GENETIC ANALYSIS FOR YIELD AND RESISTANCE TO YELLOW VEIN MOSAIC IN OKRA

(*Abelmoschus esculentus* (L.) Moench)

P. SINDHUMOLE

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Department of Plant Breeding and Genetics
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM- 695 522

DECLARATION

I hereby declare that this thesis entitled "**Genetic Analysis for Yield and Resistance to Yellow Vein Mosaic in Okra (*Abelmoschus esculentus* (L.) Moench)**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other university or society.

Vellayani,
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P. SINDHUMOLE
(99-21-05)

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Certified that this thesis entitled "**Genetic Analysis for Yield and Resistance to Yellow Vein Mosaic in Okra (*Abelmoschus esculentus* (L.) Moench)**" is a record of research work done independently by Mrs. P. Sindhumole (99-21-05) 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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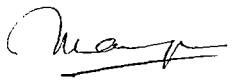

Dr. P. Manju
(Chairman, Advisory Committee)
Associate Professor
Department of Plant Breeding and Genetics
College of Agriculture, Vellayani
Thiruvananthapuram.

Approved by

Chairman **:**

30/8/03

Dr. (Mrs.) P. MANJU
Associate Professor,
Department of Plant Breeding and Genetics,
College of Agriculture, Vellayani,
Thiruvananthapuram – 695 522

Members **:**

Chandramony.D
30.8.03

Dr. (Mrs.) D. CHANDRAMONY
Professor and Head,
Department of Plant Breeding and Genetics,
College of Agriculture, Vellayani,
Thiruvananthapuram – 695 522

30.8.03

Dr. B. RAJAGOPALAN
Professor,
Department of Plant Pathology,
College of Agriculture, Vellayani,
Thiruvananthapuram – 695 522

30/8/03

Dr. K. RAJMOHAN
Associate Professor and Head,
Department of Pomology and Floriculture,
College of Agriculture, Vellayani,
Thiruvananthapuram – 695 522

30-8-03

Dr. VIJAYARAGHAVAKUMAR
Associate Professor,
Department of Agricultural Statistics,
College of Agriculture, Vellayani,
Thiruvananthapuram – 695 522

External Examiner :

T.S. Raveendran
30-8-2003
(T.S. RAVEENDRAN)
Director, CPBG, TNAU, CBE.

Dedicated to

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Introduction

1. INTRODUCTION

Vegetables, the important protective foods, are excellent sources of protein, vitamins, carbohydrate and minerals. India has second position in world scenario for vegetable production by standing next only to China. Okra (*Abelmoschus esculentus* (L.) Moench) is an important vegetable of the world being produced in the tropical and sub-tropical low land regions of Asia, Africa, America and warmer parts of Mediterranean regions. India proudly claims the position of the largest producer of okra by occupying an area of about 3,83,000 ha with a production of 24,50,000 tons (Verma, 2000). This significant achievement could be attributed to the development of high yielding varieties and hybrids possessing resistance to biotic and abiotic stresses. Assam, Bihar, Orissa and West Bengal are the states which contribute to the major production of okra in the country.

Okra, a highly adaptable crop, is grown throughout the country for its tender green fruits which are cooked and consumed in various forms and also used for canning. Besides being rich in protein, vitamins, minerals (especially iron) and dietary fibre, the high iodine content makes it unique among vegetables and helps it to play a vital role in controlling goitre disease especially for vegetarians. Seeds form a nutritious ingredient of cattle feed whereas mucilage finds its use in the manufacture of gums. The juice of over-ripe fruits is an ideal substitute for shampoo. Also, the plant as a whole serves as a source of fibre. Owing to these myriad uses, okra possesses high demand in inland market along with great export potential.

In spite of high production, the average productivity of okra in our country is merely 14.8 t ha^{-1}. The major problem underlying this low productivity is the high susceptibility of most of the cultivars now in vogue to yellow vein mosaic (YVM), the most dreaded disease of okra. Being a viral one which is transmitted mainly by white fly (*Bemisia*

tabaci), use of insecticides could be resorted to for vector control. However, as alternate day harvest of tender fruits is the common practice, insecticide application would lead to toxicity. Moreover, cultivation of okra during summer season has been problematic and less economic. These pinpoint the need to evolve okra varieties resistant to YVM which are suitable for summer cultivation (Peter, 1998).

Hence, it is highly essential to identify the sources of YVM resistance and study the inheritance of resistance to develop high yielding YVM resistant varieties of okra. Studies on the inheritance pattern of YVM resistance in okra carried out so far are very much limited.

Efficiency of selection for the improvement of both qualitative and quantitative traits depends upon the nature and magnitude of gene effects involved in the inheritance of a particular character. Generation mean analysis helps to understand the nature and magnitude of gene action using the means of various generations.

In the light of these facts, the present investigation was undertaken with the following objectives.

★To identify the source of YVM resistance and estimate the genetic variability for yield and yield attributes from the okra germplasm collected from various parts of India

★To compare the relative incidence of YVM during various phases of crop growth

★To assess the occurrence of population of vectors (white fly and leaf hopper) and their association on YVM incidence during various crop stages of okra genotypes

★To estimate the combining ability and heterosis by line x tester analysis

★To estimate the additive, dominance and epistatic gene action involved in the inheritance of yield, its components and YVM resistance through generation mean analysis for developing high yielding disease resistant varieties.

Review of Literature

2. REVIEW OF LITERATURE

The literature available on various aspects of the present investigation is reviewed hereunder:

2.1 ORIGIN

The genus *Abelmoschus* is believed to be of Asiatic or African origin and its centres of diversity include West Africa, India and South East Asia (Chevalier, 1940; Siemonsma, 1982; Hamon and Hamon, 1991; Bisht *et al.*, 1995). The theories available so far suggest India (Masters, 1875), Ethiopia (Vavilov, 1951), West Africa (Chevalier, 1940) and tropical Asia (Grubben, 1977) as the centre of origin of *Abelmoschus esculentus*, thus making it a matter of controversy.

Polyphyletic origin of *A. esculentus* was proposed by Joshi and Hardas (1956), who reported an allopolyploid genome which arose through hybridisation between one species with n = 29 and the other with n = 36 followed by chromosome doubling. Presence of *A. tuberculatus* (2n = 58) genome in *A. esculentus* (2n = 130) was also confirmed.

2.2 TAXONOMY

Okra, *Abelmoschus esculentus*, belongs to the family Malvaceae. Cultivated okra was earlier represented as *Hibiscus esculentus* L. (Waalkes, 1966; Bates, 1968).

Abelmoschus was divided into two groups by Waalkes (1966), of which the first group consisted of three cultivated forms (*A. esculentus*, *A. manihot* and *A. moschatus*) and the second one included three wild forms (*A. crinitus*, *A. angulosus* and *A. ficulneus*). Some modifications like inclusion of *A. tuberculatus* and grouping of all subspecies and varieties of *A. manihot* were suggested by Bates (1968). Discovery of an African cultivated species by Chevalier (1940) made the genus little more complex and it was rediscovered by Siemonsma (1982) and described as *A. caillei*.

International okra workshop (IBPGR, 1990) adopted a classification (Table 1) based on the available cytogenetical evidence consisting of nine species and it included a cultivated species *A. caillei* which was wrongly identified earlier as *A.manihot* ssp.*manihot*.

Table 1. Classification of the genus *Abelmoschus* adopted by International okra workshop (1990)

Sl. No.	Name of species	Chromosome number (2n)
1.	*A. moschatus* Medikus ssp. *moschatus* var. *moschatus* ssp. *moschatus* var. *beautiformis* (Mast.) Hochr. ssp. *biakinensis* (Hochr.) Borss ssp.*tuberosus* (Span) Borss	72
2.	*A. manihot* (L.) Medikus	60-68
3.	*A. tetraphyllus* Roxb. Graham var. *tetraphyllus* var. *pungens* (Roxb.) Hochr.	130-138
4.	*A. esculentus* (L.) Moench	72-108-144
5.	*A. tuberculatus* Pal and Singh	58
6.	*A. ficulneus* (L.) W. and A.	72
7.	*A. crinitus* Wall	-
8.	*A. angulosus* Wall	56
9.	*A. caillei* (*A. chev.*) Stevels	185-199

2.3 CYTOGENETICS

Chromosome number vary greatly among the members of genus *Abelmoschus*. The lowest chromosome number (2n = 56) was observed for *A. angulosus* (Ford, 1938) whereas the highest 2n number (close to 200) was reported for *A. caillei* (Singh and Bhatnagar, 1975).

Though great variation was observed for the chromosome number of *A. esculentus*, the most frequently observed was 2n = 130. Occurrence of 2n = 72, 108, 120, 132 and 144 was considered as an indication of regular series of polyploids with x = 12 by Dutta and Naug (1968).

Charrier (1984) suggested three ploidy levels where *A.moschatus* (n=36), *A. ficulneus* (n=36), *A.tuberculatus* (2n = 29), *A. esculentus* (n = 36) and *A.manihot* (n=30–34) are at ploidy level 1; *A.esculentus* (n =62–65) and *A. tetraphyllus* (n = 69) are at ploidy level 2 and *A. caillei* (n = 99) is at ploidy level 3. The genus, therefore, may be a "polyspecies complex" where continuous interchange of genes throughout its evolution has complicated the determination of relationships.

2.4 REPRODUCTIVE BIOLOGY

Although okra is assumed to be a self pollinated crop, hermaphrodite flowers display entomophilous features and crossing to an extent of 4 to 42 per cent had been observed by researchers (Purewal and Randhawa, 1947; Venkitaramani, 1952; Martin, 1983; Akoroda, 1986).

Depending on the species, variety, season and location, varying degrees of outcrossing (upto 60 %) occurs in okra (Engels and Chandel, 1990). Hamon and Koechlin (1991 a,b) classified *A. esculentus* as an obligate autogamous species.

Crossing occurs in okra mainly due to entomophily and protogyny. But as selfing is more common than crossing, it is designated as an often cross pollinated crop.

2.5 GENETIC VARIABILITY

Presence of variability among genotypes is a pre-requisite for any crop improvement programme. Considerable variation has been reported for several characters in okra by various researchers (Thaker *et al.*, 1981b, Chedda and Fatokun, 1982; Palaniveluchamy *et al.*, 1983 and Soubanbabu and Sharma, 1983).

Length and number of fruits and yield plant^{-1} exhibited considerable variability (Murthy and Bavaji, 1980). Vashistha *et al.* (1982) observed significant difference for yield and agronomic characters except ridges fruit^{-1}. A narrow range of variability (13.1 to 14.3 %) was observed for crude fibre content among 56 *Hibiscus esculentus* hybrids by Elangovan *et al.* (1983) and they recommended the lines AE-106 and AE-974 for breeding fruits with low fibre content.

In a study of six *A. esculentus* types over two seasons, the highest yield and seed oil content (15%) were recorded for Dwarf GLP and Penta Green whereas Clamson Spineless also was a high yielder (Blennerhassett and El-Zeftawi, 1986). Sujatha *et al.* (1986) observed that Pusa Makhmali had the highest seed oil content (17.3%) among sixteen taxa of *Hibiscus* and *Abelmoschus* including nine cultivars of *A. esculentus*.

Twenty eight accessions of okra varied for plant height, node of first fruit set, fruits and yield plant^{-1} and the highest yielder was Pusa Selection 6-2 (Korla and Sharma, 1987b).

Genetic variability in ten morphological characters among eighteen okra accessions was measured by Ariyo (1990a). When the performance of seven okra varieties was studied, Bhubaneswar-1 had the credit of being the best yielder with the highest fresh pod weight while AE-180 was the earliest bearer and Pusa Sawani was the tallest with maximum pods (Nandi, 1990). Jeyapandi and Balakrishnan (1992) observed the highest variability for yield plant^{-1} followed by plant height and seeds pod^{-1}.

Bindu (1993) reported significant variation among 70 genotypes for most of the traits except fruiting phase and leaf axil bearing first flower. During a comparison of eight genotypes and their 28 hybrids, considerable variation was observed for the characters under study (Kumbhani *et al.*, 1993). Among the six YVM resistant / tolerant okra varieties from various regions of India, compared with Pusa Sawani during various seasons, AROH-1 had the highest mean yield followed by Arka Anamika and Sel-4 (Mathew *et al.*, 1993). In an evaluation involving six yield related traits of

eight okra cultivars at Tarai region of Uttar Pradesh, Singh *et al.* (1993) observed the highest mean yield over two years for Parbhani Kranti (9.1 t ha^{-1}) followed by Punjab-7 and Punjab Padmini (9.0 and 8.8 t ha^{-1} respectively).

Damarany and Farag (1994) noticed significant variation for twelve characters while evaluating thirteen cultivars of okra for two successive summer seasons at Assiut. Blondy was the earliest and the highest yielder with maximum pods $plant^{-1}$. The highest per cent of seed protein as well as fibre was noticed for Balady and Lee respectively. The tallest type Balady was also bestowed with the least fibre content (%) while Dwarf Long Pod Green was the shortest type.

