50	64 86	58 0	52 56	46 40	41 40	29 63	39 6	22 35
5	YVM intens ty	00	1 73	1 00	1 73	00	3 33	1 00	1 00	3 0	2 46	30	2 36	1 90	1 00	60	1 93	0 77
6	Shoot and fruit borer incidence	(20 4) 2 02	(6 97) 8 58	(20 04) 1 80	(5 02) 6 80	(7 35) 9 29	(9 57) 11 29	(24 29) 7 40	(2 52) 13 48	(2 2) 13 00	(17 90) 9 66	(1 65) 4 1	(18 53) 0 17	(18 75) 10 48	(23 02) 15 4	(12 60) 4 90	(24 64) 7 82	5 29

* The values in brackets indicate transformed values

Table 3

ANOVA

1. HEIGHT OF PLANT

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	111.343	55.672	0.468
Treatment	15	12671.750	844.783	7.106**
Error	30	3566.563	118.885	
Total	47	16349.660		

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

2. Number of branches

The anova is given in Tables 2 and 4. Significant difference was observed for this character, among the treatments. Treatment 16 recorded the highest value (3.70) followed by treatment 13 (1.92), while treatment 1 had the lowest value (0.07).

3. Leaf area

The results presented in Tables 2 and 5 indicated that there was no significant difference among the treatments. Treatment 11 had the maximum value (734.66) and treatment 1 had the minimum value (299.33).

4. Days to flowering

The results are shown in Tables 2 and 6. There was significant difference among the treatments for days to flowering. Treatment 8 recorded the highest mean value (69.63) followed by treatment 3 (69.43) while treatment 9 gave the lowest estimate (41.53).

5. Number of fruits per plant

The results are presented in Tables 2 and 7. The treatments differed significantly for this character. The highest value of 9.17 was recorded by treatment 16 followed

Table 4

ANOVA

2. NUMBER OF BRANCHES

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	0.500	0.250	1.753
Treatments	15	41.498	2.767	19.399**
Error	30	4.278	0.143	
Total	47	46.276		

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

Table 5

ANOVA

3. LEAF AREA

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	383498	191749	5.315*
Treatments	15	868890	57926	1.606
Error	30	1082370	36079	
Total	47	2334758		

* Significant at 5% level of significance

Table 6

ANOVA

4. DAYS TO FLOWERING

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	37.094	18.547	0.361
Treatments	15	4875.325	325.022	6.327**
Error	30	1541.297	51.377	
Total	47	6453.719		

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

Table 7

ANOVA

5. NUMBER OF FRUITS/PLANT

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	0.288	0.144	0.050
Treatments	15	119.039	7.936	2.765**
Error	30	26.092	2.869	

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

by treatment 13 (8.73). Treatment 15 recorded the lowest value of 3.03.

6. Fruiting phase

The results are presented in Tables 2 and 8. Significant differences among the treatments were observed. The maximum value of 61.93 was observed for treatment 16, followed by treatment 1 with 57.83 and treatment 15 recorded the lowest value (27.90).

7. First fruiting node

The results are given in Tables 2 and 9. No significant difference was observed among the treatments. Treatment 3 had the highest value (7.70) and treatment 11 the lowest value (4.80).

8. Number of flowers per plant

The results presented in Tables 2 and 10 showed that the treatments differed significantly. Treatment 16 recorded the highest mean value (12.50) followed by treatment 13 (11.42). The lowest value was observed for treatment 15 (4.46).

9. Weight of fruits per plant

Results are given in Tables 2 and 11. There was

Table 8

ANOVA

6. FRUITING PHASE

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	18.102	9.051	0.328
Treatments	15	3075.203	205.014	7.434**
Error	30	827.375	27.579	
Total	47	3920.680		

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

Table 9

ANOVA

7. 1st FRUITING NODE

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	52.396	26.198	20.837**
Treatments	15	24.014	1.601	1.373
Error	30	37.719	1.257	
Total	47	114.129		

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

Table 10

ANOVA

8. NUMBER OF FLOWERS/PLANT

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	17.799	8.899	1.917
Treatments	15	201.991	13.466	2.900**
Error	30	139.286	4.643	
Total	47	359.076		

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

Table 11

ANOVA

9. WEIGHT OF FRUITS/PLANT

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	3757	1878.50	0.451
Treatments	15	186795.30	12453.02	2.994**
Error	30	124798.30	4159.942	
Total	47	315350.60		

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

significant difference among the treatments for this trait, with treatment 16 giving the maximum value of 351.91 followed by treatment 13 with 293.31 and treatment 15 giving the lowest value 103.30.

10. Weight of single fruit

The results are presented in Tables 2 and 12. Significant difference was observed among the treatments. Treatment 3 recorded the highest value (42.12) followed by treatment 7 (41.43). Treatment 15 recorded the lowest value of 24.38.

11. Percentage of fruit set

The results are given in Tables 2 and 13. There was no significant difference among the treatments. Treatment 8 had the maximum percentage of fruitset (60.68) and treatment 15 recorded the lowest value (44.38).

12. Length of fruit

The results are presented in Tables 2 and 14. The treatments differed significantly for this character. Treatment 16 exhibited the maximum value 20.69 followed by treatment 4 with 20.03. Treatment 15 had the least length of fruit (11.92).

Table 12

ANOVA

10. WEIGHT OF SINGLE FRUIT

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	50.074	25.037	1.329
Treatments	15	1247.961	83.197	4.419**
Error	30	564.852	18.825	
Total	47	1862.887		

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

Table 13

ANOVA

11. PERCENTAGE OF FRUIT SET

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	131.031	65.516	1.342
Treatments	15	1168.234	77.882	1.595
Error	30	1464.547	48.818	
Total	47	2763.813		

Table 14

ANOVA

12. LENGTH OF FRUIT

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	0.834	0.417	0.105
Treatments	15	254.679	16.979	4.309**
Error	30	118.192	3.939	
Total	47	373.706		

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

Table 15

ANOVA

13. GIRTH OF FRUIT

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	3.455	1.729	2.548
Treatments	15	107.765	7.184	10.596**
Error	30	20.341	0.678	
Total	47			

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

13. Girth of fruit

The results are given in Tables 2 and 15. Significant difference was observed among the treatments. The maximum girth was recorded by treatment 7 (9.17) followed by treatment 8 (9.12). The lowest value was noticed for treatment 11 (4.42).

14. Number of seeds per fruit

The results presented in Tables 2 and 16 showed that the treatments differed significantly. Treatment 3 had the highest value (83.76) followed by treatment 1 (80.56). The lowest value for this trait was recorded by treatment 15 (29.63).

15. Yellow vein mosaic intensity

Results are given in Tables 2 and 17. There was significant difference among the treatments for this character. The highest intensity was recorded by treatment 6 (3.33) followed by treatment 9 (3.10) and the least intensity was exhibited by treatments 1,3,5,7,8 and 14 (1.00).

16. Shoot and fruit borer incidence

The results are presented in Tables 2 and 18. Significant difference was observed among the treatments. Treatment

Table 16

ANOVA

14. NUMBER OF SEEDS/FRUIT

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	1076.641	538.320	2.995
Treatments	15	12782.490	852.166	4.741**
Error	30	5392.141	179.738	
Total	47	19251.27		

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

Table 17

ANOVA

15. YVM INTENSITY

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	1.205	0.603	2.777
Treatments	15	26.589	1.773	8.168**
Error	30	6.511	0.217	
Total	47	34.305		

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

Table 18

ANOVA

16. SHOOT AND FRUIT BORER INCIDENCE

SOURCE	D.F.	S.S.	M.S.S.	F
Replication	2	30.322	15.161	1.501
Treatments	15	625.848	41.723	4.131**
Error	30	302.979	10.099	
Total	47	959.149		

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

16 had the highest shoot and fruit borer incidence (24.64) followed by treatment 7 (24.29) and treatment 11 had the lowest incidence (11.65).

II. Estimation of phenotypic variance, genotypic variance and genetic parameters

The phenotypic variance, genotypic variance and coefficient of variation are presented in Table 19.

1. Phenotypic variance

Leaf area registered the maximum phenotypic variance (43361.33) followed by weight of fruits per plant (6924.30) and number of seeds per fruit (403.88). The lowest value was observed for yellow vein mosaic intensity (0.74). Very low phenotypic variance was observed for number of branches, number of fruits per plant, first fruiting node, girth of fruit etc.