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

In an evaluation of 30 genotypes across four environments, Pusa Sawani and Strain 6316 were the most stable genotypes with respect to days to 50 per cent flower while White Velvet and Strain 7116 had the highest stability for days to first flower and plant height respectively (Mandal and Dana, 1994). Sheela (1994) reported good genetic diversity in okra germplasm which consisted of 56 accessions for all the characters under investigation except stem girth, YVM incidence and leaf webber attack.

Bindu *et al.* (1997) observed wide range of variation for most of the traits including branches and leaves $plant^{-1}$, leaf area, fruit length, days to first flower, plant height, seeds $fruit^{-1}$ and fruit weight $plant^{-1}$. Significant variation among six parental strains and their 30 F_1 hybrids was reported by Rajani and Manju (1997) for days to first flower, first fruiting node, number of leaves, branches, flowers and fruits $plant^{-1}$, leaf area, length and girth of fruits, individual fruit weight, fruit set (%), fruiting phase, yield $plant^{-1}$, plant height and YVM incidence. Yassin and Anbu (1997) observed wide

variability for plant height, single fruit weight, branches, fruits and yield plant^{-1} but not for length and girth of fruits.

Significant variability was observed for all the characters studied in F_2M_2 and F_3M_3 families by John (1997) and John *et al.* (1999) and in F_4M_4 and F_5M_5 families by Philip (1998). Out of the twelve okra varieties evaluated, Panchsira was the best performer with maximum yield (15.4 t ha^{-1}) as well as fruits plant^{-1} (35.1) while Pusa Sawani also performed well (Dutta, 1999).

During a two-year yield evaluation at Iran, Annie Oakley and Dashtestan were identified as the high yielding cultivars (Langaroodi and Kazerani, 1999). IC-39135, IC-9856 and Punjab Padmini were the highest yielders among 48 okra types which varied for characters including nodes plant^{-1}, days to 50 per cent flower, fruiting phase, fruit weight and marketable fruit yield plant^{-1} (Sood, 1999).

Twenty two okra genotypes exhibited wide variation for plant height, days to first flower, number of leaves, nodes and fruits plant^{-1}, seeds fruit^{-1}, fruit weight and yield (Hazra and Basu, 2000). Variation was moderate for fruit length and primary branches whereas low for node of first flower, ridges fruit^{-1} and dry fruit weight. Philip *et al.* (2000) studied the variability in F_4 generation of irradiated interspecific hybrids in okra and observed significant variation for branches and fruits plant^{-1}, average fruit weight, crude fibre content of fruits, yield and incidence of YVM as well as fruit and shoot borer. Singh (2000) reported that Prabhani Kranti produced the highest yield and pod weight besides being YVM resistant, for all the three years tried.

In a comparative study conducted by Amjad *et al.* (2001) in Faisalabad, Pakistan involving four Indian cultivars *viz.*, Pusa Sawani, Parbhani Kranti, Hybrid Bhindi Sakshi and Krisma-51, a local cultivar Sabz Pari excelled for seed germination, earliness, average weight and yield of green pods, seed yield, seeds pod^{-1} and 1000-seed weight. Green pod length was maximum in Hybrid Bhindi Sakshi (12.88 cm) which was on par

with Sabz Pari (12.55 cm). Bas and Koludar (2001) characterised 45 cultivars of okra, collected in Turkey for pomological and morphological traits and noticed a distinct leaf shape, which was absent in IBPGR descriptor and also considerable variation in leaf colour, leaf shape, fruit shape, length of mature fruits, quality and earliness.

The study of 44 okra genotypes collected from NBPGR by Gandhi *et al.* (2001) revealed significant variability for all the thirteen traits under investigation including plant height, height at first fruit set, internodal length, fruits and branches plant^{-1}, length and girth of fruits and yield plant^{-1} of dry fruits and seeds. Lal *et al.* (2001) assessed the response of three okra varieties to varying sowing dates under Tarai foot hills of Himalayas and obtained the highest green pod yield (85.9 q ha^{-1}) for Parbhani Kranti, followed by Pusa Sawani (8.4 q ha^{-1}) and P-7 (72.5 q ha^{-1}). P-7 exhibited the lowest YVM virus infection (0.3 %) while Pusa Sawani showed the highest (41.4 %).

Genetic diversity of 39 *Abelmoschus* accessions including fifteen *A. esculentus* types was investigated at DNA level using RAPD procedure by Martinello *et al.* (2001). Thirty one random decamer primers were employed to amplify DNA by PCR and 103 RAPD fragments were generated. Based on molecular data, dendrograms were formulated for assessing the genetic distance among genotypes. The researchers concluded that molecular approach has high potential, similar to multivariate analysis, in the characterisation of okra germplasm.

Yadav and Dhankhar (2001) assessed the influence of nine sowing dates at 20 days interval *viz.*, from March 5th to August 12th and three positions of fruit (lower, middle and upper) for seed yield, quality, vigour and viability. Seeds sown on 13th June resulted in higher seed yield of better quality. Delayed sowing drastically reduced seed yield and deteriorated seed vigour and viability. Seeds from lower and middle position fruits exhibited higher test weight, vigour index and viability than those from upper position fruits.

Broad range of variation and high mean values were noticed in rainy season for fruits plant^{-1}, days to 50 per cent flower and branches plant^{-1} and in spring-summer season for fruit yield and plant height as reported by Dhankhar and Dhankhar (2002). Samnotra *et al.* (2002) assessed the difference in leaf characteristics of okra cultivars and opined that PKS-404, Nath Shoba, Arka Anamika and Varsha Uphar exhibited very broad leaves recording maximum leaf width indices and minimum lacination indices.

2.6 COEFFICIENT OF VARIATION

Thaker *et al.* (1981b) noticed high GCV for plant height, leaf area, fruit number, fruit weight and yield plant^{-1}. According to Balachandran (1984), number and yield of fruits had high PCV and ECV while percent fruit set and non-bearing nodes and branches per plant exhibited high GCV. Reddy *et al.* (1985) recorded the highest GCV as well as PCV for fruit yield and plant height while high estimates of GCV and PCV were observed for plant height, leaf number and fruit weight plant^{-1} by Mathews (1986). Estimates of GCV were high for plant height, seeds pod^{-1} and yield plant^{-1} but moderate for number and length of pods noticed by Yadav (1986). As per the reports of Balakrishnan and Balakrishnan (1988), fruits and yield plant^{-1} had high GCV and PCV.

Pods, branches and pod yield plant^{-1} were found to have high GCV compared to other characters studied (Vijay and Manohar, 1990). Jeyapandi and Balakrishnan (1992) reported high PCV for 100-seed weight and pod weight which along with pod number had high GCV also. Maximum and minimum GCV were observed for fruit weight plant^{-1} and days to first flower respectively (Bindu, 1993).

Damarany and Farag (1994) reported low coefficients of variation for all the twelve characters studied including plant height, earliness, yield plant^{-1}, fibre content of fruits and protein content of seeds. High GCV was exhibited by fruit weight plant^{-1}, leaf area, plant height, fruits plant^{-1}, single fruit weight and branches plant^{-1} while moderate GCV and PCV were

noticed for average fruit weight (Sheela, 1994). High PCV was observed for fruits and yield plant^{-1} and 100-seed weight by Lakshmi *et al.* (1996).

GCV was high for fruit weight plant^{-1}, single fruit weight, branches and fruits plant^{-1}, fruit length, leaf area and plant height while low for leaves and flowers plant^{-1}, fruit girth, seeds fruit^{-1}, days to first flower and leaf axil of first flower (Bindu *et al.*, 1997). John (1997) noticed high GCV for branches plant^{-1} and seeds fruit^{-1} in all the irradiated treatments in F_2M_2 and F_3M_3 generations and high to moderately high for leaves, flowers, fruits and fruit weight plant^{-1} in F_3M_3 generations of irradiated interspecific hybrids of okra.

According to Panda and Singh (1997), branches, pods and yield plant^{-1} showed high GCV and PCV. Rajani and Manju (1997) reported that PCV and GCV were the highest for fruit yield plant^{-1} followed by leaf area but low for fruit girth, YVM incidence, days to first flower, first fruiting node, fruiting phase and fruit length. PCV and GCV were high for branches and yield plant^{-1} whereas low for plant height and single fruit weight (Yassin and Anbu, 1997).

Philip (1998) noticed high GCV and PCV for flower number and YVM disease. GCV was the highest for number of primary branches whereas moderate for plant height, leaves, fruits and yield plant^{-1} (Hazra and Basu, 2000).

Dhankhar and Dhankhar (2002) noticed high PCV and GCV for branches, fruits, yield and plant height in both rainy and spring-summer seasons. For fruit yield and plant height, values of PCV and GCV were almost equal indicating that environment had little effect but days to first flower and fruits and branches plant^{-1} had some influence by environment. Moreover, PCV and GCV were higher for all the traits during rainy season than spring-summer.

2.7 HERITABILITY AND GENETIC ADVANCE

Genetic advance was maximum for plant height followed by fruit number, days to first flower and yield (Murthy and Bavaji, 1980). Moreover, maximum heritability (narrow sense) was recorded for days to flower followed by plant height and fruits plant^{-1}.

Phenotypic selection was suggested to be promising for pod number and yield due to their high heritability (Rao and Ramu, 1981). Thaker *et al.* (1981b) noticed moderate heritability for plant height, fruit length and fruit number but low heritability for leaf area, fruit weight and yield whereas all these traits except fruit number displayed high genetic advance. Among the various yield contributing factors, the highest estimates of both heritability and genetic advance were displayed by plant height as reported by Palaniveluchamy *et al.* (1982). High heritability was exhibited by first fruiting node and days to 50 per cent flower (Partap *et al.*, 1982). Scope for improving the traits *viz.*, fruits, plant height and root length was indicated by their high estimates of heritability and genetic advance (Vashistha *et al.*, 1982).

As per the reports of Balachandran (1984), heritability was high for days to 50 per cent flower, flowering duration, fruit set (%) and branches plant^{-1} while both heritability and genetic advance were moderately low in the case of length and number of fruits and single fruit weight. However, plant yield displayed low estimates of heritability and genetic advance.

Reddy *et al.* (1985) reported high heritability and genetic advance for plant height, branches and yield plant^{-1} while high heritability was reported by Alex (1986) for plant height, days to flower and fruiting phase and by El-Macksoud *et al.* (1984) for earliness in flowering, fruits and fruit weight. Sheela (1986) recorded moderate to high heritability but low genetic advance for number and weight of fruits plant^{-1}, crude fibre content and YVM incidence.

Heritability estimates were high in F_2 than in F_1 for yield and some of its related characters except days to flower (Singh, 1986). Yadav (1986)

reported high heritability for all the traits studied including plant height, pods, pod length, seeds pod^{-1} and yield plant^{-1}.

Balakrishnan and Balakrishnan (1988) suggested fruit number and fruit weight plant^{-1} as efficient and reliable indices for improving the yield in okra as they had high heritability coupled with high genetic advance Heritability was high for days to 50 per cent flower and first picking, fruit girth, fruit wall thickness and fruit weight (Sadashiva, 1988).

High heritability for branches plant^{-1} was reported by Ariyo (1990b) while Vijay and Manohar (1990) opined that plant height, branches plant^{-1} and ridges pod^{-1} had maximum heritability and genetic advance over mean. High heritability and genetic advance were observed for number, length and weight of pods as well as yield plant^{-1} (Jeyapandi and Balakrishnan, 1992). Days to first flower and branches plant^{-1} were highly influenced by environment as reported by Patel and Dalal (1992).

Among the eleven yield components studied, leaves, pods and primary branches plant^{-1} were associated with high genetic advance but medium heritability (Gondane and Lal, 1994). Meghwal and Khandelwal (1994) observed high heritability coupled with high genetic advance for the characters plant height, internodal distance, node number, fruit weight and yield. Heritability as well as genetic advance were high for fruit weight plant^{-1}, plant height, leaf area and seeds fruit^{-1} but low for YVM incidence as reported by Sheela (1994).

A study of eleven characters in okra revealed high heritability for all the traits except total pods and weight of borer affected pods plant^{-1} (Patil, 1995). However, the values of genetic advance revealed that real progress in improvement of characters could be made only for weight of marketable pods, plant height and resistance to pod borer.

Bindu *et al.* (1997) reported that leaf area, fruit length, single fruit weight, fruit weight plant^{-1} and plant height exhibited high heritability coupled with moderately high genetic advance. Moderate heritability and low genetic advance were noticed for number of leaves and flowers and

fruit girth whereas leaf axil of first flower and seeds fruit^{-1} were with low heritability and genetic advance. High heritability and genetic advance were noticed for branches plant^{-1} and seeds fruit^{-1} in F_2M_2 generation and for flowers, fruits and fruit weight plant^{-1} in F_3M_3 generation of irradiated interspecific hybrids (John, 1997).