2. Genotypic variance

The maximum genotypic variance was recorded by leaf area (7282.33) followed by weight of fruits per plant (2764.35) and height of plant (241.97). The lowest value was observed for first fruiting node (0.12). Low values of genotypic variance were recorded by number of branches, number of fruits

per plant, number of flowers per plant, girth of fruit and yellow vein mosaic intensity.

3. Genetic parameters

a. Phenotypic coefficient of variation

Number of branches per plant exhibited maximum phenotypic coefficient of variation (90.73) followed by yellow vein mosaic intensity (49.98). Moderate values of phenotypic coefficient of variation were exhibited by leaf area, number of fruits per plant, number of flowers per plant, weight of fruits per plant and number of seeds per fruit. Low phenotypic coefficient of variation was recorded by height of plant, days to first flowering, fruiting phase, first fruiting node, weight of single fruit, length of fruit, girth of fruit and shoot and fruit borer incidence. The least value was recorded by percentage of fruit set (14.34).

b. Genotypic coefficient of variation

Maximum genotypic coefficient of variation was recorded by number of branches (84.16). This was followed by yellow vein mosaic intensity (41.97). Moderately high genotypic coefficient of variation was noted for number of fruits per plant, number of flowers per plant, weight of fruits per plant, girth of fruit and number of seeds per fruit. Height

Table 19. Phenotypic and genotypic variances, mean and phenotypic and genotypic coefficient of variation

Characters	Phenotypic variance	Genotypic variance	Mean($\bar{x}$)	P.C.V.	G.C.V.
1. Height of plant	360.85	241.97	83.90	22.64	18.54
2. Number of branches	1.02	0.88	1.11	90.73	84.16
3. Leaf area	43361.33	7282.33	492.44	42.29	17.33
4. Days to flowering	142.60	91.22	54.46	21.93	17.54
5. Number of fruits per plant	4.56	1.69	5.48	38.96	23.72
6. Fruiting phase	86.72	59.15	48.49	19.21	15.86
7. 1st fruiting node	1.37	0.12	6.53	17.94	5.19
8. Number of flowers/plant	7.58	2.94	7.87	35.01	21.80
9. Weight of fruits/plant	6924.30	2764.35	202.71	41.05	25.94
10. Weight of single fruit	40.29	21.46	34.17	18.58	13.56
11. Percentage fruit set	58.51	9.69	53.33	14.34	5.84
12. Length of fruit	8.29	4.35	15.91	18.09	13.10
13. Girth of fruit	2.85	2.17	6.84	24.68	21.55
14. Number of seeds/fruit	403.88	224.14	57.34	35.05	26.11
15. YVM intensity	0.74	0.52	1.72	49.98	41.97
16. Shoot and fruit borer incidence	20.64	10.54	18.90	24.04	17.17

of plant, leaf area, days to flowering, fruiting phase, weight of single fruit, percentage fruit set, length of fruit and shoot and fruit borer incidence recorded moderate values of genotypic coefficient of variation. The least genotypic coefficient of variation was recorded by first fruiting node (5.19), while percentage fruit set also recorded a low value of 5.84.

C. Heritability in the broad sense

The results are given in Table 20. The highest value for heritability was recorded by number of branches per plant (85.98 per cent) followed by girth of fruit (76.18 per cent) and yellow vein mosaic intensity (70.49 per cent). High values of heritability were recorded by fruiting phase, plant height, days to flowering and fruiting phase, while weight of single fruit, length of fruit, number of seeds per fruit and shoot and fruit borer incidence, showed moderate values of heritability. However leaf area, number of fruits per plant, first fruiting node, number of flowers per plant, weight of fruits per plant and percentage fruit set showed very low values of heritability. The lowest value was registered by first fruiting node (8.39 per cent).

d. Expected genetic advance

Results are given in Table 20. The highest estimate

Table 20. Heritability and expected genetic advance

Characters	Heritability (%)	Expected genetic advance as percentage of mean
1. Height of plant	67.05	26.24
2. Number of branches	85.98	1.78
3. Leaf area	16.79	14.62
4. Days to flowering	63.96	15.74
5. Number of fruits/plant	37.05	1.63
6. Fruiting phase	68.20	13.08
7. 1st fruiting node	8.39	0.20
8. Number of flowers/ plant	38.78	2.20
9. Weight of fruits/plant	39.92	33.75
10. Weight of single fruit	53.26	6.96
11. Percentage fruit set	16.55	2.61
12. Length of fruit	52.45	3.11
13. Girth of fruit	76.18	2.65
14. Number of seeds/fruit	55.49	22.97
15. YVM intensity	70.49	1.25
16. Shoot and fruit borer incidence	51.07	4.78

71

of expected genetic advance was observed for weight of fruits per plant (33.75) followed by height of plant (26.24). First fruiting node recorded the lowest value for genetic advance (0.20). Comparatively low values were recorded by number of branches, number of fruits per plant, number of flowers per plant, percentage fruit set, length of fruit, girth of fruit, yellow vein mosaic intensity and shoot and fruit borer incidence.

III. Phenotypic and genotypic correlation among the various characters

The results are given in Table 21 and Fig.1.

1. Height of plant

This trait showed significant and positive phenotypic correlation to number of branches, leaf area and yellow vein mosaic disease intensity. It showed negative and significant association with days to flowering, fruiting phase and girth of fruit. Positive non-significant phenotypic association was observed with number of fruits per plant, first fruiting node, number of flowers per plant, weight of fruits per plant and length of fruit, while, phenotypic correlation was negative and non significant with weight of single fruit, percentage fruit set and shoot and fruit borer incidence.

Positive genotypic correlation to number of branches, leaf area, number of fruits per plant, first fruiting node, length of fruit and yellow vein mosaic intensity were recorded. Leaf area recorded the highest value. Days to flowering, fruiting phase, number of flowers per plant, weight of fruits per plant, weight of single fruit, percentage fruit set, girth of fruit, number of seeds per fruit and shoot and fruit borer incidence showed negative genotypic correlation. Days to flowering recorded the highest negative genotypic correlation.

2. Number of branches

There was positive significant phenotypic correlation with number of fruits per plant, number of flowers per plant, weight of fruits per plant, length of fruit and yellow vein mosaic intensity. Days to flowering, weight of single fruit, girth of fruit and number of seeds per fruit showed negative and significant phenotypic correlation with this trait. Leaf area had non-significant positive correlation. Fruiting phase, first fruiting node, percentage fruit set and shoot and fruit borer incidence exhibited negative and non-significant phenotypic correlation.

Positive genotypic correlation was observed with leaf area, number of fruits per plant, number of flowers per plant,

weight of fruits per plant, percentage fruit set, length of fruit, yellow vein mosaic intensity and shoot and fruit borer incidence. Length of fruit had the highest positive genotypic correlation with number of branches. Days to flowering, fruiting phase, first fruiting node, weight of single fruit, girth of fruit and number of seeds per fruit showed negative genotypic correlation to this trait. Highest negative genotypic correlation to number of branches was recorded by days to flowering.

3. Leaf area

Significant negative phenotypic correlation was observed for days to flowering, fruiting phase, weight of single fruit, percentage fruit set, girth of fruit and shoot and fruit borer incidence with this trait. Number of fruits per plant, first fruiting node, number of flowers per plant, weight of fruits per plant, length of fruit and number of seeds per fruit recorded negative non-significant phenotypic correlation with this trait. Yellow vein mosaic intensity recorded positive non-significant phenotypic correlation.

First fruiting node, length of fruit and yellow vein mosaic intensity had positive genotypic correlation with leaf area, yellow vein mosaic intensity having the highest

genotypic correlation. Negative genotypic correlation with days to flowering, number of fruits per plant, fruiting phase, number of flowers per plant, weight of fruits per plant, weight of single fruit, percentage fruit set, girth of fruit, number of seeds per fruit and shoot and fruit borer incidence were observed. Fruiting phase, weight of single fruit, girth of fruit, and shoot and fruit borer incidence recorded high negative genotypic correlation with leaf area.

4. Days to flowering

There was positive significant phenotypic correlation with fruiting phase, first fruiting node, weight of single fruit, percentage fruit set, girth of fruit and number of seeds per fruit. The correlation with yellow vein mosaic intensity was significant and negative. Positive non-significant phenotypic correlation was exhibited by shoot and fruit borer incidence. Number of fruits per plant, number of flowers per plant, weight of fruits per plant, and length of fruit were negatively correlated with days to flowering and the correlation was non-significant.

Positive genotypic correlation with fruiting phase, weight of single fruit, percentage fruit set, girth of fruit, number of seeds per fruit and shoot and fruit borer incidence was observed, girth of fruit showing the highest value. Number

of fruits per plant, first fruiting node, number of flowers per plant, weight of fruits per plant, length of fruit and yellow vein mosaic intensity recorded negative genotypic correlation with days to flowering. Yellow vein mosaic intensity had the highest negative genotypic correlation with days to flowering.

5. Number of fruits per plant

Fruiting phase, number of flowers per plant, weight of fruits per plant, weight of single fruit, percentage fruit set, and length of fruit showed positive significant phenotypic correlation with number of fruits per plant. First fruiting node, girth of fruit, number of seeds per fruit, yellow vein mosaic intensity and shoot and fruit borer incidence had positive non-significant phenotypic correlation.

Fruiting phase, number of flowers per plant, weight of fruits per plant, weight of single fruit, percentage fruit set, length of fruit, girth of fruit and shoot and fruit borer incidence recorded positive genotypic correlation with number of fruits per plant. Number of flowers per plant recorded the highest positive genotypic correlation. First fruiting node, number of seeds per fruit and yellow vein mosaic intensity were negatively correlated with number of

fruits per plant, first fruiting node recording the highest negative genotypic correlation.

6. Fruiting phase

First fruiting node, number of flowers per plant, weight of fruits per plant, weight of single fruit, percentage fruit set, length of fruit, girth of fruit number of seeds per fruit and shoot and fruit borer incidence were positively and significantly correlated to fruiting phase phenotypically. Yellow vein mosaic intensity showed negative non-significant phenotypic association with this trait.

Positive genotypic correlation was recorded by number of flowers per plant, weight of fruits per plant, weight of single fruit, percentage fruit set, length of fruit, girth of fruit, number of seeds per fruit and shoot and fruit borer incidence. Percentage fruit set recorded the highest genotypic correlation with fruiting phase. First fruiting node and yellow vein mosaic intensity recorded negative genotypic correlation with this trait.

7. First fruiting node

Significant positive phenotypic correlation was recorded with weight of single fruit, percentage fruit set, and girth of fruit. Number of flowers per plant, weight of fruits per

plant, length of fruit, number of seeds per fruit, yellow vein mosaic intensity and shoot and fruit borer incidence showed non-significant positive phenotypic correlation.

Weight of single fruit, girth of fruit, number of seeds per fruit, yellow vein mosaic intensity and shoot and fruit borer incidence exhibited positive genotypic correlation with this trait. The highest positive genotypic correlation was recorded by girth of fruit. Negative genotypic correlation with first fruiting node was shown by number of flowers per plant, weight of fruits per plant, percentage fruit set and length of fruit, length of fruit giving the highest negative genotypic correlation.

8. Number of flowers per plant

There was significant and positive phenotypic correlation to weight of fruits per plant, length of fruit and shoot and fruit borer incidence. Positive non-significant phenotypic correlation to this trait was recorded by weight of single fruit, percentage fruit set, girth of fruit, number of seeds per fruit and yellow vein mosaic disease intensity.

Weight of fruits per plant, weight of single fruit, percentage fruit set, length of fruit, girth of fruit, yellow vein mosaic intensity and shoot and fruit borer incidence

Table 2 Phenotypic and genotypic correlation coefficients between pairs of characters

	Height of plant (X_1)	Number of branches (X_2)	Leaf area (X_3)	Days to flowering (X_4)	Number of fruits per plant (X_5)	Fruiting phase (X_6)	First fruiting node (X_7)	Number of flowers per plant (X_8)	Weight of fruits per plant (yield) (X_9)	Weight of single fruit (X_{10})	Percentage fruit set (X_{11})	Length of fruit (X_{12})	Girth of fruit (X_{13})	Number of seeds per fruit (X_{14})	YVM intensity (X_{15})	Shoot and fruit borer incidence (X_{16})
Height of plant (X_1)	1 000	0 3778**	0 3549*	0 5482**	0 606	0 289*	0 2 57	0 1380	0 1388	0 2353	0 1859	0 677	0 4 55**	0 2005	0 43 4**	0 2374
Number of branches (X_2)	0 4444	1 000	0 2411	0 7092**	0 3525*	0 0777	0 1674	0 3299*	0 3038*	0 3*60*	0 0720	0 4074**	0 5639**	0 497**	0 5074**	0 00 4
Leaf area (X_3)	1 2175	0 3667	1 000	0 3703*	0 425	0 450**	0 0953	0 0457	0 2067	0 5477**	0 4580**	0 0444	0 5537**	0 1985	0 104	0 4762**
Days to flowering (X_4)	0 75 0	0 850	0 6292	1 000	0 0526	0 39 4**	0 3561*	0 11 6	0 0176	0 5707**	0 726**	0 1887	0 749**	0 5633**	0 679**	0 843
Number of fruits per plant (X_5)	0 0399	0 5177	0 2955	0 3091	000	0 5354**	0 134	0 8887**	0 9656**	0 3726**	0 5169**	0 5446**	0 2359	0 0809	0 0478	0 2677
Fruiting phas (X_6)	0 3948	0 0382	1 1738	0 170	0 7600	1 000	0 3246*	0 5031**	0 6003**	0 7859**	0 7019**	0 5633**	0 6677**	0 4885**	0 1155	0 5250**
First fruiting node (X_7)	0 54 8	-0 6151	0 452	0 119	0 4299	0 0848	1 000	0 0043	0 348	0 4597**	0 4491**	0 7 6	0 3825**	0 2820	0 0049	0 2620
Number of flowers per plant (X_8)	0 0771	0 4728	-0 7888	0 3095	0 9964	0 7525	0 2205	000	0 8624**	0 277	0 556	0 8**	0 978	0 0 66	0 0363	0 3 9*
Weight of fruits per plant (yield) (X_9)	0 0727	0 3978	0 6348	0 1840	0 9716	0 8888	0 2346	0 9987	1 000	0 5215**	0 5367**	0 5 78**	0 3478	0 13 3	0 0424	0 3267*
Weight of single fruit (X_{10})	0 5670	0 4413	1 1636	0 4705	0 3735	0 8640	0 0870	0 4556	0 59 5	1 000	0 7093**	0 2975*	0 8648**	0 5635**	0 23 6	0 4950**
Percentage fruit set (X_{11})	0 6526	0 0078	0 7609	0 2887	0 9241	413	0 8360	0 9094	1 0799	0 89 9	1 000	0 5037**	0 6026**	0 4409**	0 08	0 06
Length of fruit (X_{12})	0 2968	0 7 60	0 2092	0 90 3	0 8075	0 40 7	0 8425	0 6685	0 7367	0 05>	0 2209	1 000	0 0 88	0 220	0 3394*	0 0673
Girth of fruit (X_{13})	0 5987	0 645	2 25	0 7488	0 1489	0 6483	0 3389	0 077	0 3514	0 91 8	0 7596	0 42 0	000	0 >629**	0 4753**	0 4377**
Number of seeds per fruit (X_{14})	0 4407	0 7325	-0 6584	0 7288	0 0669	0 5584	0 322	-0 2758	0 0627	0 6610	0 9816	0 1900	0 6898	000	0 4299**	0 0124
YVM intensity (X_{15})	0 6616	0 5791	0 699	0 9246	0 0090	0 0775	0 1989	0 0985	0 0662	0 3497	0 4878	0 6925	0 5851	0 4938	1 000	0 0242
Shoot and fruit borer incidence (X_{16})	0 470	0 0108	1 3512	0 1 49	0 6452	0 8440	0 0203	0 9417	0 7759	0 7385	0 /694	0 1563	0 644	0 0325	0 0324	000

Upper off diagonal elements = Phenotypic correlation coefficients

Low r off diagonal elements = Genotypic correlation coefficients

showed positive genotypic correlation with this trait. Weight of fruits per plant recorded the highest positive genotypic correlation. Number of seeds per fruit recorded negative genotypic correlation to number of flowers per plant.

9. Weight of fruits per plant

Weight of single fruit, percentage fruit set, length of fruit and shoot and fruit borer incidence recorded positive significant phenotypic correlation, while, girth of fruit, number of seeds per fruit and yellow vein mosaic intensity had positive non-significant association with this character.

Positive genotypic correlation was observed with weight of single fruit, percentage fruit set, length of fruit, girth of fruit, number of seeds per fruit and shoot and fruit borer incidence. Percentage fruit set recorded the highest value. Yellow vein mosaic disease intensity exhibited negative genotypic correlation with weight of fruits per plant.

10. Weight of single fruit

This trait showed positive and significant phenotypic correlation with percentage fruit set, length of fruit, girth of fruit, number of seeds per fruit and shoot and fruit borer

incidence. Yellow vein mosaic intensity was negatively correlated to weight of single fruit and the correlation was non-significant.