Yield plant^{-1} had high estimates of heritability and genetic advance (Rajani and Manju, 1997). High heritability but low genetic advance were observed for branches and first fruiting node. Estimates of heritability were moderate to high for single fruit weight, yield plant^{-1}, fruiting phase, plant height and YVM incidence and low for fruit set (%) and flowers and fruits plant^{-1}. According to Yassin and Anbu (1997), plant height, branches, fruits, single fruit weight and yield plant^{-1} displayed high heritability whereas genetic advance (as % of mean) was maximum for branches plant^{-1} followed by fruits and yield plant^{-1}. Low values were observed for both heritability and genetic advance for single fruit weight and plant height.

Philip (1998) noticed maximum GCV and PCV for flowers plant^{-1}, followed by YVM incidence, fruit and shoot borer incidence and branches plant^{-1} whereas minimum for days to first flower in F_4M_4 generation. The highest GCV and PCV were observed for YVM incidence followed by fruit and shoot borer incidence while the lowest values were for plant duration followed by fruit girth, leaf area and days to first flower.

Gandhi *et al.* (2001) observed medium to high heritability for all characters, of which fruit length (64.4 %), height of first fruit set (55.88 %) and fruit girth (43.60 %) were the highest. However, these traits were coupled with varied genetic advance *ie.*, high, medium and low respectively suggesting the complexity of genetic mechanism in the expression of these characters.

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

2.8 CORRELATION AND PATH ANALYSES

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

Fruit yield was highly correlated with seeds fruit^{-1}, number and length of fruits but only to a lower degree with plant height and days to flower (Arumugam and Muthukrishnan, 1981a). Partap *et al.* (1982) observed a direct positive contribution of fruit number and single fruit weight towards yield. Vashistha *et al.* (1982) noticed that yield in bhindi depended primarily on plant height, fruit number and fruit length.

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

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

Alex (1986) observed positive correlation for yield with flower number, fruiting phase as well as number, length and weight of fruits plant^{-1}. In all the three generations studied, major contributing yield traits were plant height, earliness, flowers and fruits (Mathews, 1986). Correlation studies revealed that flowers, fruits, length, girth and weight of

single fruit, fruiting phase, stem girth and seeds fruit^{-1} were the important contributing characters towards yield (Sheela, 1986). Yadav (1986) noticed positive correlation of plant height, pod length and pod number with yield.

For yield plant^{-1}, correlation coefficients were calculated among fifteen characters using 30 okra genotypes by Ariyo *et al.* (1987). Yield was correlated genotypically with length, width and weight of edible pods, seeds pod^{-1}, 100-seed weight, mature pod length and branch number, phenotypically with edible pod length, 100-seed weight and branches plant^{-1} and environmentally with length and weight of edible pods and plant height. Edible pod weight had the greatest positive direct effect on pod yield in both early and late seasons. Although edible pod weight was the best index of yield, since it cannot be assessed visually in the field, edible pod width was suggested as better criterion for selection in view of its close association with pod weight.

Sheela *et al.* (1988a) reported that stem girth had maximum positive direct effect on yield followed by pods plant^{-1}. The directly influencing components of yield were plant height, leaf area, branches, fruit length and fruits plant^{-1} (Kale *et al.*, 1989).

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

Ariyo (1992) suggested number and weight of pods as the major yield components. Positive association of fruit yield with days to 50 per cent flower, plant height, number of nodes and fruits, length and diameter of fruits, seeds fruit^{-1}, 100-seed weight and days to maturity was noticed by Fageria *et al.* (1992). Among the eighteen component characters studied, positive association with green fruit yield plant^{-1} was noticed for plant height and fruit characters *viz.*, number, length, girth and weight of fruits whereas path analysis revealed number and length of fruits as the most important variables (Mishra and Singh, 1992). Internodal length along with number, length, girth and weight of pods should be considered together as the primary yield determining traits in okra (Sundhari *et al.*, 1992).

Bindu (1993) reported that yield plant^{-1} had positive genotypic correlation with leaf area and flowers, fruits and branches plant^{-1} whereas maximum association was with weight of single fruit. She further suggested that the model for selection of high yielding okra varieties should be based on the number of fruits and branches and single fruit weight, owing to their high direct influence on yield. Plant height displayed significant correlation with node of first fruit, days to first flower and internodal length (Patel *et al.*, 1993).

According to Sheela (1994), leaves plant^{-1},leaf area, branches plant^{-1}, fruit girth and single fruit weight could be considered as the major characters contributing to yield in okra. Fruit number and single fruit weight displayed maximum positive direct effects on yield whereas with regard to YVM incidence, maximum positive and negative direct effects were recorded for branch number and single fruit weight respectively. Selection of early flowering types with increased fruit weight was suggested for enhancing the level of YVM resistance.

Fruit yield plant^{-1} showed positive correlation with branches plant^{-1}, seeds fruit^{-1} and fruit attributes *viz.*, length, girth and individual weight (Dash and Mishra, 1995). A study involving 50 genotypes to assess the interrelationships among eleven characters revealed pod number and weight

of edible pods as the most important traits contributing towards yield (Gondane *et al.*, 1995).

Lakshmi *et al.* (1996) reported the positive association of yield with nodes, branches and fruits plant^{-1}. Moreover, high direct effects were exerted by nodes, pods, pod weight and seeds pod^{-1} on yield. Subhasini *et al.* (1996) reported the existence of negative association of yield with days for pod setting and observed that number and weight of pods were the most important variables.

John (1997) analysed correlations in F_2M_2 and F_3M_3 generations of gamma irradiated interspecific crosses between *A. esculentus* var. Kiran and *A. manihot*. At 20 kR, 30 kR and 40 kR irradiation doses in both generations, positive association was noticed for weight of fruits plant^{-1} with leaves, flowers and fruits plant^{-1} and also between number of fruits and branches. Fruit yield plant^{-1} at 30 kR was associated positively with fruiting phase and plant duration. Average fruit weight exhibited negative correlation with flowers and fruits plant^{-1} in the treatments with 20 kR and 30 kR in F_2M_2 generation and in all the treatments (10 kR to 40 kR) in F_3M_3 generation.

As per the reports of Philip (1998), fruit yield plant^{-1} displayed positive association with plant height and leaves, branches, flowers and fruits plant^{-1} in both F_4M_4 and F_5M_5 generations of irradiated interspecific hybrids between *A.esculentus* and *A.manihot*. Besides, average fruit weight also had positive correlation with yield in F_5M_5 generation.

Based on the association analysis conducted in F_1 hybrids of okra, Indurani (1999) reported a strong positive association between number and yield of fruits plant^{-1}. Marketable yield plant^{-1}, fruit weight, fruit length, fruits plant^{-1} and plant height exhibited positively significant correlation as well as high direct effect with total yield plant^{-1} (Dhall *et al.*, 2000).

Correlation analysis using 62 inbred lines during rainy and spring-summer seasons revealed that during both seasons, fruit yield was associated positively with fruits and branches plant^{-1} and plant height and

negatively with days to 50 per cent flower while fruits plant^{-1} was correlated positively with branches plant^{-1} and negatively with days to 50 per cent flower (Dhankhar and Dhankhar, 2002). Maximum direct effect on yield was exerted by fruits plant^{-1} during both seasons and high indirect effects were exerted by plant height and branches plant^{-1}. The researchers suggested the selection of plants with high fruits, branches and medium plant height for improving the yield.

Correlation analysis of nineteen traits in the F_5M_5 generation of irradiated interspecific hybrids of okra revealed the positively significant correlation of yield plant^{-1} with leaves, branches, flowers and fruits plant^{-1}, average fruit weight and plant height (Philip and Manju, 2002).

2.9 FRUIT AND SHOOT BORER INCIDENCE

The fruit and shoot borer (*Earias* spp.) is one of the most ubiquitous pests causing damage to okra fruits and shoots to the extent of 90 per cent (Duzyaman, 1997). Since effective management of this pest is cumbersome and expensive and use of insecticides is health hazardous, identification of sources of resistance and breeding for resistant types had been emphasised by Sharma and Arora (1993).

Among the 21 varieties and seven F_1 crosses screened in the field and lab conditions, AE-52, AE-69, AE-79 and Sel 1 – 1 x AE-79 were the least susceptible to borer attack, owing to the hard skin with tough and sparse hairs on their fruits (Teli and Dalaya, 1981). Mote (1982) evaluated the resistant varieties, AE-79, AE-72, AE-57, AE-3 and Wonderful Pink, all with dense long hairs, which had the best resistance with the lowest eggs laid, the least entry of larvae into fruits and the lowest fruit infestation in the field while Sel.6-2 and Sel.2-2 expressed moderate resistance.

Chelliah and Srinivasan (1983) stated that the wild species *A. manihot* had resistance to *Earias* spp. When 72 genotypes of okra were evaluated in Haryana under field conditions, less than 10 per cent (on the weight basis) of Narnaul Special 6 (2), Perkins Long Green, Clamson

Spineless, White Snow and Sel.Round were infested (Kashyap and Verma, 1983). Dhawan and Sidhu (1984) studied the incidence of *Earias* spp. on okra in Punjab and observed that maximum damage occurred to shoots and flowers in mid August and to fruits and buds in late October. The pest population increased slowly upto mid September and rapidly thereafter while heavy rainfall adversely affected the population build up. Dutta (1984) stated that Arka Abhay displayed tolerance to fruit borer.

Of the fourteen okra varieties grown in hot weather season, AE 75, Pusa Sawani, Long Green, Indo American Hybrid and White Velvet exhibited tolerance to shoot infestation by *E. vittella* while Indo American hybrid and Koparawadi Local were resistant to fruit infestation whereas none was resistant during rabi (Madav and Dumbre, 1985).

According to Dhandapani (1986), Co-1 and Pusa Sawani respectively were the most and least resistant varieties against *E. vittella*. In a green house study on moth attraction and egg laying preference of fruit and shoot borer, Sagav-1 attracted the fewest moths before and after flowering and also had the lowest eggs laid on shoots and fruits (Patil *et al.*, 1986).

Field response of okra germplasm to infestation by fruit and shoot borer was investigated by Sardana and Dutta (1989) during 1986 and 1987 in 33 and 42 genotypes respectively. In the former year, the least affected genotype was IC-6653 (2.4 %) followed by Bhindi-6-Dhari (2.8 %) and Lam Sel.1 (3.8 %) whereas Sel.10 (38.7 %) was the most susceptible type. During the latter year, Bhindi-6-Dhari was the least susceptible (2.4 %). On the basis of fruit weight, infestation percentage was the lowest in Bhindi-6-Dhari (1.2 %) and Rajen-12 (1.8 %) during both the years.

Sharma and Dhankhar (1989) evaluated 97 okra genotypes during 1979-80 and 1980-81 and noticed the lowest fruit infestation in Long Green Smooth, followed by All Season-1, Sel.2-2 (the highest yielder), IC-6497 and IC-6316. As per the reports of Vyas and Patel (1990), maximum larval mortality was recorded in Gujarat Okra-1 and minimum in Pusa Sawani The same researchers in 1991 suggested Gujarat Okra-1 as the most suitable

variety on the basis of least damage caused by *E. vittella* and the marketable fruit yield. Bright sunshine hours and maximum and mean temperature showed significant positive influence whereas mean vapour pressure and relative humidity had negative influence on larval activity in okra (Zala *et al.*, 1991).

The crosses Pusa Sawani x Smooth Green, Pusa Sawani x PI-496620, IHR-4 x Green Velvet, IHR-4 x Clamson Spineless, IHR-4 x PI-489782, Smooth Green x PI-489782 and Smooth Green x PI-496681 showed lower incidence of borer than the check parent Pusa Sawani, as reported by Patil (1995). John (1997) opined that irradiation of interspecific okra hybrids increased the fruit and shoot borer incidence and it was maximum for 30 kR. Borer infestation was low in F_4M_4 and F_5M_5 generations of interspecific hybrids (Philip, 1998).

Field screening of nine okra cultivars by Srinivasa and Sugeetha (2001) revealed the highest fruit borer damage on GOH-1 and that no cultivar was totally free from infestation. Among the eleven promising okra hybrids and three cultivars of okra, DVR-2 was the highest yielder of green pods along with the least susceptibility to fruit borer (Pandey *et al.*, 2002). Screening of okra germplasm against fruit and shoot borer revealed Okra N-6 as the least affected type as observed by Jalgaonkar *et al.* (2002).

2.10 YELLOW VEIN MOSAIC DISEASE

Yellow vein mosaic, the most dreaded disease of okra, infects at all the crop stages and incurs heavy losses in the crop by affecting the growth, quality and yield. The first report of this disease was from Mumbai by Kulkarni (1924). The name "yellow vein mosaic" was proposed by Uppal *et al.* (1940) who established virus as the causal agent.

Disease symptoms include vein clearing followed by chlorosis and swelling of veins, slight downward curling of leaf margins, twisting of petioles, yellowing of fruits, general dwarfing and growth retardation (Capoor and Varma, 1950). Also, the virus was neither sap transmissible

nor transmitted through seed or parasitic activity of dodder, but transmissible through grafting and by white fly (*Bemisia tabaci*). Spread by white fly was also established by Varma (1952) who added that ability and efficiency of white fly to acquire and transmit the virus increased when vectors were fasted for one hour before acquisition feeding. The ability to retain the virus for a long period makes it a very potent vector (Varma, 1955). However, during rainy season (July to September) white flies were not common on the crop whereas okra leaf hopper (*Empoasca devastans* (Dist.)) was abundant on the diseased plants.