Percentage fruit set, girth of fruit, number of seeds per fruit, and shoot and fruit borer incidence recorded positive genotypic correlation with this trait, the highest value being exhibited by girth of fruit. Length of fruit and yellow vein mosaic intensity were negatively correlated to weight of single fruit.

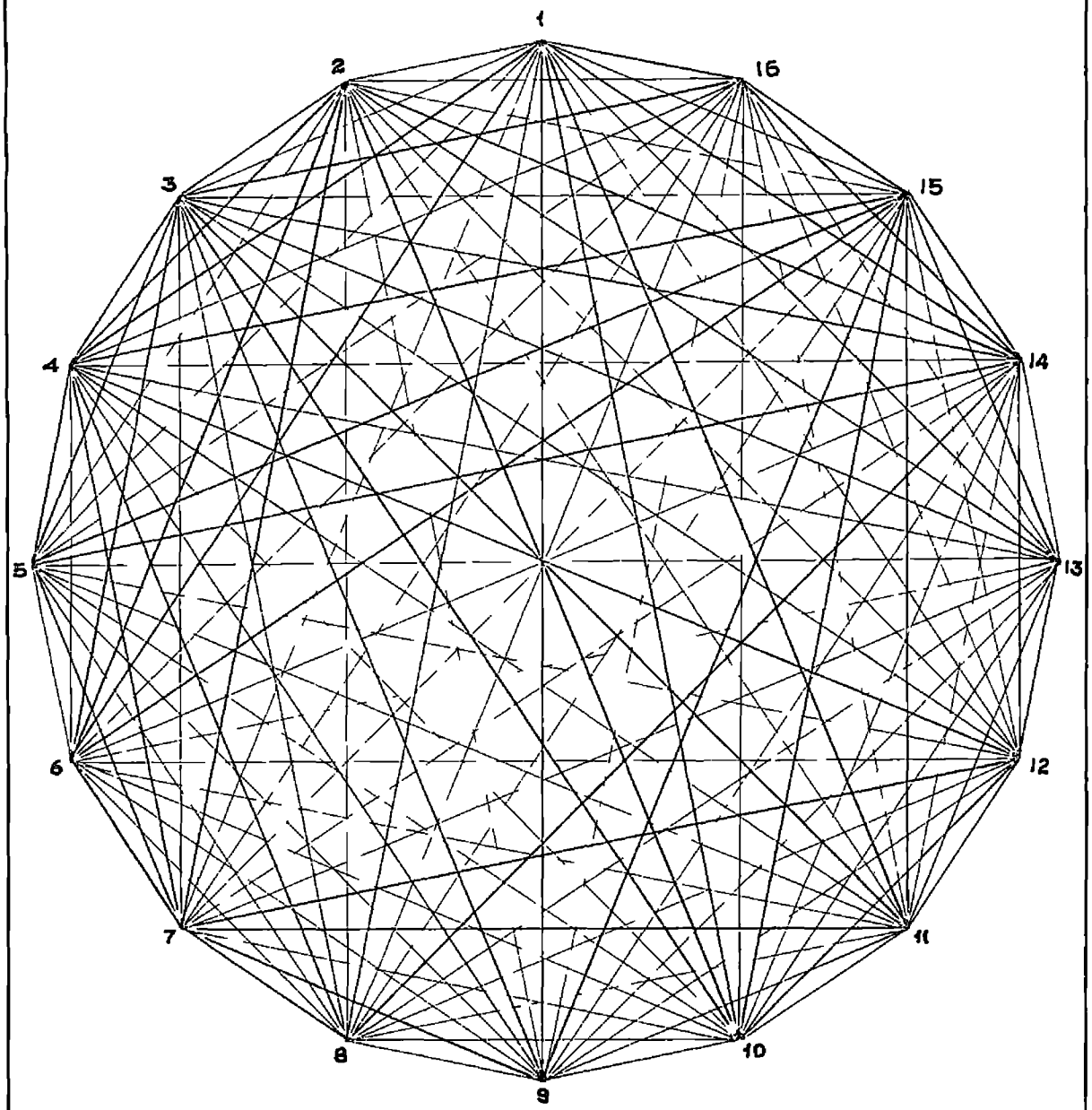
11. Percentage of fruit set

This character had positively phenotypic correlation to length of fruit, girth of fruit and number of seeds per fruit. Shoot and fruit borer incidence exhibited positive non-significant phenotypic correlation while yellow vein mosaic intensity showed negative non-significant correlation.

Positive genotypic correlation to length of fruit, girth of fruit, number of seeds per fruit and shoot and fruit borer incidence was recorded. Number of seeds per fruit recorded the highest positive genotypic correlation to this trait. Yellow vein mosaic intensity showed a negative genotypic correlation to percentage of fruit set.

Figure 1. Genotypic correlations between 16 characters

1. Height of plant
2. Number of branches per plant
3. Leaf area
4. Days to flowering
5. Number of fruits per plant
6. Fruiting phase
7. First fruiting node
8. Number of flowers per plant
9. Weight of fruits per plant
10. Weight of single fruit
11. Percentage fruit set
12. Length of fruit
13. Girth of fruit
14. Number of seeds per fruit
15. Yellow vein mosaic intensity
16. Fruit and shoot borer incidence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POSITIVE GENOTYPIC CORRELATION
NEGATIVE GENOTYPIC CORRELATION

FIGURE 1

12. Length of fruit

Significant positive phenotypic correlation to yellow vein mosaic intensity was recorded. Girth was negatively and non-significantly correlated to length of fruit, while number of seeds per fruit and shoot and fruit borer incidence were positively and non-significantly correlated to this trait.

Yellow vein mosaic intensity and shoot and fruit borer incidence recorded positive genotypic correlation to length of fruit, the former trait showing higher correlation. Girth of fruit and number of seeds per fruit were negatively correlated to this trait.

13. Girth of fruit

Positive and significant phenotypic correlation to girth of fruit was recorded by number of seeds per fruit and shoot and fruit borer incidence. Significant negative correlation was shown by yellow vein mosaic intensity.

Number of seeds per fruit and shoot and fruit borer incidence exhibited positive genotypic correlation to girth of fruit, while yellow vein mosaic intensity showed negative genotypic correlation.

14. Number of seeds per fruit

Significant negative phenotypic correlation to yellow

vein mosaic intensity and non-significant positive correlation to shoot and fruit borer incidence were recorded.

Yellow vein mosaic intensity and shoot and fruit borer incidence recorded negative genotypic correlation to number of seeds per fruit.

15. Yellow vein mosaic intensity

This character was positively correlated to shoot and fruit borer incidence and the correlation was non-significant.

Negative genotypic correlation to shoot and fruit borer incidence was recorded.

IV. Path coefficient analysis

Path coefficient analysis was done so as to obtain a clear picture of the direct and indirect effects of plant height, number of branches, number of fruits per plant, first fruiting node, number of flowers per plant, and length of fruit to yield. The direct and indirect effects obtained by path coefficient analysis of these six characters and yield are presented in Table 22 Fig. 2.

From the result it was seen that the maximum direct effect on yield was contributed by number of fruits per plant.

Its indirect effects through plant height and first fruiting node were positive while the indirect effects via number of branches per plant, number of flowers per plant and length of fruit were negative.

Plant height also exhibited a positive direct effect, next to number of fruits per plant. The indirect effects via all the other characters except number of fruits per plant were negative.

The direct effect of number of branches was negative. Positive indirect effects via height of plant, number of fruits per plant and first fruiting node were recorded, while the indirect effects through number of flowers per plant and length of fruit were negative.

First fruiting node also had a negative direct effect towards yield. The indirect effects via all other characters except number of fruits per plant were positive.

Number of flowers per plant exhibited a negative direct effect and the indirect effects through plant height, number of fruits and first fruiting node were positive. The indirect effects through number of branches per plant and length of fruit were negative.

Table 22. Direct and indirect effects and correlation of various characters on yield in bhindi

Character	Height of plant (X_1)	Number of branches per plant (X_2)	Number of fruits per plant (X_3)	First fruiting node (X_4)	Number of flowers per plant (X_5)	Length of fruit (X_6)	Correlation
Height of plant (X_1)	0.1483	-0.0745	0.0560	-0.0831	-0.0091	-0.1103	-0.0727
Number of branches per plant (X_2)	0.0659	-0.1675	0.7273	0.0944	-0.0561	-0.2662	0.3978
Number of fruits per plant (X_3)	0.0059	-0.0867	1.4048	0.0660	-0.1182	-0.3002	0.9716
First fruiting node (X_4)	0.0804	0.1030	-0.6040	-0.1535	0.0262	0.3133	-0.2346
Number of flowers per plant (X_5)	0.0114	-0.0792	1.3998	0.0338	-0.1186	-0.2485	0.9987
Length of fruit (X_6)	0.0440	-0.1199	1.1344	0.1293	-0.0793	-0.3718	0.7367

Residue = 0.2624

Direct effects are underlined

A negative direct effect was shown by length of fruit. Positive indirect effects through plant height, number of fruits per plant and first fruiting node were recorded while the indirect effects through number of branches per plant and number of flowers per plant were negative.

In this study, the residual effect was worked out to be 0.2624.

Figure 2. Path diagram showing the direct effects and interrelationship between yield and selected characters

Y - Yield

X_1 - Height of plant

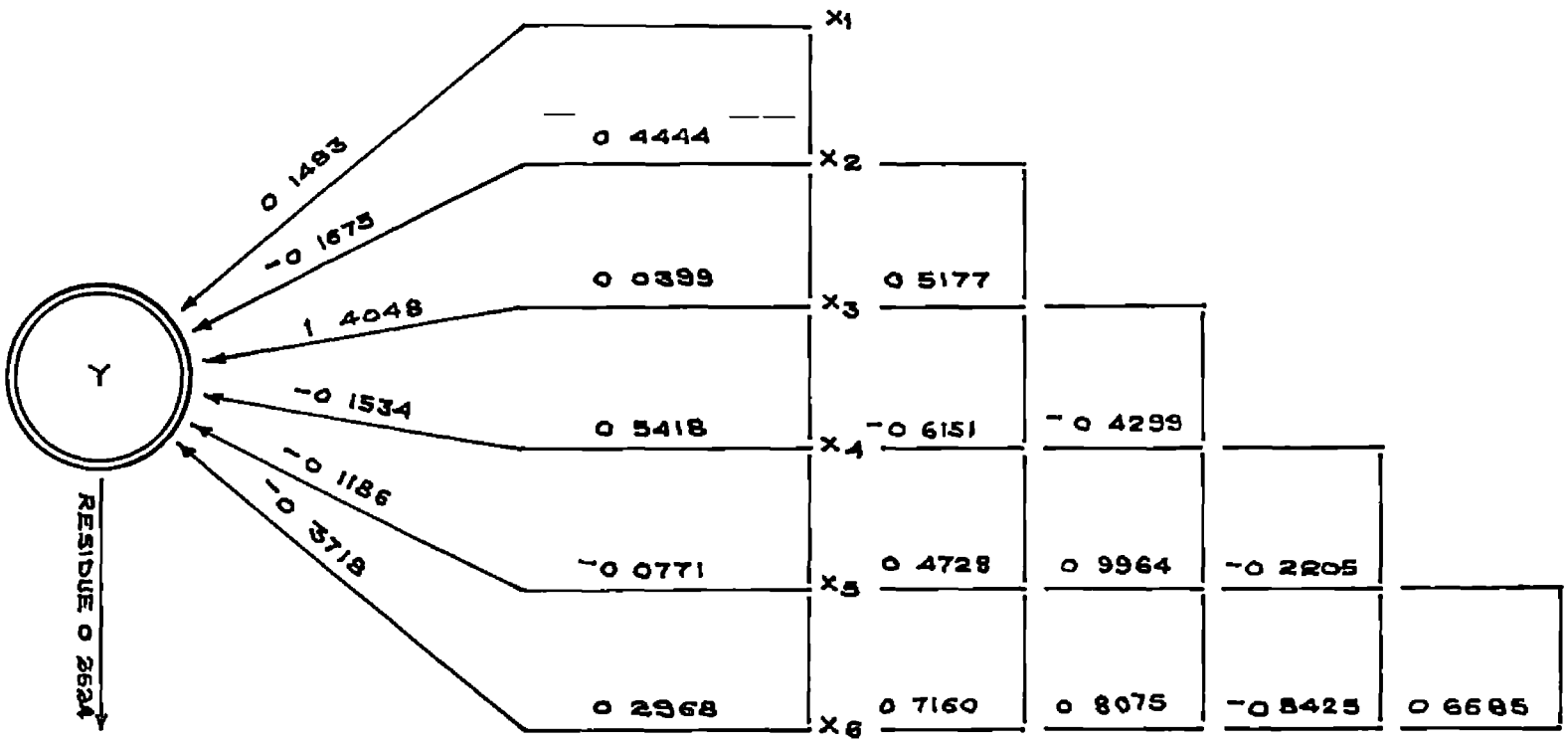
X_2 - Number of branches per plant

X_3 - Number of fruits per plant

X_4 - First fruiting node

X_5 - Number of flowers per plant

X_6 - Length of fruit



DIRECT EFFECTS SHOWN IN THE ARROWS
INTERRELATIONSHIPS SHOWN IN THE STEPS

FIGURE 2

DISCUSSION

The availability of disease or pest-resistant varieties of economic plants is of basic importance to the farmer. This is especially so, in the case of vegetables in which pesticides have to be used with caution. Besides, many of the virus diseases are difficult to be controlled by such methods. Therefore, breeding of resistant varieties assumes greater importance. The effective execution of this objective through conventional breeding methods is always difficult since the breeder has to see that he improves or at least maintains the important agronomic characters that vary during the breeding programme. The task becomes more difficult if the source of resistance is of a wild type with many undesirable genes under recombination circuit.

In the present study, the F_4 progeny lines of the crosses of two susceptible cultivars of Abelmoschus esculentus viz., Co-1 and K.S. 17 with A. manihot which was found to be highly resistant to yellow vein mosaic, were evaluated for resistance to the disease and various other characters which are associated with yield. The results are discussed in the following pages.

Variability

A programme of breeding aimed at the improvement of

yield and disease resistant characters require adequate information on the extent of variation available in the population. The scope for selection in the breeding population depends on the extent of genetic variability present in the segregating population.

Variance and coefficient of variation help to measure the variability in a population. It is necessary to partition the overall variability into heritable and non-heritable components.

The difference between the genotypes were highly significant for 13 out of 16 characters. The estimates of variance components indicated only little difference between phenotypic and genotypic variances for the characters viz., number of branches per plant, number of fruits per plant, first fruiting node, girth of fruit and yellow vein mosaic intensity (Table 19). This indicates that variations observed in these characters were mainly due to genetic causes and that environment had only negligible influence over them and there is better scope of improvement of these characters through selection. This finding is in conformity with the results of Mathews (1986) that only little difference existed between phenotypic and genotypic variance for number of branches per plant, number of fruits per plant, girth of fruit and yellow

vein mosaic intensity. Kaul et al. (1979) observed very high genetic variation for yellow vein mosaic intensity and number of fruits per plant.

On the other hand, the characters viz., height of plant, leaf area, days to flowering, weight of fruits per plant, number of seeds per fruit showed very wide difference between phenotypic and genotypic variance denoting the greater influence of environment over them, while the rest of the characters viz., fruiting phase, number of flowers per plant, weight of single fruit, percentage fruit set, length of fruit and shoot and fruit borer incidence exhibited moderate difference. The finding that wide difference exist between phenotypic and genotypic variance for plant height, days to flowering and weight of fruits per plant agrees with the results of Mathews (1986).

Genetic parameters

High genotypic coefficient of variation observed for number of branches per plant and yellow vein mosaic intensity indicates the presence of high degree of genetic variability and better scope for selecting yellow vein mosaic resistant lines. The high values observed for number of branches per plant and percentage of plants infected with yellow vein

mosaic were conformative to the findings of Meshra and Chhonkar (1979) and Kaul et al. (1979). However, Mathews (1986) recorded very low genotypic coefficient of variation for yellow vein mosaic intensity, contrary to the results of this study.

Moderately high values of genotypic coefficient of variation were recorded for number of fruits per plant, number of flowers per plant, weight of fruits per plant, girth of fruit, and number of seeds per fruit. The moderately high values of genotypic coefficient of variation recorded for weight of fruits per plant and number of fruits per plant is in conformity with the findings of Majumdar et al. (1974), Kaul et al. (1974), Mathews (1986) and Yadav (1986). The moderately high genotypic coefficient of variation observed in this study for number of seeds per fruit agrees with the findings of Yadav (1986) and for number of flowers per plant agrees with the findings of Mathews (1986).