Depending upon the stage of crop growth at which infection occurs, yield loss ranged from 50 to 90 per cent (Sastry and Singh, 1974). Infection during early crop phase resulted in total loss of yield as well as quality while 88 per cent, 80 per cent and 60 per cent of yield reduction was noticed in plants infected at 30, 50 and 60 days after germination respectively. Chelliah *et al.* (1975) also reported an yield loss of 88 per cent in plants infected at 30 days stage. Adverse effect of this disease on plant height, branches, fruits and yield was confirmed by Sinha and Chakrabarti (1976).

In the opinion of Singh *et al.* (1983), YVM infection enhanced total, reducing and non-reducing sugars (except in fruits), dextrin, resin and total nitrate and nitrate nitrogen in leaves, stem and fruits but reduced starch, ammoniacal nitrogen and total free aminoacids in diseased plant parts.

During a field survey, Sharma *et al.* (1985) noticed that leaves infected with bhindi YVMV were not susceptible to powdery mildew and infection if occurs, was restricted to green areas only. Moreover, virus infected leaves had greater amount of aminoacids, sugars and phenolic compounds than in leaves infected with powdery mildew while these compounds were the least in healthy leaves. Atiri and Ibidapo (1989) observed synergistic effect in mixed infection of bhindi mosaic and leaf curl viruses.

YVM infected fruits turned yellow, reduced in size and their carotene content declined by 35 to 60 per cent while protein Nitrogen reduced by 16 per cent (Chander, 1990). According to Handa and Gupta (1993), complete eradication of the vector of YVM could not be achieved even with proper cultural practices, chemical control and use of resistant cultivars. YVM incidence is a limiting factor in okra production, which could reduce the yield by 30 to 70 per cent (Duzyaman, 1997).

In a study on the effect of age of okra plants on susceptibility to YVMV, Pun and Doraiswamy (1999) noticed that lesser the age of inoculation, greater was the damage incurred for plant growth and yield. Pun *et al.* (1999) stated that direct antigen coating (DAC) ELISA on nitrocellulose membrane could be successfully employed to detect YVMV infected okra plants and single viruliferous white flies.

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

2.10.1 Genetics of YVM Resistance

The occurrence of symptomless condition, a type of genetically controlled resistance, was first reported by Singh *et al.* (1962) in a West Bengal variety IC-1542 of *A. esculentus*. In the crosses between IC-1542 as resistant parent and Pusa Makhmali, S-72 and S-91 as susceptible parents, two loci were involved and presence of dominant alleles at both loci was necessary for causing susceptibility to the disease. Thakur (1976) opined that segregation ratios in backcross generations and BC_2F_2 generations of the cross of Pusa Sawani with *A. manihot* ssp. *manihot* suggested the complementary dominant nature of resistant genes.

Contradicting these, Arumugam and Muthukrishnan (1981b) concluded that YVM resistance was conditioned by a single dominant gene (Y) based on the inheritance studies carried out using the crosses of *A. manihot* and susceptible varieties of *A. esculentus* under natural epiphytotic conditions. On studying the crosses of Pusa Sawani with *A. manihot* ssp. *manihot*, Jambhale and Nerkar (1981) pointed out the involvement of a single dominant gene in confering YVM resistance. Dominance of YVM resistance in *A. manihot* was also reported by Dhillon and Sharma (1982).

Sharma and Dhillon (1983) concluded from the segregation ratios in the backcrosses of *A. esculentus* x *A. manihot* ssp. *manihot* that YVM resistance was controlled by two complementary genes with additive effects. They also noticed that in some plants of the resistant parent, F_1 and transgressive segregants, YVM symptoms appeared either on top leaves or in new shoot growth produced in the late season, especially with fall in temperature, suggesting the sensitivity of resistance genes to environmental changes. Hence resistance to YVMV in *A. manihot* ssp. *manihot* might be contributed by polygenes. Sharma and Sharma (1984) also agreed to this polygenic viewpoint.

According to Pillai (1984), YVM resistance was controlled by dominant nuclear genes whereas a single dominant gene confered YVM resistance as stated by Mathews (1986). Role of two pairs of genes in the expression of YVM resistance was emphasised by Sadashiva (1988) on noticing the segregation pattern for disease reaction in F_1, F_2 and backcross generations of two crosses (IIHR 1 – 16 x Key Stone and IIHR 2 – 48 x Key Stone). Resistance was expressed only when at least one gene pair was in homozygous dominant condition whereas heterozygosity of both genes resulted in intermediate expression.

Preponderance of additive gene action for YVM incidence was reported by Veeraraghavathatham (1989) who also noticed complementary interallelic interaction for YVM resistance in F_2 generation. Involvement of minor genes as modifiers along with major genes in YVM resistance and

the importance of additive gene effects for viral resistance were stressed by Vashisht (1990). Importance of additive genetic variance for YVM incidence was reported by Veeraraghavathatham and Irulappan (1990).

Pulliah *et al.* (1998) assessed the inheritance of resistance to YVMV in okra using six generations of each of the crosses involving three resistant (R) varieties (Arka Anamika, Punjab Padmini, Arka Abhay) and three susceptible (S) varieties (Pusa Sawani, Local and Pusa Makhmali). Chi-square test suggested that resistance was controlled by two dominant genes which were complementary in S x S and S x R crosses whereas duplicate in R x R crosses.

To determine the nature of inheritance of YVM tolerance of the variety ISPA Okra-1, Ali *et al.* (2000) crossed it with three susceptible genotypes *viz.*, Parbhani Kranti, Sl-44 and Sl-46. Segregation pattern of disease reaction in their F_2 and backcross generations reflected light into the quantitative nature of tolerance with possibly two major factors and dependent on gene dosage with incomplete gene action.

2.10.2 Source of YVM Resistance

A. pungens exhibited true resistance to YVM whereas symptomless condition was observed in *A. tuberculatus* (Pal *et al.*, 1952). During a screening of 43 okra varieties in West Bengal, pink types appeared as resistant (Varma and Mukherjee, 1955). Immunity to YVM was noticed by Nariani and Seth (1958) in *A. manihot* var. *pungens*, *A. crinitus*, *Hibiscus vitifolius* and *H. panduraeformis*, while screening various related species by graft inoculation as well as by feeding viruliferous white flies.

Okra varieties IHR 15 – 1 and IHR 20-1 were reported to be resistant to YVM by Nath (1970). According to Sandhu *et al.* (1974), YVM resistance was confined to wild species such as A. *manihot, A. critinus, A. moschatus* and *A. pungens* whereas okra varieties *viz.*, IC-1542, Sel.1 and Sel.2-2 along with *A. tuberculatus* showed tolerance. They also reported that an accession (EC-31830) under the name Austem Koko from Ghana

introduced by the Division of Plant introduction, IARI, New Delhi and identified as *A. manihot* ssp. *manihot* was immune to YVM. On noticing high resistance to YVM in two accessions of *A. manihot*, one each from Africa and Japan, Arumugam *et al.* (1975) produced viable F_1 seeds by crossing them with *A. esculentus*, but 40 per cent sterility occurred in F_2.

Resistant (though self sterile) hybrids could be produced by crossing *A. ficulneus* with cultivated okra (Hossain and Chattopadhyay, 1976). *A. manihot* ssp. *tetraphyllus* was assigned as a promising source of YVM resistance by Ugale *et al.* (1976) and Mamidwar *et al.* (1979). Singh and Thakur (1979) reported symptomless carrier type of resistance in the wild species *A. manihot* ssp. *manihot*.

Gopimony and Nair (1982) developed hybrids with YVM resistance by crossing *A. esculentus* var. Kilichundan and *A. moschatus*, though their seed recovery was very low. Jambhale and Nerkar (1983) transferred YVM resistance from *A. manihot* to Pusa Sawani and some resistant plants were obtained from the backcrosses of this hybrid to Pusa Sawani. Some of the segregants derived from the crosses of Pusa Sawani with *A. manihot* and *A. manihot* ssp. *manihot* had improved seed fertility and YVM resistance. Chelliah and Srinivasan (1983) noticed the presence of YVM resistance in *A.manihot* and *A. manihot* ssp. *tetraphyllus*.

The wild species *A. manihot* (Pillai, 1984) and its two subspecies *viz.*, *manihot* (Sharma and Sharma, 1984) and *tetraphyllus* (Dutta, 1984) were successful donors for imparting YVM resistance. High degree of symptomless carrier type of YVM resistance was identified in *A. esculentus* variety EC-31830 from Ghana and it was utilised for crossing programmes with Pusa Sawani (Sharman and Sharma, 1984).

In the view of Nerkar and Jambhale (1985), only the wild species *viz.*, *A.tetraphyllus*, *A.manihot* and *A.caillei* could act effectively as the donors of resistance for varietal improvement. *A.manihot* was the source of YVM resistance in the synthesis of Parbhani Kranti (Jambhale and Nerkar, 1986). On screening five varieties under field conditions, Khan and

Mukhopadhyay (1986) observed tolerance in S1-1. Madhusoodanan and Nazeer (1986) stated that 'Guineen' type of okra, a potential source of YVM resistance, was originated through the natural hybridisation between *A. esculentus* and *A. manihot*. Studies on resistance to YVM using 27 varieties under field conditions revealed that KbS-312 was the most resistant while KS-303, KS-322, KS-323 and AS-312 showed low infection percentage (Singh and Singh, 1986). Sadashiva (1988) located symptomless carrier type of YVM resistance in thirteen okra inbreds.

Hybrids with field resistance to YVM could be generated using *A. tetraphyllus* as the resistance source (Babu and Dutta, 1990) whereas *A. tetraphyllus* var. *tetraphyllus* donated the resistance genes for the development of Arka Anamika and Arka Abhay (IIHR, 1991). Among the 157 advanced germplasm lines and seven cultivars / hybrids evaluated for field reaction to YVM virus over two years, the most resistant line was EMS-8 while 36 and 39 individual plant selections of Punjab Padmini and EMS-8 respectively were free from virus (Arora *et al.*, 1992). During a field trial with 22 genotypes exposed to white flies carrying YVM virus, Bora *et al.* (1992) observed Arka Anamika as totally disease free and GOH-4 and GOH-6 as highly resistant.

Among six selected varieties of okra, the lowest YVM incidence was noticed in Sel-4 and Arka Anamika as observed by Mathew *et al.* (1993). High YVM resistance was exhibited by Punjab Padmini, Punjab-7 and Parbhani Kranti (Sharma *et al.*, 1993).

Sheela (1994) utilised *A. caillei* and *A. tetraphyllus* as donors of YVM resistance for producing resistant interspecific okra hybrids. According to Rajamony *et al.* (1995), in Southern Kerala, the species such as *A. tetraphyllus*, *A. manihot* ssp. *tetraphyllus*, *A. ficulneus*, *A. moschatus* and *Hibiscus huegeli* were resistant and the cultivated types Arka Anamika, Parbhani Kranti and Vijay were tolerant to YVM. Among the twelve varieties observed by Srivastava *et al.* (1995), Varsha Uphar and HRB-55 were free from disease while Arka Anamika was moderately resistant.

Chandran (1996) utilised *A. moschatus*, *A.tetraphyllus* and *A.manihot* as the source of YVM resistance for producing interspecific hybrids with okra varieties Kiran and Anakomban and among these, *A.manihot* was the best since its hybrids were with maximum fruit set as well as viable seeds (Chandran and Rajamony, 1997). AROH-2 and Parbhani Kranti were tolerant and asymptomatic among the thirteen okra cultivars evaluated by Poopathi *et al.* (1996).

Sangar (1997) recorded high resistance for Arka Anamika, resistance for Arka Abhay and moderate resistance for Parbhani Kranti and V-6 while these Arka varieties were reported as YVM resistant by Sannigrahi and Choudhary (1998) also. The progenies belonging to Sel-4 x Sel-10, Sel- 4 x P-7 and P-7 x Sel-10 were free from YVM (Fugro and Rajput, 1999). After screening seven okra genotypes, Indurani (1999) selected MF-3, OHD-1, Arka Anamika and Varsha Uphar as resistant parents for the production of YVM resistant hybrids and they succeeded in the development of two high yielding F_1 hybrids (OHD – 1 x Varsha Uphar and Varsha Uphar x Arka Anamika) with fair resistance.

During a two year screening programme in Haryana, Batra and Singh (2000) noticed freedom from disease for four open pollinated varieties (Okra No. 6, LORM-1, VRO-3 and P-7) and two hybrids (DVR-1and DVR-2) and tolerance for one variety (VRO-4).