Plant height, leaf area, days to flowering, fruiting phase, weight of single fruit, length of fruit, and shoot and fruit borer incidence showed moderate values of genotypic coefficient of variation. Similar observations were made by Rao (1972) regarding plant height and days to flowering. The moderate genotypic coefficient of variation observed for fruit

length agrees with the findings of Mathews (1985) and Yadav (1986). However, contrary to the moderate value recorded for plant height in this study, Mathews (1986) and Yadav (1986) reported high genotypic coefficient of variation for this character. Rao and Kulkarni (1978) observed that the contribution of plant height to total variability was higher than that of days to flowering, which was found to be true in the present study also. High genotypic coefficient of variation for weight of single fruit reported by Majumdar et al. (1974) is not confirmed in the present study.

The low genotypic coefficient of variation recorded by first fruiting node is in conformity with the findings of Sheela (1986). Percentage fruit set also recorded low genotypic coefficient of variation in this study.

However, with the help of genotypic coefficient of variation alone it is not possible to estimate the amount of heritable variation. Burton (1952) suggested that genotypic coefficient of variation along with heritability would provide a better picture of the amount of advance to be expected by phenotypic selection.

In the present study, plant height, number of branches per plant, days to flowering, fruiting phase, girth of fruit

and yellow vein mosaic intensity recorded high heritability values indicating that they are less influenced by environment. Similar reports were made by, Rao (1972) for plant height and days to flowering; Singh et al. (1974) for fruit girth; Lal et al. (1977) for days to flowering and fruit thickness, Singh and Singh (1978) for days to flowering, Meshra and Chhonkar (1979) for number of branches per plant, plant height and yellow vein mosaic infection; Mahajan and Sharma (1979) for fruit girth, Murthy and Bavaji (1980) for plant height, days to flowering and girth of fruit; Arumugam and Muthukrishnan (1981) for yellow vein mosaic intensity; Palaniveluchamy et al. (1982) for plant height, Maksoud et al. (1984) for earliness of flowering; Reddy et al. (1985) for plant height and number of branches, Palve et al. (1985) for days to flowering; Sheela (1986) for fruiting phase and Yadav (1986) for plant height. Contrary to these reports, low heritability values for plant height were reported by Majumdar et al. (1974) and Partap et al. (1980).

Moderate values of heritability were recorded for weight of single fruit, length of fruit, number of seeds per fruit and shoot and fruit borer incidence. Moderate heritability recorded for fruit length is in agreement with the findings of Yadav (1986). However, high heritability

values for this trait was recorded by Singh (1974); Mahajan and Sharma (1979); Murthy and Bavaji (1980) and Palve et al (1985). Regarding number of seeds per fruit, high heritability values were observed by Meshra and Chhonkar (1979) and Yadav (1986). Contrary to the moderate values of heritability recorded for weight of single fruit in the present study, Majumdar et al. (1974) and Maksoud et al. (1984) recorded high values for this character, while Ngah and Graham (1973) reported low value for the trait.

Low heritability values were observed for leaf area, number of fruits per plant, first fruiting node, number of flowers per plant, weight of fruits per plant and percentage fruit set. The low heritability values recorded for weight of fruits per plant was conformative to the findings of Ngah and Graham (1973), Lal et al. (1977) and Palaniveluchamy et al. (1982). Partap et al. (1980) got similar results for both weight of fruits and number of fruits per plant while Korla and Sharma (1984) observed moderate heritability value for first fruiting node. Contrary to the above results, high values of heritability were reported by Ramu (1976), Singh and Singh (1978), Murthy and Bavaji (1980), Maksoud et al. (1984) and Palve et al. (1985) for number of fruits per plant and yield.

Heritability values alone may not provide a clear predictability of the breeding value. Heritability in conjunction with genetic advance is more effective and reliable in predicting the resultant effect of selection, than heritability alone (Johnson et al., 1955 a). High heritability and appreciable genetic advance were recorded by plant height, days to flowering and fruiting phase. Number of seeds per fruit also exhibited moderately high values of heritability and appreciable genetic advance. High heritability and genetic advance together indicate the role of additive gene action for the character concerned as suggested by Panse (1957). The above result is in agreement with the findings of Lal et al. (1977) and Singh and Singh (1978) for days to flowering and of Sheela (1986) for fruiting phase and Yadav (1986) for number of seeds per fruit.

High heritability and low genetic advance were recorded for number of branches per plant, girth of fruit and yellow vein mosaic intensity; while moderately high heritability and low genetic advance were observed for weight of single fruit, length of fruit and shoot and fruit borer incidence. High heritability and low genetic advance observed for number of branches per plant, girth of fruit and yellow vein mosaic intensity are in agreement with the findings of Mathews (1986)

while the result regarding fruit girth, fruit length and shoot and fruit borer incidence agrees with the results of Sheela (1986). Similar reports of high heritability and low genetic advance for fruit girth was made by Ngah and Graham (1973) and Lal et al. (1977) and for fruit length by Yadav (1986). Contrary to the present finding of high heritability and low genetic advance for yellow vein mosaic intensity, Sheela (1986) observed high heritability and high genetic advance. High heritability and low genetic advance observed in the present study is attributed to the role of non-additive genes in the expression of these characters (Panse 1957, Liang et al., 1972 and Tikka et al., 1977).

Low heritability and low genetic advance were observed for number of fruits per plant, first fruiting node, number of flowers per plant and percentage fruit set in the present study indicating that these characters are highly influenced by environmental factors. Kulkarni et al. (1978) reported that number of fruits per plant was under non-additive gene action. Similar report of low heritability and low genetic advance for number of fruits was made by Partap et al. (1980). Low heritability and low genetic advance observed for percentage fruit set in this study agrees with the results of Sheela (1986). However, the present finding regarding number of

fruits per plant differs from the findings of Rao and Kulkarni (1977), Meshra and Chhonkar (1979), Majumdar et al. (1974) and Mathews (1986).

Correlation studies

Yield, an extremely complex character is the result of many growth functions of the plant. It is an example of integration in which the components of yield are partially independent in their development. Therefore, an estimation of the interrelationship between yield and yield attributing characters is vital. This would facilitate effective selection for simultaneous improvement of one or many yield attributing components. The intensity and direction of association between characters can be measured by genotypic and phenotypic correlation coefficients (Mode and Robinson, 1959). While, a knowledge of phenotypic correlation of metric characters with each other and especially yield is useful in designing effective breeding programmes, genotypic correlation provides a reliable measure of genetic association between the characters and helps to differentiate the vital associations useful in breeding from non-vital ones (Falconer, 1981). This information on genotypic correlation can be used in the prediction of correlated response to direct selection, in the construction of selection indices and in the selection of some

characters which have no value in themselves but are useful indication of more important ones under consideration (Robinson et al., 1951; Johnson et al., 1955 b). Indirect selection is a must when the character in question has low heritability and or is not exactly measurable (Singh et al., 1977).

In the present study, height of plant exhibited positive genotypic correlation with number of branches per plant, leaf area, number of fruits per plant, first fruiting node, fruit length and yellow vein mosaic intensity. The positive genotypic correlation observed for plant height with number of branches per plant agrees with the findings of Majumdar et al. (1974) and Elangovan et al. (1980), while positive genotypic correlation recorded between plant height and fruit length conforms to the reports of Maksoud et al. (1984). The result that plant height is positively correlated to number of fruits per plant is in agreement with the findings of Rao and Kulkarni (1978).

Days to flowering, fruiting phase, number of flowers per plant, weight of fruits per plant, weight of single fruit, percentage fruit set, girth of fruit, number of seeds per fruit and shoot and fruit borer incidence showed negative genotypic correlation with plant height. The negative

genotypic correlation of height of plant with weight of fruits per plant is contradictory to the observations made by Singh et al. (1974), Ramu (1976), Roy and Chhonkar (1976), Singh and Singh (1978) and Maksoud et al. (1984). In the present study, even though the number of fruits per plant has positive genotypic correlation to plant height, the weight of fruits per plant was negatively correlated to height. Height of plant showed positive genotypic correlation with fruit length, while the correlation is negative with fruit girth, number of seeds per fruit and fruiting phase. So, the reduction in the weight of fruits per plant as height increases, may be attributed to the proportionate reduction in the fruit girth, number of seeds per fruit and fruiting phase.

Number of branches per plant showed positive genotypic correlation with leaf area, number of fruits per plant, number of flowers per plant, weight of fruits per plant, percentage fruit set, length of fruit, yellow vein mosaic intensity and shoot and fruit borer incidence. The positive genotypic association of number of branches with yield observed in the present study is in agreement with the findings of Singh et al. (1974), Roy and Chhonkar (1976), Singh and Singh (1978, 1979), Elangovan et al. (1980) and Sheela (1986).