The F_1 hybrids derived from highly resistant parents viz., HRB-55 x Arka Anamika, Parbhani Kranti x HRB-9-2 and BO-1x P-7 exhibited high resistance to YVM (Deo *et al.*, 2000). Evaluation of thirteen advanced breeding lines of okra by Dutta *et al.* (2000) resulted in the identification of IIHR 108-1-31-2, IIHR 116-12-23-1and IIHR 120-11-8-2 as the most promising resistant lines. Rattan and Bindal (2000) noticed complete resistance to YVM for the lines 407, 409, 417 and 430 and their F_1 hybrids.

In an evaluation of 157 germplasm lines of okra including some related species under natural epiphytotic conditions, three accessions each of *A. tetraphyllus* and *A. ficulneus* and one accession each of *A. manihot*

ssp. *manihot*, *Hibiscus panduraeformis* and *H. vitifolius* were completely disease free (Vinod *et al.*, 2000).

Bhagat *et al.* (2001) observed lower dissemination rate of YVM in Parbhani Kranti than Pusa Sawani and Vaishali Vadhu at Bihar. Rajamony *et al.* (2002) stated that *A. ficulneus*, *A.moschatus*, A. *tetraphyllus*, *A. manihot* ssp.*tetraphyllus* and *H. heugelii* were resistant to YVMV under hot spot situations *A. manihot* showed mild symptoms especially in the young and tender leaves with recouping tendency later. The cultivated types Arka Anamika and Parbhani Kranti expressed tolerance.

Out of the fifteen lines, two testers and their 30 hybrids assessed by Ravisankar (2002), a line AE-238 and two hybrids *viz.*, AE-238 x Parbhani Kranti and AE – 265 x Parbhani Kranti were disease free during field screening, grafting and vector transmission studies. High resistance was noticed for two lines and thirteen hybrids of okra (Ravisankar *et al.*, 2002).

2.10.3 Biochemical Basis of YVM Resistance

Compared to susceptible plants, YVM resistant okra parents and F_1S possessed higher contents of phenols, flavanoids, amide and nitrate nitrogen, aminoacids, total and reducing sugars, total carbohydrates and chlorophyll a and b but lower contents of total, nitrite and protein nitrogen (Arumugam and Muthukrishnan, 1981b). As per the observations of Ahmed *et al.* (1994), total phenols, orthodihydroxy phenols, flavanols, total proteins, and soluble proteins were high in virus-free plants of YVM resistant plants while the enzymes, peroxidase and polyphenol oxidase exhibited no significant difference between virus-free (both susceptible and resistant) cultivars. Viral infection generally increased the total protein in both resistant and susceptible cultivars, to a greater extent in the latter. After inoculation, total phenols, orthodihydroxy phenols and flavanols decreased in resistant lines accompanied by an increase in the activity of peroxidase and polyphenol oxidase, whereas this was reversed in the susceptible lines. Higher amount of phenols and their oxidation products

such as quinines (formed by increased peroxidase and polyphenol oxidase) may be responsible for the reduction in virus multiplication in resistant lines.

Bhagat and Yadav (1997) assessed the carbohydrate content in healthy and YVMV inoculated leaf samples of Parbhani Kranti (resistant), Vaishali Vadhu (susceptible) and Pusa Sawani (highly susceptible) and observed that the healthy leaves of both the susceptible cultivars showed a higher content of reducing, non reducing and total sugars than the resistant one while in diseased leaves, their amount increased in all cultivars, the increase being greater in susceptible cultivars than resistant.

2.11 COMBINING ABILITY

Many researchers have reported the magnitude of GCA as greater than that of SCA for yield as well as length, girth and weight of fruits (Partap and Dhankhar, 1980a; Thaker *et al.*, 1981a; Reddy *et al.*, 1985; Veeraraghavathatham and Irulappan, 1991).

According to the reports of Singh and Singh (1979b), *gca* effects were higher than *sca* effects for days to flower but lower for fruits plant^{-1} whereas both were equally important for branches plant^{-1} in okra. Also, higher SCA variance was noticed for fruit yield. Thaker *et al.* (1981a) observed higher *gca* effects for length and average weight of fruits.

During a half diallel analysis involving seven okra varieties, *sca* effect was significant for fruit yield plant^{-1} whereas both *gca* and *sca* effects were significant for days to 50 per cent flower, fruit length, fruits plant^{-1} and nodes on main stem (Poshiya and Shukla, 1986a). Moreover, New Selection x AE-91 was the most promising cross for yield improvement. Vijay and Manohar (1986a) calculated combining ability estimates in okra from a 10 x 10 diallel (excluding reciprocals) in which *gca* effects were highly significant for number, weight, length, thickness and yield of fruits, days to 50 per cent flower, height at first fruiting node, plant height, branches, internode length and seeds while the crosses of Pusa

Sawani with Clamson Spineless and IC-8911 were noted for pod yield and yield components except pod length.

According to Sadashiva (1988), in a 9 x 9 partial diallel analysis, both *gca* and *sca* effects were important for all the characters *viz.*, days to 50 per cent flower and first picking, plant height, branches plant^{-1}, node of first flower, nodes plant^{-1}, internodal length, fruits and yield plant^{-1} and length, girth, wall thickness, weight and dry weight of fruits. However, GCA variances were higher than SCA variances. In addition to this, high x high and high x low parental combinations of *gca* effects produced good *sca* effects.

Information on combining ability effects was derived by Sundhari *et al.* (1992) from the data on ten yield related traits in six inbreds and their hybrids from a full diallel cross in which GCA: SCA ratios were lower than unity and Arka Abhay was the best combiner for yield and fruits plant^{-1}. Arora (1993) crossed ten genotypes in a half diallel fashion and evaluated them with F_1 and F_2 generations for combining ability of six yield components. Pusa Sawani, Vaishali Vadhu, Foam Barelley and Pusa Sawani x Foam Barelley had the highest SCA values for most of characters under study. Vasline (1993) carried out combining ability analysis using fifteen parents and 36 hybrids derived from 12 line x 3 tester crosses of okra and inferred AE-110 and AE-158 as good general combiners and also that high *sca* effect was exhibited by the hybrids with high x high or high x medium combiners.

Combining ability for yield and related components involving nine parents and their hybrids from a diallel cross (without reciprocals) was investigated by Chavadhal and Malkhandale (1994) who concluded that GCA and SCA variances were highly significant for all the characters except days to 50 per cent flower. Significant *gca* and *sca* effects were noticed by Patel *et al.* (1994) for all the characters under evaluation except fruiting branches plant^{-1} during combining ability analysis for dry seed yield and its contributing traits from a 10 x 10 diallel cross (excluding

reciprocals). GCA:SCA ratio was less than unity for dry seed yield plant^{-1}, number and weight of seeds pod^{-1} and 1000-seed weight and the best general combiner for seed yield plant^{-1} and 1000-seed weight was Gujarat Bhindi.

Lakshmi *et al.* (1995) reported that *sca* estimates for yield were the highest for Parbhani Kranti x Arka Abhay followed by PB No. 58 x Punjab Padmini in a diallel analysis of eight parents and 28 hybrids. Patil (1995) reported that the parents PI-489782 followed by PI-496620 had high *gca* status whereas IHR-4 and PI-496681 exhibited average *gca* for fruit yield and the hybrids IHR-4 x PI-489782, Pusa Sawani x Smooth Green, Pusa Sawani x PI-496620 and IHR-4 x Green Velvet had high positive *sca* effects. PI-489782 exhibited low negative values for pod borer infestation along with high positive *gca* for good pods plant^{-1}, total pods plant^{-1}, leaves plant^{-1} and plant height with short internodes. It would be possible to develop hybrids with resistance to pod borer involving PI-489782 as its combination with other parents generally produced hybrids with least infestation of pod borer.

In the opinion of Sivakumar *et al.* (1995), P7 was the best general combiner for fruit yield and fruit number plant^{-1} during a combining ability evaluation for seven yield components. Vaishali Vadhu and Local Akola were the best general combiners with significant *gca* effects for maximum number of characters whereas five crosses exhibited significant *sca* effects for most of the characters including yield and fruits plant^{-1} (Wankhade *et al.*, 1995).

Lakshmiprasanna (1996) studied combining ability in okra using ten hybrids from five parents and reported significant GCA and SCA variances for all the 24 characters studied. Variance due to SCA was higher in all the characters except pedicel length, days to first flower and 50 per cent flower. length and girth of pods and borer infested pods plant^{-1}. Moreover, the parents having high x high status resulted in high *sca* component.

Combining ability analysis in okra using 8x8 diallel cross (excluding reciprocals) revealed that variances due to GCA and SCA were highly significant and SCA variances were higher than the corresponding GCA variances for all the characters except fruit girth (Ahmed *et al.*, 1997) Perkins Long Green was a good combiner for days to first fruit set, node of first pod appearance, plant height, branches plant^{-1}, seeds fruit^{-1}, pods plant^{-1} and fruit yield plant^{-1}. SB-5 was the best general combiner for height at first fruiting node, fruit girth, average pod weight, seed number and fruit yield plant^{-1}.

As per the information on combining ability derived from data on eleven yield components in ten parents and their F_1 hybrids, HRB-55, Pusa Sawani, DL-1-87-5 and JO-5 were good general combiners for yield plant^{-1} (Pawar *et al.*, 1999a). Indurani (1999) crossed four parents in a diallel fashion to analyse the combining ability and adjudged Varsha Uphar as the best general combiner for individual fruit weight, yield plant^{-1}, phenol content in leaves and crude fibre content in fruits and the hybrids MF-3 x Varsha Uphar, MF-3 x Arka Anamika and Varsha Uphar x Arka Anamika as the best specific combiners for fruits plant^{-1}, individual fruit weight and yield plant^{-1}.

Combining ability analysis for seed yield, its components and seed quality in okra carried out by Pal and Hossain (2000) revealed Punjab Padmini as the best general combiner for seed weight plant^{-1} and most of its components while BO-1 was the best combiner for protein content and Pusa Sel-1 for both oil and sugar content. Crosses with superior *sca* effects were Vaisali Vadhu x Pusa Sel-1, Sel-71-14 x Punjab Padmini and BO-1 x Sel-71-14.

Rajani *et al.* (2001) analysed the combining ability of six genetically divergent parental strains of okra using diallel analysis with respect to yield and a few related attributes and reported that NBPGR / TCR-861 was the best general combiner for single fruit weight and fruit length and NBPGR / TCR-864 for yellow vein mosaic resistance. Among the hybrids, NBPGR /

TCR -893 x NBPGR / TCR-864 exhibited outstanding *sca* effects for yield while NBPGR / TCR-865 x NBPGR / TCR-438 and NBPGR / TCR-893 x NBPGR / TCR-861 were notable for length, girth and average weight of fruits. Best general combiner for plant height, days to first flower, fruits plant^{-1} and yield plant^{-1} was AE-202 and for internodal length, fruit length and fruit girth was AE-264 while best specific combination for plant height was AE-264 x AE-285, AE-211 x AE-190 for internodal length, AE-280 x AE-190 for days to flower and fruit girth, AE-265 x AE-190 for first fruiting node, AE-198 x AE-285 for fruit length, AE-219 x AE-190 for fruits and yield plant^{-1} (Ravisankar *et al.*, 2002).

According to Yadav *et al.* (2002), P-7, BO-2, 6318 and 7309 were good combiners for fruit weight and Pusa Sawani for fruit weight, branches plant^{-1} and length of first fruiting node. They sorted out a few crosses involving high x high, average x average and high x average general combiners possessing high *sca* effects.

2.12 HETEROSIS

In a diallel analysis (without reciprocals) involving seven varieties and their hybrids, IC-6653 x IC-6316 exhibited heterosis for number, length and yield of fruits while IC-6653 x IC-12930 was heterotic for yield and number (branch^{-1} as well as plant^{-1}) of fruits (Partap and Dhankhar, 1980b). High relative heterosis and heterobeltiosis were observed by Elangovan *et al.* (1981) for plant height, branches, earliness, first fruiting node, yield, 100-seed weight and fruit attributes (number, length and width).

Hybrid vigour in okra was reported by Partap *et al.* (1981) and Thaker *et al.* (1981a, 1982). Dhillon and Sharma (1982) noticed heterosis for plant height, branches and fruits plant^{-1}. Heterosis over mid parental value was positive for plant height, fruit traits (number, length and weight), days to first virus appearance and yield (marketable and total) but negative for nodes plant^{-1} (Singh, 1983). Balachandran (1984) noticed desirable

heterosis over mid, better and standard parents for number, length and weight of fruits.

Agarrado and Rasco (1986) evaluated 45 F_1 hybrids along with their parents and noticed that the best hybrid (124977 x 370028) out-yielded the standard cultivar Smooth Green by 76.7 per cent. Relative heterosis was strongly expressed by most of the hybrids for yield, days to first flower, internodal distance and length, weight and number of pods plant^{-1} whereas heterobeltiosis was noticed for yield, length, diameter and weight of pods.

Out of the thirty crosses examined by Changan and Shukla (1986) eighteen and fourteen displayed heterosis over mid and better parents respectively. On noticing heterosis for plant height and length and weight of pods, El-Macksoud *et al.* (1986) justified the commercial utilisation of hybrid vigour in okra.