The negative genotypic association recorded by number of branches per plant with days to flowering, fruiting phase, first fruiting node, weight of single fruit, girth of fruit and number of seeds per fruit was contrary to the results of Sheela (1986).

Leaf area had positive genotypic correlation with first fruiting node, fruit length and yellow vein mosaic intensity which is in agreement with the findings of Sheela (1986). This indicates that a reduction in leaf area will lead to a reduction in the yellow vein mosaic intensity. Days to flowering, number of fruits per plant, fruiting phase, number of flowers per plant, weight of fruits per plant, weight of single fruit, percentage fruit set, girth of fruit, number of seeds per fruit and shoot and fruit borer incidence exhibited negative genotypic correlation with leaf area, indicating that an increase in leaf area is accompanied by a reduction in yield probably due to an increase in yellow vein mosaic intensity.

Days to flowering recorded positive genotypic correlation with fruiting phase, weight of single fruit, percentage fruit set, girth of fruit, number of seeds per fruit and shoot and fruit borer incidence, while negative association was observed with number of fruits per plant, first

fruiting node, number of flowers per plant, weight of fruits per plant, length of fruit and yellow vein mosaic intensity. Thus as the number of days taken for flowering increases there is a corresponding increase in the number of seeds per fruit, girth of fruit and weight of single fruit, but not in yield due to a proportionate reduction in the number of fruits and fruit length. This is in conformity with the findings of Majumdar et al. (1974) that yield is negatively correlated with days to flowering.

Number of fruits per plant recorded positive genotypic correlation with fruiting phase, number of flowers per plant, weight of fruits per plant, weight of single fruit, percentage fruit set, length of fruit, girth of fruit and shoot and fruit borer incidence, which was in agreement with the findings of Sheela (1986) that positive genotypic correlation existed between number of fruits per plant and the four characters viz., number of flowers per plant, weight of fruits per plant, weight of single fruit and length of fruit. The finding that number of fruits per plant and yield are positively related conforms to the observations made by Singh et al. (1974), Majumdar et al. (1974), Ramu (1976), Roy and Chhonkar (1976), Singh and Singh (1978, 1979), Ajmal et al. (1979), Mahajan and Sharma (1979), Elangovan et al.

(1980), Arumugam and Mathukrishnan (1981), Meshra and Singh (1985), and Yadav (1986). Negative genotypic correlation was observed for number of fruits with first fruiting node, number of seeds per fruit and yellow vein mosaic intensity. The negative genotypic association between number of fruits and first fruiting node agrees with the observations of Sheela (1986).

Fruiting phase exhibited positive genotypic correlation with number of flowers per plant, weight of fruits per plant, weight of single fruit, percentage fruit set, fruit length, fruit girth, number of seeds per fruit and shoot and fruit borer incidence. Positive genotypic correlation recorded for fruiting phase with number of flowers per plant, weight of fruits per plant, weight of single fruit, fruit length, fruit girth and number of seeds per fruit agrees with the findings of Sheela (1986). However, negative genotypic association was observed for this character with first fruiting node and yellow vein mosaic intensity. This result is in agreement with the findings of Sheela (1986).

Positive genotypic correlation was exhibited by first fruiting node with weight of single fruit, girth of fruit, number of seeds per fruit, yellow vein mosaic intensity and shoot and fruit borer incidence, whereas it recorded negative

correlation with number of flowers per plant, weight of fruits per plant, percentage fruit set and fruit length indicating that, as higher the position of the node of first fruit set is, lesser will be the number of flowers, weight of fruits per plant and percentage fruit set. The positive genotypic correlation of first fruiting node with weight of single fruit and fruit girth, and its negative genotypic association with number of flowers per plant and weight of fruits per plant are in conformity with the findings of Sheela (1986).

Number of flowers per plant was found to have positive genotypic correlation with weight of fruits per plant, weight of single fruit, percentage fruit set, fruit length, fruit girth, yellow vein mosaic intensity and shoot and fruit borer incidence. It exhibited negative genotypic correlation with number of seeds per fruit, which is contradictory to the report of Sheela (1986).

The positive genotypic correlation recorded by weight of fruits per plant with weight of single fruit conforms to the findings of Roy and Chhonkar (1976), Maksoud et al. (1984), Meshra and Singh (1985) and Sheela (1986). Weight of fruits per plant recorded positive genotypic correlation with fruit length which is in agreement with the results of Singh and Singh (1978, 1979), Mahajan and Sharma (1979), Elangovan et al.

(1980), Arumugam and Muthukrishnan (1981), Sheela (1986) and Yadav (1986). The positive genotypic correlation exhibited by weight of fruits per plant with fruit girth agrees with the findings of Elangovan et al. (1980) and Sheela (1986) while the positive association with number of seeds per fruit conforms to the findings of Arumugam and Muthukrishnan (1981) and Sheela (1986). The negative genotypic correlation recorded by weight of fruits per plant with yellow vein mosaic intensity is in agreement with the findings of Meshra and Singh (1986).

Weight of single fruit had positive genotypic correlation with percentage fruit set, fruit girth, number of seeds per fruit and shoot and fruit borer incidence, while it recorded negative genotypic association with fruit length and yellow vein mosaic intensity. Positive genotypic association of weight of single fruit with fruit girth and number of seeds per fruit is in conformity with the findings of Sheela (1986). However, contradictory to the present finding, Sheela (1986) recorded positive association between weight of single fruit and fruit length.

Percentage fruit set was found to show positive genotypic correlation with fruit length, fruit girth, number of seeds per fruit and shoot and fruit borer incidence, while

negative genotypic association was observed with yellow vein mosaic intensity indicating a higher percentage of fruit set in the absence of the disease.

The negative genotypic association of fruit length with fruit girth observed in the present study is contradictory to the results of Sheela (1986).

Fruit girth showed positive genotypic correlation to number of seeds per fruit and shoot and fruit borer incidence, while it was negatively correlated with yellow vein mosaic intensity. Positive association of fruit girth with number of seeds per fruit agrees with the results of Sheela (1986). Number of seeds per fruit exhibited negative genotypic correlation with yellow vein mosaic intensity and shoot and fruit borer incidence indicating the presence of more number of seeds, in fruits, on plants with, a lesser incidence of the above disease and pest.

Yellow vein mosaic intensity showed negative genotypic correlation with shoot and fruit borer incidence.

Interrelationship between characters gives an idea about the effect of selection for one character on the improvement of others. The major yield components recognised in the present study are number of branches per plant, number of

Plate A - A yellow vein mosaic resistant F_4 plant selected from treatment 1-2


A

Plate B - A F_4 plant selected from treatment 1-4 showing disease resistance and desirable fruit characteristics


B

fruits per plant, fruiting phase, number of flowers per plant, weight of single fruit, percentage fruit set, fruit length and girth of fruit.

Partap et al. (1979) identified the major yield attributing characters to be number of flowers per plant, number of fruits per plant, fruit length and fruit weight. Sheela (1986) observed number of fruits per plant, number of branches, length, girth and weight of single fruit, total number of flowers, fruiting phase, number of seeds per fruit as the important yield components. Mathews (1986) reported the major yield contributing characters in bhindi to be the number of fruits per plant, number of flowers per plant, plant height and earliness in flowering. In the present study, yellow vein mosaic intensity was negatively correlated with days to flowering, number of fruits per plant, fruiting phase, weight of fruits per plant, weight of single fruit, percentage fruit set, fruit girth, number of seeds per fruit and shoot and fruit borer incidence indicating that plants affected by the disease gives considerably lower yields

Path coefficient analysis

Coefficients of correlation measure the intensity and direction of character association in a crop (Moce and

Robinson, 1959). Fruit yield in bhindi depends upon many yield components, since yield is a polygenic character. Correlations are often misleading, as they measure only the association between two characters and may not give a complete picture of the components contributing to yield. The correlations between any two characters, which is being measured do not exist by themselves alone, but are part of complicated pathway of yield, in which indirect effects of other traits will also exist. In such situations a knowledge of association of different quantitative characters on a sound basis will be useful. The path coefficient analysis devised by Wright (1921) provides an effective means of finding out direct and indirect causes of association and permits critical examination of given correlation and measures the relative importance of each factor. The maximum direct effects towards yield was exerted by number of fruits per plant. This conforms to the findings of Roy and Chhonkar (1976). Its direct effect was more than its correlation value. This is because its indirect effects via number of branches per plant, number of flowers per plant and length of fruit were negative. The indirect effects through plant height and first fruiting node were positive.