In a 7 x 7 diallel analysis, heterosis was the highest for pods and yield plant^{-1} and New selection x AE-91 was the most heterotic for yield (Poshiya and Shukla, 1986b). Among the 45 okra hybrids evaluated for heterobeltiosis, the highest values for pod yield were measured for Pusa Sawani x Clamson Spineless (64.93 %) and Pusa Sawani x IC 8911 (66.81 %) and these two hybrids, together with Pusa Sawani x Sel. 6–1 and Sel. 6-1 x Summer Beauty, exhibited the highest estimates for days to 50 per cent flower (Vijay and Manohar, 1986b).

Korla and Sharma (1988) reported that helterobeltiosis was observed in none of the crosses under study for seeds fruit^{-1}, in one for seed weight fruit^{-1} and in two for 100-seed weight. Significant heterosis for fruit number and yield plant^{-1} was reported by Radhika (1988). During a 9 x 9 diallel analysis by Sadashiva (1988), heterosis over mid, better and best parents were noticed in six crosses for earliness, two crosses for days to first picking, three crosses for plant height, three crosses for node of first flower, nineteen crosses for fruits plant^{-1} and eleven crosses for fruit yield plant^{-1}. Sheela *et al.* (1988b) observed desirable heterosis in six hybrids for major economic characters such as fruit number and fruit weight plant^{-1} and

identified Selection 2 –2 x Kilichundan and Sevendhari x Kilichundan as superior which outyielded the standard cultivar Pusa Sawani by 65.1 per cent and 50.3 per cent respectively.

Punjab Padmini x Parbhani Kranti displayed the highest heterobeltiosis for six yield components during an evaluation of nineteen lines and their F_1 hybrids with respect to six yield components (Shukla *et al.*, 1989; Shukla and Gautam, 1990). Interspecific hybrids of *A. esculentus* x *A. tetraphyllus* displayed heterosis for plant height (23.82 %) and fruit number (20.03 %) as reported by Babu and Dutta (1990) whereas Sundhari *et al.* (1992) observed relative heterosis (24.57 %) and heterobeltiosis (12.52 %) for fruit yield.

According to Kumbhani *et al.* (1993), the high heterosis for yield plant^{-1} noticed in 28 hybrids seemed to have resulted from the combined effect of heterosis for yield components such as number, girth and length of pods, plant height and internodal length. The hybrids which offered the highest heterosis for yield were Padra 18–6 x KS-312 and Punjab Selection x KS-312.

During a 6 x 6 diallel analysis, only EMS – 8 x Punjab Padmini had heterobeltiosis for earliness whereas Sel. 10 x Punjab Padmini and Sel-14 x Punjab Padmini exhibited heterosis over the better parent for plant height and fruits plant^{-1} (Mandal and Dana, 1993). In the opinion of Singh and Mandal (1993), heterosis over mid and better parents were the highest for early yield and fruits plant^{-1} among the fifteen hybrids derived from six okra varieties.

Heterobeltiosis for yield plant^{-1} was the highest in Pusa Sawani x Parbhani Kranti, during an evaluation of fifteen hybrids and their six parents (Dayasagar, 1994). Majority of the interspecific hybrids of *A. esculentus* with *A. caillei* and *A. tetraphyllus* displayed negative heterosis for yield and its components (Sheela, 1994). However, a few of them manifested desirable heterosis for days to flower and length and number of fruits.

Manifestation of heterosis for all the characters under study was pointed out by Rajani (1995). When compared to mid parent, better parent and standard check, NBPGR / TCR-861 x NBPGR / TCR – 893 was the most outstanding for yield and yield related characters along with heterosis for tolerance to fruit and shoot borer. The cross, NBPGR / TCR 893 x NBPGR / TCR 864 was heterotic for earliness in flowering. In general, parents NBPGR / TCR 893 and NBPGR / TCR 861 either alone or together produced heterotic combinations.

According to Animon (1996), irradiated interspecific hybrids of okra showed considerable heterosis over both parents for most of the economic characters and they were more vigorous. Hybrid treatments exhibited significant positive heterosis for days to first flower and last fruiting over cultivated parent and for flowers, fruits and weight of fruits over both parents. Significant negative heterosis over cultivated parent for fruit borer incidence was shown by the control and the hybrids irradiated at 10 and 20 kR. All the hybrid treatments manifested significant negative heterosis over cultivated parent for YVM incidence.

Ahmed *et al.* (1999) evaluated 28 F_1 crosses and eight parents and observed maximum heterosis for pods plant^{-1} (74.77 %) followed by average fruit weight (62.59 %) and branches plant^{-1} (52.50 %). Moreover, SB – 3 x Punjab – 7, SB – 5 x Pusa Sawani, Perkins Long Green x SB – 5 and Perkins Long Green x Parbhani Kranti could be considered as potential hybrids for commercial exploitation.

When heterotic effects of six characters were studied by Panda and Singh (1999) in twenty crosses of okra, the highest heterosis was observed for pod yield (45.62 %) and pods plant^{-1} (28.32 %). According to Singh and Sood (1999) in a set of 8 x 8 diallel crosses, four hybrids *viz.*, P-7 x Arka Abhay, P-7 x Arka Anamika, P-7 x Parbhani Kranti and Parbhani Kranti x Arka Abhay showed maximum standard heterosis for fruit yield.

Heterosis analysis of 45 hybrids and their ten parents revealed that hybrid vigour was high for branches, pods and yield plant^{-1} and plant

height, moderate for first fruiting node, girth and length of pods and nodes plant^{-1} while days to both 50 per cent flowering and first picking exhibited low heterosis (Pawar *et al.*, 1999b). Among the various crosses which exhibited significant relative heterosis and heterobeltiosis for yield plant^{-1}, Khoda – 11 x Pusa Sawani was the best performer (with values 41.43 % and 35.42 % respectively).

Manifestation of heterosis for yield plant^{-1} was evidenced by significant superiority of thirteen of the eighteen crosses, while only two hybrids showed significant negative estimates for heterobeltiosis and the best hybrid combination was 7D – 2 x HB – 55 (62.66 %) as opined by Pathak *et al.* (2001). Prakash *et al.* (2001) observed that the direct and reciprocal hybrids of Parbhani Kranti and Arka Abhay possessed significant heterosis for plant height, capsule weight, capsule length and seed yield plant^{-1}.

Saha and Kabir (2001) analysed the economic heterosis of six commercial hybrids with reference to five cultivars. All the hybrids exhibited significant economic heterosis for yield (62.70 to 98.75 %) and its components except branches plant^{-1} and very high estimates were noticed for Hybrid Bhindi No.7, Pan Brand and Supriya. During a 7 x 7 diallel analysis, P- 7 x Arka Abhay had the highest heterobeltiosis (68 %) which produced 80 per cent more fruits than the control cultivar, Pusa Sawani (Sood and Sharma, 2001). Its yield advantage arose from heterosis for fruits and nodes plant^{-1} and plant height.

Based on heterosis studies AE-219 x AE-190, AE-264 x AE-285 and AE-265 x AE-190 were selected as top ranking hybrids by Ravisankar (2002). Studies on heterosis revealed maximum standard heterosis of 51.88 per cent for plant height and –0.70 per cent for days to flower in AE-264 x AE-285, -18.66 per cent for internodal length in AE-238 x AE-285, -4.29 per cent for first flowering node in AE-280 x AE-190, 56.99 per cent for fruit length in AE-264 x AE-190, 11.15 per cent for fruit girth in AE-219 x AE-285, 46.09 per cent for fruits plant^{-1} and 70.69 per cent for yield plant^{-1}

in AE-219 x AE-190 over the standard check Parbhani Kranti (Ravisankar *et al.*, 2002).

2.13 GENE ACTION

Gene action in okra with respect to various characters are presented in Table 2.

2.14 GENERATION MEAN ANALYSIS

Segregation ratios in backcross and BC_2F_2 generations revealed that YVM resistance was conditioned by two complementary dominant genes (Thakur, 1976; Sharma and Dhillon, 1983). Five crosses of resistant cultivars IC-7194, IC-8899, IC-12930, Bhindi Loroai-1 and Bhindi Loroai-3 and the susceptible cultivars Pusa Sawani and Sel.6-2, their F_2 progenies and backcrosses were analysed for resistance to jassid (*Amrasca biguttula biguttula*) in okra by Sharma and Gill (1984) who opined that resistance was controlled by dominant genes.

Korla and Sharma (1987a) during an evaluation of six okra parents and their F_1, F_2 and backcross generations observed non-allelic interactions for yield in most of the cases, suggesting the importance of epistasis in the expression of yield. However, Vaishali Vadhu x IC-16260, Pusa Sawani x IC-16260 and Long Green x EC-68475 exhibited partial to complete dominance for yield, with additive gene effects being significant. Over dominance for yield was observed in Vaishali Vadhu x EC-68475, Pusa Selection 6 – 2 x EC-68475 and Pusa Sawani x EC-68475. Again in 1988, Korla and Sharma studied six generations of *Abelmoschus esculentus* for three seed characters *viz.*, number and weight of seeds fruit^{-1} and 100 seed weight and observed high dominance gene action in three heterotic cross combinations.

Sadashiva (1988) analysed the segregation pattern for YVM reaction in F_1, F_2 and backcross generations of two crosses *viz.*, IIHR 1 – 16 x Key stone and IIHR 2 – 48 x Key stone and suggested the involvement of two loci in imparting resistance for YVMV. Studies conducted by Randhawa (1989) on four generations along with parents of the cross Pusa Sawani x Punjab Padmini for nine agronomic traits and resistance to YVM revealed that most of the

Table 2. Gene action in okra

Character	Additive	Non-additive	Dominance	Additive x additive	Additive x dominance	Dominance x dominance	Over dominance
Days to first flower	Partap and Dhankhar (1980a) Partap *et al.* (1981) Partap *et al* .(1982) Sivakumar *et al.* (1996) Panda and Singh (2000) Ravisankar *et al.* (2002) Yadav *et al.* (2002)	Partap and Dhankhar (1980a) Elangovan *et al.* (1981) Dhillon and Sharma (1982) Singh and Singh (1984) Shukla *et al.* (1989) Rajani (1995) Singh *et al.* (1995)	Wankhade *et al* .(1995)	Korla *et al.* (1985)			
Days to 50 % flower	Partap *et al.* (1981,1982) Chavadhal and Malkhandale (1994)						
Leaf axil bearing first flower	Partap *et al.* (1981) Panda and Singh (2000)	Elangovan *et al.* (1981) Vijay and Manohar (1986a)					
Leaf axil bearing first fruit	Partap *et al.* (1981,1982) Ravisankar *et al.* (2002)	Elangovan *et al.* (1981) Rajani and Manju (1997)					
Flowers plant^{-1}		Rajani (1995)					
Nodes plant^{-1}	Patel *et al.* (1994)					Lal *et al.* (1975)	
Internodal length	Patil (1995)	Ravisankar *et al.* (2002)					
Leaves plant^{-1}	Patil (1995)						

Character	Additive	Non-additive	Dominance	Additive x additive	Additive x dominance	Dominance x dominance	Over dominance
Branches plant^{-1}	Patel *et al.* (1994) Yassin and Anbu (1997) Panda and Singh (2000) Yadav *et al.* (2002)	Elangovan *et al.* (1981) Rajani and Manju(1997)	Lal *et al.* (1975)				
Plant height	Partap and Dhankhar (1980a) Reddy *et al.* (1985) Veeraraghavathatham and Irulappan (1990) Yadav *et al.* (2002)	Elangovan *et al.* (1981) Veeraraghavathatham and Irulappan (1990) Patil (1995) Yassin and Anbu (1997) Pitchaimuthu and Dutta (2002) Ravisankar *et al.* (2002)	Kulkarni (1975)	Arumugam and Muthukrishnan (1979) Panda and Singh (2000)		Korla *et al.* (1985)	
Fruits plant^{-1}	Partap and Dhankhar (1980a) Partap *et al.* (1981) Thaker *et al.* (1981a) Reddy *et al.* (1985) Vashisht (1990) Veeraraghavathatham and Irulappan (1990, 1991) Sivakumar *et al.* (1996) Yassin and Anbu (1997) Panda and Singh (2000) Yadav *et al.* (2002)	Partap and Dhankhar (1980a) Elangovan *et al.* (1981) Partap *et al.* (1981) Thaker *et al.* (1981a) Singh *et al.* (1995) Veeraraghavathatham and Irulappan (1990) Sivakumar *et al.* (1995) Sood (2001) Ravisankar *et al.* (2002) Pitchaimuthu and Dutta (2002)	Lal *et al.* (1975)	Kulkarni *et al.* (1978) Korla *et al.* (1985)			

Table 2. (continued...)

Character	Additive	Non-additive	Dominance	Additive x additive	Additive x dominance	Dominance x dominance	Over dominance
Fruit length	Partap and Dhankhar (1980a) Thaker *et al.* (1981a) Singh and Singh (1984) Reddy *et al.* (1985) Veereraghavathatham and Irulappan (1991) Patil (1995) Panda and Singh (2000) Yadav *et al.* (2002)	Partap and Dhankhar (1980a) Elangovan *et al.* (1981) Shukla *et al.* (1989) Veeraraghavathatham and Irulappan (1990) Singh *et al.* (1995) Rajani (1995) Sivakumar *et al.* (1996) Ravisankar *et al.* (2002) Yadav *et al.* (2002)	Rajani (1995) Rajani and Manju (1999)				
Fruit girth	Partap and Dhankhar (1980a) Thaker *et al.* (1981a) Reddy *et al.* (1985) Vijay and Manohar (1986a) Veeraraghavathatham and Irulappan (1990,1991) Ahmed *et al.* (1997) Yadav *et al.* (2002)	Veeraraghavathatham and Irulappan (1990) Rajani (1995) Ravisankar *et al.* (2002)					Panda and Singh (2000)
Length to girth ratio of fruits		Sivakumar *et al.* (1996)					

Table 2. (continued...)

Character	Additive	Non-additive	Dominance	Additive x additive	Additive x dominance	Dominance x dominance	Over dominance
Average fruit weight	Thaker *et al.* (1981a) Veeraraghavathatham and Irulappan (1991) Wankhade *et al.* (1995)	Vijay and Manohar (1986a) Veeraraghavathatham and Irulappan (1991) Rajani (1995) Singh *et al.* (1995) Wankhade *et al.* (1995) Sivakumar *et al.* (1996) Yassin and Anbu (1997) Pitchaimuthu and Duttta (2002)	Rajani (1995) Rajani and Manju (1999)				
Ridges fruit^{-1}	Lal *et al.* (1975)	Pitchaimuthu and Duttta (2002)	Lal *et al.* (1975)				
Locules pod^{-1}	Patel *et al.* (1994)						
Yield	Partap and Dhankhar (1980a) Partap *et al.* (1981) Thaker *et al.* (1981a) Reddy *et al.* (1985) Veeraraghavathatham (1989) Vashisht (1990) Yassin and Anbu (1997) Panda and Singh (2000) Yadav *et al.* (2002)	Partap *et al.* (1981) Veeraraghavathatham (1989) Rajani (1995) Singh *et al.* (1995) Sivakumar *et al.* (1995, 1996) Ravisankar *et al.* (2002) Pitchaimuthu and Dutta (2002)	Wankhade *et al.* (1995) Rajani and Manju (1999)				Randhawa (1989)

Table 2. (continued...)

Character	Additive	Non-additive	Dominance	Additive x additive	Additive x dominance	Dominance x dominance	Over dominance
Marketable yield		Pitchaimuthu and Dutta (2002)					
Seeds pod^{-1}	Panda and Singh (2000)	Patel *et al.* (1994) Rajani (1995)					
Dry seed yield plant^{-1}		Patel *et al.* (1994)					
Seed weight pod^{-1}	Panda and Singh (2000)						
1000-seed weight	Panda and Singh (2000)	Patel *et al.* (1994)					

characters showed partial to complete dominance except for yield plant^{-1} which displayed overdominance while ANOVA and means of each generation indicated the predominance of additive gene effects thereby suggesting selection for high yielding varieties in early generations.

Pulliah *et al.* (1996) evaluated six genetical populations (P_1, P_2, F_1, F_2, BC_1 and BC_2) of okra developed from the crosses of six commercial okra cultivars for four yield components and indicated the importance of dominance x dominance gene effects in the inheritance of plant height, days to 50 per cent flower and nodes and fruits plant^{-1}. They suggested heterosis breeding and intermating of selects in advanced generations for improving these characters.

Generation mean analysis carried out by Deo *et al.* (1998) in six generations of five crosses of okra in respect of pod yield and its components showed the importance of both additive and dominance gene effects, followed by additive x additive and dominance x dominance gene effects. Hence breeding methods which could simultaneously exploit both additive and non additive gene effects were suggested.

Inheritance of resistance to leaf hopper investigated by Hooda *et al.* (1999) in two resistant x susceptible crosses of okra using six standard generations revealed the significance of both additive and dominance effects. Backcross method was recommended to improve leaf hopper resistance. However, selection for resistance genes in later generations also was suggested until the achievement of homozygosity.

Tripathi and Arora (2001) carried out triple test cross analysis using six generations involving the parents, F_1, L_1 (F_2 x P_1), L_2 (F_2 x P_2) and L_3 (F_2 x F_1) derived from two intervarietal crosses of Pusa A-4 x KS-410 and AG-26 x Pb-8. The results revealed epistasis for days to first flower, days to first picking, fruit weight, fruits plant^{-1}, pod length, marketable yield, total yield and plant height and also significant estimates of both additive and dominance components for all the traits in both the crosses. Partial dominance existed for all the characters in both crosses except overdominance for fruit weight and plant height in Pusa A-4 x KS-410.

Materials and Methods

3. MATERIALS AND METHODS

The present study was undertaken at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2001-2002 as four major experiments with a view to study the genetic basis and inheritance pattern of important quantitative and qualitative characters including yield and yellow vein mosaic resistance in okra. The details of materials used and methods adopted for the study are presented below:

3.1 MATERIALS

A germplasm collection of 101 okra varieties / genotypes obtained from various parts of India (Table 3) including known yellow vein mosaic (YVM) resistant varieties, varieties released by Kerala Agricultural University, types from NBPGR Regional Station, Vellanikkara and local collections formed the materials for the study.

3.2 METHODS

3.2.1 Germplasm Evaluation

Two parallel experiments as detailed below were laid out using 101 genotypes of okra during Summer 2001.

3.2.1.1 Screening for YVM disease resistance

An experiment using 101 genotypes was conducted during Summer 2001 to screen for YVM disease resistance. Randomised Block Design with two replications at a spacing of 60 x 45 cm and ten plants per treatment per replication was used for the evaluation. A susceptible variety (Kiran) was raised as border plants to provide sufficient inoculum for the natural incidence of disease in the field. The experiment was completely devoid of plant protection measures. Scoring for disease incidence was done as per the rating scale by Arumugam *et al.* (1975) during four stages of the crop *viz.*, 30 days after sowing

Table 3. Germplasm collection of okra

Treatment No.	Variety / Genotype	Source
1	NBPGR /TCR-1185	NBPGR Regional Station, Vellanikkara, Thrissur
2	NBPGR /TCR-1943	-do-
3	NBPGR /TCR-1883	-do-
4	NBPGR /TCR-1948	-do-
5	NBPGR /TCR-2145	-do-
6	NBPGR /TCR-1674	-do-
7	NBPGR /TCR-1676	-do-
8	NBPGR /TCR-1581	-do-
9	NBPGR /TCR-1728	-do-
10	NBPGR /TCR-1981	-do-
11	NBPGR /TCR-1722	-do-
12	NBPGR /TCR-1828	-do-
13	NBPGR /TCR-1508	-do-
14	NBPGR /TCR-1507	-do-
15	NBPGR /TCR-2020	-do-
16	NBPGR /TCR-1498	-do-
17	NBPGR /TCR-1569	-do-
18	NBPGR /TCR-1533	-do-
19	NBPGR /TCR-1471	-do-
20	NBPGR /TCR-1963	-do-
21	NBPGR /TCR-1524	-do-
22	NBPGR /TCR-1929	-do-
23	NBPGR /TCR-1966	-do-
24	NBPGR /TCR-1998	-do-
25	NBPGR /TCR-1982	-do-
26	NBPGR /TCR-1999	-do-
27	NBPGR /TCR-2042	-do-
28	NBPGR /TCR-1955	-do-

29	NBPGR /TCR-2040	NBPGR Regional Station. Vellanikkara. Thrissur
30	NBPGR /TCR-2168	-do-
31	NBPGR /TCR-1988	-do-
32	NBPGR /TCR-1999	-do-
33	NBPGR /TCR-2146	-do-
34	NBPGR /TCR-2060	-do-
35	NBPGR /TCR-2055	-do-
36	NBPGR /TCR-2048	-do-
37	NBPGR /TCR-2019	-do-
38	NBPGR /TCR-1871	-do-
39	NBPGR /TCR-1783	-do-
40	NBPGR /TCR-1777	-do-
41	NBPGR /TCR-1552	-do-
42	NBPGR /TCR-808	-do-
43	NBPGR /TCR-1957	-do-
44	NBPGR /TCR-776	-do-
45	NBPGR /TCR-2235	-do-
46	NBPGR /TCR-760	-do-
47	NBPGR /TCR-128-A	-do-
48	NBPGR /TCR-2137	-do-
49	NBPGR /TCR-2177	-do-
50	NBPGR /TCR-2173	-do-
51	NBPGR /TCR-2228	-do-
52	NBPGR /TCR-2192	-do-
53	NBPGR /TCR-2187	-do-
54	NBPGR /TCR-1753	-do-
55	NBPGR /TCR-1899	-do-
56	NBPGR /TCR-2061	-do-
57	NBPGR /TCR-2048	-do-
58	NBPGR /TCR-2235	-do-
59	NBPGR /TCR-1966	-do-
60	NBPGR /TCR-1975	-do-

61	NBPGR /TCR-1956	NBPGR Regional Station, Vellanikkara, Thrissur
62	NBPGR /TCR-1934	-do-
63	NBPGR /TCR-1904	-do-
64	NBPGR /TCR-1479	-do-
65	Peechi Local	Peechi, Thrissur
66	Kanhangad Local	Kanhangad, Kasaragod
67	Chittarikkal Local	Chittarikkal, Kasaragod
68	Mavungal Local	Mavungal, Kasaragod
69	Eranakulam Local	Eranakulam
70	Mananthavady Local	Mananthavady, Wayanad
71	Pudukad Local	Pudukad, Thrissur
72	Kollam Local-1	Kollam
73	Kollam Local-2	Kollam
74	Kilikolloor Local	Kilikolloor, Kollam
75	Kattayikkonam Local	Kattayikkonam, Thiruvananthapuram
76	Kazhakkoottam Local	Kazhakkoottam, Thiruvananthapuram
77	Nedumangad Local	Nedumangad, Thiruvananthapuram
78	Goureesapattom Local	Goureesapattom, Thiruvananthapuram
79	Kakkamoola Local	Kakkamoola, Thiruvananthapuram
80	Arka Anamika	IIHR, Bangalore
81	NBPGR/TCR-874	NBPGR Regional Station, Vellanikkara, Thrissur
82	MDU-1	TNAU, Coimbatore
83	NBPGR/TCR-985	NBPGR Regional Station, Vellanikkara, Thrissur
84	NBPGR/TCR-893	NBPGR Regional Station, Vellanikkara, Thrissur
85	Parbhani Kranti	Marathwada Agricultural University, Parbhani

86	Varsha Uphar	Haryana Agricultural University, Hisar
87	Salkeerthi	College of Horticulture, Vellanikkara, Thrissur
88	Aruna	College of Horticulture, Vellanikkara, Thrissur
89	Arka Abhay	IIHR, Bangalore
90	Selection-13	Department of Plant Breeding and Genetics, College of Agriculture, Vellayani
91	Selection-46	Department of Plant Breeding and Genetics, College of Agriculture, Vellayani
92	Anakkomban-I	Palappoor, Thiruvananthapuram
93	Anakkomban-II	Kalliyoor, Thiruvananthapuram
94	Kiran	Department of Plant Breeding and Genetics, College of Agriculture, Vellayani
95	Kannur Local Red	Kannur
96	Nileshwaram Local	Nileshwaram, Kasaragod
97	Pananchery Local	Pananchery, Thrissur
98	Kalavoor Local	Kalavoor, Alappuzha
99	Balussery Local	Balussery, Kozhikode
100	Koyilandy Local	Koyilandy, Kozhikode
101	Payyannur Local	Payyunnur, Kannur

(30 DAS), 50 days after sowing (50 DAS), 70 days after sowing (70 DAS) and final harvest. The vector population of both white fly and leaf hopper were recorded in the morning and evening hours at the above four stages of the crop.

3.2.1.2 Evaluation for yield traits

The 101 genotypes were laid out in Randomised Block Design with two replications at a spacing of 60 x 45 cm and ten plants per treatment per replication during Summer 2001 to evaluate the yield and yield attributes. Cultural and manurial practices were followed as per Package of Practices Recommendations of KAU (1996). Observations on yield and yield attributes were recorded and biochemical traits were analysed.

3.2.2 Development of F_1s

Five high yielding YVM susceptible types and three resistant types, identified from the trials on evaluation and screening of germplasm, were selected as parental lines and testers respectively for developing F_1S. The five lines and three testers were raised in a L x T crossing block during Kharif 2001 and fifteen F_1 hybrids were produced. The technique of crossing suggested by Giriraj and Rao (1973) was adopted.