Height of plant also exhibited a positive direct

Plate C - A F_4 plant selected from treatment 1-6 showing disease resistance and desirable fruit characteristics


C

effect towards yield and this was more than its correlation value with yield. It exhibited negative indirect effects through number of branches per plant, first fruiting node, number of flowers per plant and fruit length. The above results conform to the findings of Majumdar et al. (1974) and Rao and Kulkarni (1978) that plant height exhibited a positive direct effect towards yield. Singh and Singh (1979) reported that plant height and fruit number per plant had the highest direct effect on yield.

Number of branches per plant, first fruiting node, number of flowers per plant and fruit length showed negative direct effects. However, number of flowers per plant, fruit length and number of branches per plant exerted very high indirect effect on yield through number of fruits per plant, which had the highest direct effect. First fruiting node exhibited a negative indirect effect through number of fruits per plant and its indirect effect through fruit length only, was appreciably high. Number of flowers per plant made the highest indirect contribution to yield via number of fruits per plant.

It is concluded from the present study that, selection should be based on number of fruits per plant, height of plant, number of flowers per plant, fruit length and

number of branches per plant. The model used in this analysis accounts for 80 per cent of variability, leaving only 20 per cent for random variation. This is indicated by the residual factor of 0.2624 in the path diagram.

Therefore, it is recommended on the basis of the present investigation carried out in bhindi, that for the selection of a high yielding variety, the model for selection should be based on more number of fruits per plant, tall stature, more number of flowers per plant, increased fruit length and more number of branches per plant.

Selection of desirable F_4 progeny lines

As evident from the path analysis, the model for selection of a high yielding variety is to be based on tall stature, more number of branches per plant, more number of fruits and flowers per plant and increased fruit length. But the correlation studies reveal that yellow vein mosaic intensity is positively correlated with all the above characters except number of fruits per plant and fruit length. Scoring for yellow vein mosaic intensity in the different F_4 progeny lines revealed that plants resembling the wild parent A. manihot, in its short stature, lesser number of branches, increased fruiting phase, increased number of

Plate D - A F_4 plant selected from treatment 2-2 for disease resistance and desirable fruit characteristics


D

fruits per plant, increased fruit girth and number of seeds per fruit, were resistant to the disease. However, the fruits of these were found not conforming to the quality standards of the cultivated forms and had higher percentage of shoot and fruit borer incidence. Hence these were not selected. There were certain plants resembling the cultivated bhindi (A. esculentus) which were resistant to the disease and had desirable fruit characters. These plants (Plates A to F) were selected to advance to the F_5 generation.

Plate E - A F_4 plant selected from treatment 2-3 for disease resistance and desirable fruit characteristics


E

SUMMARY

SUMMARY

The experiment on the evaluation of the F_4 generation derived from an interspecific hybridisation programme involving two yellow vein mosaic susceptible cultivars of Abelmoschus esculentus viz., CO.1 and K.S.17 and a semi-wild species A. manihot resistant to the disease was conducted at the Department of Plant Breeding, College of Agriculture, Vellayani during 1987-'88.

The F_4 lines were grown in a field trial in Randomized Block Design with three replications and evaluated for resistance to yellow vein mosaic disease and various other characters associated with yield. Data were collected on sixteen characters viz., plant height, number of branches per plant, leaf area, days to flowering, number of fruits per plant, fruiting phase, first fruiting node, number of flowers per plant, weight of fruits per plant, weight of single fruit, percentage fruit set, length of fruit, girth of fruit, number of seeds per fruit, yellow vein mosaic intensity and shoot and fruit borer incidence.

The following are the important results obtained in this investigation.

1. Analysis of variance revealed significant differences among the treatments for 13 out of 16 characters studied.

Plate F - A F_4 plant selected from treatment 2-1 for disease resistance and desirable fruit characteristics


F

2. Of the 16 characters genotypic coefficient of variation was maximum for number of branches per plant and minimum for first fruiting node. Yellow vein mosaic intensity also exhibited high genotypic coefficient of variation. For characters like number of branches per plant, number of fruits per plant, first fruiting node, girth of fruit and yellow vein mosaic intensity, there was only little difference between phenotypic and genotypic variance. But for characters viz., plant height, days to flowering, weight of fruits per plant and number of seeds per fruit there was wide difference between phenotypic and genotypic variance indicating higher environmental influence.

3. Heritability estimate was maximum for number of branches per plant while first fruiting node recorded the least heritability value. Characters like plant height, days to flowering, fruiting phase, girth of fruit and yellow vein mosaic intensity also exhibited high heritability indicating lesser environmental influence on these characters.

4. Genetic advance was maximum for weight of fruits per plant followed by height of plant. High heritability coupled with appreciable genetic advance was recorded by plant height, days to flowering and fruiting phase indicating

the role of additive gene action in the expression of these characters. Number of seeds per plant exhibited moderately high heritability and appreciable genetic advance while high heritability and low genetic advance was recorded for number of branches per plant, fruit girth and yellow vein mosaic intensity. Moderately high heritability and low genetic advance were observed for weight of single fruit, fruit length and shoot and fruit borer incidence. Low heritability and low genetic advance for number of fruits per plant, first fruiting node, number of fruits per plant and percentage fruit set were recorded.

5. At the genotypic level, yield per plant showed positive correlation with almost all characters except plant height, leaf area, days to flowering, first fruiting node and yellow vein mosaic intensity. Number of fruits per plant, fruiting phase, number of flowers per plant, percentage fruit set and fruit length show high positive correlation to yield. The maximum association with yield per plant was recorded by percentage fruit set.

6. Path coefficient analysis at the genotypic level revealed that number of fruits per plant and plant height exerted high direct influence on yield. Number of branches per

plant, number of flowers per plant and fruit length exerted very high indirect effect on yield through number of fruits per plant. The model used in this analysis accounts for 80 per cent of the variability leaving only 20 per cent for random variation.

Thus for selection of a high yielding variety of bhindi, the model for selection should be based on number of fruits per plant, plant height, number of flowers per plant, fruit length and number of branches per plant.

7. From the F_4 generation, six plants were selected which were resistant to the disease and had desirable attributes. Selfed seeds from these were collected for advancing to the F_5 generation.

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* Originals not seen

PROGENY STUDIES OF INTERSPECIFIC CROSSES OF *Abelmoschus*

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ABSTRACT OF A THESIS SUBMITTED
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ABSTRACT

A study was conducted at the Department of Plant Breeding, College of Agriculture, Vellayani during 1987-'88 aimed at evaluating the F_4 generation of interspecific hybrids between two yellow vein mosaic susceptible cultivars of Abelmoschus esculentus and the resistant semi-wild species, A. manihot for yellow vein mosaic resistance and yield. The estimation of genetic parameters of important economic characters, the association among these characters and the path coefficient analysis were undertaken.

The F_4 progeny lines were evaluated in an RBD with three replications. The genotypes showed significant differences in most of the characters studied. Genotypic coefficient of variation was maximum for number of branches per plant and minimum for first fruiting node. Plant height, days to flowering and fruiting phase showed high heritability and appreciable genetic advance while number of seeds per fruit recorded moderately high heritability and appreciable genetic advance indicating the presence of additive gene action. Number of branches per plant, fruit girth and yellow vein mosaic intensity exhibited high heritability and low genetic advance, while weight of single fruit, fruit length and shoot and fruit borer incidence recorded moderately high

heritability and low genetic advance.

Correlation studies revealed that number of branches per plant, number of fruits per plant, fruiting phase, number of flowers per plant, weight of single fruit, percentage fruit set, fruit length, fruit girth and number of seeds per fruit exhibited positive correlation to yield and could be considered as the major yield attributing characters.

Path coefficient analysis projected number of fruits per plant and plant height as the traits exerting high positive direct effect on yield, while number of branches per plant, number of flowers per plant and fruit length exerted high positive indirect effect on yield through number of fruits per plant.

The study indicated that the model for selection of a high yielding variety of bhindi should be based on number of fruits per plant, plant height, number of flowers per plant, fruit length and number of branches per plant. However, scoring for yellow vein mosaic intensity in the F_4 progenies revealed that plants resembling the wild parent A. manihot in its short stature, lesser number of branches, increased fruit girth and number of seeds per fruit were resistant to the disease. However, since the fruits of these

plants did not conform to the quality standards of cultivated bhindi and had higher percentage of shoot and fruit borer incidence, they were not selected. Plants resistant to the disease and resembling the cultivated bhindi were selected to carry forward to the next generation.