On the previous evening of crossing, the mature flower buds of both lines and testers which are due to open the next day were selected and the buds of testers were covered with butter paper cover to avoid contamination with foreign pollen. In the case of lines, a shallow circular cut was made around the fused calyx of the bud at about 1 cm from its base. Calyx cup and corolla were removed like a hood exposing the staminal column and stigma. The anthers were scraped off carefully and the flower buds were protected using butter paper covers. Pollination was done the next morning between 8 and 10 am by rubbing the stigma of parental lines with pollen grains collected from respective testers.

After pollination, the flowers were again covered and labelled. The covers were removed a day after pollination. The labelled mature fruits were harvested separately and F_1 seeds were extracted.

3.2.3 Evaluation of F_1s and Parents

The fifteen F_1 hybrids and their eight parents were evaluated along with two check varieties (Kiran and Arka Anamika) in a randomised block design with three replications at a spacing of 60 x 45 cm and ten plants per treatment per replication during Summer 2002. Observations on yield and yield attributes and incidence of YVM disease and fruit and shoot borer were recorded from the hybrids and parents. Four superior F_1s with respect to yield and YVM disease resistance were selected.

3.2.4 Building Up of Generations

The four selected F_1s were backcrossed to their respective parents to produce B_1 and B_2 generations during Kharif 2002. Simultaneously, the F_1s were selfed to develop F_2 generation.

3.2.5 Evaluation of Generations

The six generations (P_1, P_2, F_1, F_2, B_1 and B_2) of each F_1 hybrid combination (24 treatments) were evaluated during Rabi 2002 in a randomised block design with three replications. From every replication, five plants each were selected at random for recording observations in P_1, P_2 and F_1 generations whereas fifteen plants each were selected in F_2, B_1 and B_2 generations as observational plants.

3.3 OBSERVATIONS

3.3.1 Biometric Observations on Yield Traits

a. Days to first flower

The number of days taken from sowing to the blooming of first flower in each plant was recorded.

b. Leaf axil bearing first flower

Number of the leaf axil from which the first flower was produced was recorded.

c. Leaf area (cm^2)

From each observational plant, three leaves were collected from third, sixth and nineth nodes. Leaf area of these was determined graphically, averaged and recorded in square centimetres.

d. Pollen sterility (%)

During the early phase of flowering, pollen grains were collected from flowers and were stained using 1:1 glycerine : acetocarmine mixture. Considering stainability as the criterion to assess sterility, 200 pollen grains from different microscopic fields on the slide were scored in each plant. Shrivelled, unstained or partially stained pollen grains were recorded as sterile.

$$\text{Pollen sterility (\%)} = \frac{\text{Number of sterile pollen grains}}{\text{Total number of pollen grains under observation}} \times 100$$

e. Fruits $plant^{-1}$

The total number of fruits harvested from each plant was counted and recorded.

f. Average fruit weight (g)

The weight of third, sixth and ninth fruits (from bottom to top) was taken from each plant during harvest and the mean weight was estimated and expressed in grams.

g. Fruit weight $plant^{-1}$ (g)

The weight of fruits per plant was estimated as the product of average fruit weight and number of fruits per plant and expressed in grams.

h. Fruit length (cm)

The length of fruit from the base to the tip was measured on the third, sixth and nineth fruits during harvest and their mean was expressed in centimetres.

i. Fruit girth (cm)

The girth of those fruits used for recording the length was measured at the middle portion and their mean expressed in centimetres.

j. Ridges $fruit^{-1}$

The number of ridges of those fruits used for recording the length and girth was counted and mean recorded.

k. Seeds $fruit^{-1}$

The seeds were extracted from the fruits of third, sixth and nineth nodes and they were counted and mean recorded.

l. Plant duration

The number of days from sowing to final harvest of each observational plant was recorded.

m. Fruit colour

Fruit colour was scored as per the NBPGR descriptor as detailed below:

Fruit colour	Score
Green	1
Dark green	2
Yellowish green	3
Red	4
Dark red	5
Light green	6
Striated (green with purple)	7
Beige pink	8
Green with purple blend	9
Red purple	10
Watery green	11

n. Fruit pubescence

Scoring of fruit pubescence was done as per the NBPGR descriptor.

Fruit pubescence	Score
Downy	1
Slightly rough	2
Prickly	3

3.3.2 Biochemical Traits

a. Crude fibre content

For the estimation of crude fibre content, three fruits from each plant at the vegetable stage were harvested. Their crude fibre content was assessed by the method proposed by Chopra and Kanwar (1976) and expressed as percentage of fresh weight.

b. Protein content

Protein content of the fruits harvested at vegetable stage was estimated as per the method adopted by Bradford (1976).

c. Mucilage content

The fruits harvested at the vegetable stage formed the sample fruits for estimation of mucilage content. The mucilage content was estimated by following the method suggested by Hirst and Jones (1955).

3.3.3 Incidence of pest and disease

a. Fruit and shoot borer incidence

Infestation on the fruits and shoots of observational plants by fruit and shoot borer (*Earias vitella* F.) was recorded, intensity of incidence assessed and expressed in percentage.

$$\text{Percentage of infestation by fruit and shoot borer} = \frac{\text{Number of fruits infested}}{\text{Total number of fruits}} \times 100$$

b. YVM disease incidence

1. Scoring YVM disease

Each plant was observed for the characteristic gradation of symptoms on leaves and fruits. Disease intensity was scored as per the rating scale (Table 4) suggested by Arumugam *et al.* (1975).

Table 4. YVM disease rating scale

Sl. No.	Symptom	Grade	Rating scale
1	No visible symptom characteristic of the disease	Highly resistant	1
2	Very mild symptoms, basal half of primary veins remain green, mild yellowing of anterior half of primary veins, secondary veins and veinlets. Infection is also seen late in the season under field conditions	Resistant	2
3	Veins and veinlets turn completely yellow	Moderately resistant	3
4	Pronounced yellowing of veins and veinlets, 50 % of leaf lamina turn yellow, fruits exhibit slight yellowing	Susceptible	4
5	Petioles, veins, veinlets, and interveinal area turn yellow in colour. Leaves start drying from margin and fruits turn yellow	Highly susceptible	5

According to this scale, scoring for YVM disease incidence was done during the following stages of the crop:

i. 30 days after sowing (30 DAS)
ii. 50 days after sowing (50 DAS)
iii. 70 days after sowing (70 DAS)
iv. Final harvest

2. Study of vector population

Population of the two vectors of YVM disease *viz*., white fly (*Bemisia tabaci*) and leaf hopper (*Amrasca devastans*), were recorded on the plants during the above four stages of the crop. The lower side of the top three leaves in each plant were observed and the number of white flies and leaf hoppers were counted in the morning as well as evening of the same day.

3. Confirmation of disease resistance

i. Grafting

YVM resistant genotypes and hybrids identified from the above experiments were used as scions and were grafted by wedge grafting method on the susceptible variety, Kiran (used as root stock). Subsequently, further growth of the scion portion was observed and the absence of YVM disease symptoms on the new leaves was used as the criterion for the confirmation of disease resistance of the particular genotype and hybrid tested.

ii. Vector transmission

YVM resistant types were raised in pots and covered with cage. White flies were collected from YVM infected plants and starved for one to two hours. Then they were artificially inoculated with YVM virus by feeding for 4-5 hours using YVM infected leaves. After the acquisition period, the flies were released on the seedlings inside the cages. Here, the feeding of vector on the plants was ensured since they were protected

inside the cages. The seedlings which did not develop any symptom of YVM and grew normally were confirmed as YVM resistant types.

iii. Leaf pubescence

Number and length of leaf hairs in the highly resistant and susceptible genotypes were assessed using digital microscope and their photographs were taken.

iv. Phenol content

Phenol content of leaves collected from the selected lines and testers was analysed following the method suggested by Bray and Thorpe (1954).

c. Leaf roller incidence

During generation mean analysis, infestation on the leaves of observational plant by leaf roller was recorded and intensity of infestation expressed in percentage.

$$\text{Percentage of infestation by leaf roller} = \frac{\text{Number of leaves infested}}{\text{Total number of leaves}} \times 100$$

d. Leaf spot incidence

During generation mean analysis, leaves of the observational plants were observed for leaf spot incidence and disease intensity was scored as per the rating scale furnished below:

Intensity of symptom (%)	Score
0	1
1-25	2
26-50	3
51-75	4
76-100	5

3.3 STATISTICAL ANALYSIS

3.3.1 Germplasm Evaluation

3.3.1.1 Screening for YVM resistance

3.3.1.1.1 Analysis of variance (ANOVA)

Analysis of variance was carried out for YVM scores taken on morning and evening populations of white fly and leaf hoppers during each crop stage. Two factor ANOVA was done for various stages to study the interaction effects between genotypes and time for vector populations. Whenever genotype x time interaction mean square was non-significant, pooled error mean square was used for testing the significance among the genotypes.

3.3.1.1.2 Association

During each crop stage, correlation coefficients were estimated between YVM score and population of each vector.

3.3.1.2 Evaluation for yield traits

3.3.1.2.1 Analysis of variance (ANOVA)

The biometric observations recorded were subjected to ANOVA (Panse and Sukhatme, 1985) for comparison among various treatments and to estimate variance components (Table 5).

Table 5. ANOVA for each character

Source of variation	Degrees of freedom	Mean square	F
Replication	(r-1)	MSR	MSR/MSE
Treatment	(t-1)	MST	MST/MSE
Error	(r-1) (t-1)	MSE	
Total	(rt-1)		

Where, r = number of replications, t = number of treatments, MSR = Replication mean square, MST = Treatment mean square, MSE = Error variance.

Critical difference (CD) = $t_{\alpha}\sqrt{\frac{2MSE}{r}}$

Where, t_{α} is the student's t table value at error degrees of freedom and α is the level of significance.

3.3.1.2.2 Estimation of genetic parameters

a. Genetic components of variance

For each character, the phenotype and genotypic components of variance were estimated by equating the expected value of mean squares (MS) to the respective variance components (Jain, 1982). Based on this, the following variance components were estimated.

i. Genotypic variance (V_G)

$$V_G = \frac{MST - MSE}{r}$$

ii. Environmental variance (V_E)

$$V_E = MSE$$

iii. Phenotypic variance (V_P)

$$V_P = V_G + V_E$$

b. Coefficients of variation

Genotypic and phenotypic coefficients of variation were worked out using the estimates of V_G and V_P and expressed in percentage (Burton, 1952) for each trait.

i. Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{V_P}}{\bar{(X)}} \times 100$$

ii. Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{V_G}}{\bar{X}} \times 100$$

$\bar{X}$ is the mean of each character estimated over all the treatments.

c. Heritability

For each trait, heritability (broad sense) was calculated as the ratio of genotypic variance to phenotypic variance and expressed as percentage (Jain, 1982).

$$\text{Heritability } (H^2) = \frac{V_G}{V_P} \times 100$$

Heritability was categorised as :

< 30 %	→ low
31 – 60 %	→ moderate
>60 %	→ high

(Johnson *et al.*, 1955)

d. Genetic advance

Genetic advance which is the measure of genetic gain under selection, depends upon standardised selection differential, heritability and phenotypic standard deviation (Allard, 1960).

$$\text{Genetic advance (GA)} = k.\ H^2 \sqrt{V_P}$$

Where k is the standardised selection differential (2.06 at 5 % selection).

$$\text{GA as percentage of mean} = \frac{k.\ H^2 \sqrt{V_P}}{\bar{X}} \times 100$$

Genetic advance was categorised as :

< 10 %	→ low
11 – 20 %	→ moderate
> 20 %	→high

(Johnson *et al.*, 1955)

3.3.1.2.3 Association analyses

a. Correlations

Phenotypic, genotypic and environmental correlation coefficients were calculated using the respective variances and co-variances of the characters which showed significant variation in the ANOVA.

$$\text{Phenotypic correlation coefficient, } r_{P_{xy}} = \frac{Cov_P(x,y)}{\sqrt{V_P(x).\ V_P(y)}}$$

$$\text{Genotypic correlation coefficient, } r_{G_{xy}} = \frac{Cov_G(x,y)}{\sqrt{V_G(x).\ V_G(y)}}$$

$$\text{Environmental correlation coefficient, } r_{E_{xy}} = \frac{Cov_E(x,y)}{\sqrt{V_E(x).\ V_E(y)}}$$

Where, $Cov_P(x,y)$, $Cov_G(x,y)$ and $Cov_E(x,y)$ denote the phenotypic, genotypic and error co-variances between the two traits x and y respectively.

$V_P(x)$, $V_G(x)$ and $V_E(x)$ respectively are the phenotypic, genotypic and error variance for x and $V_P(y)$, $V_G(y)$ and $V_E(y)$ indicate the phenotypic, genotypic and error variance for y, in that order.

b. Path coefficients

The direct and indirect effects of component characters which has high association on yield (fruit weight plant^{-1}) were estimated through path analysis technique (Dewey and Lu, 1959).

3.3.1.2.4 Selection index

To discriminate the genotypes based on characters under study selection index developed by Smith (1936), using discriminant function of Fisher (1936) was employed. Selection index was computed based on the same characters utilised for path analysis.

The selection index is described by the function, $I = b_1x_1 + b_2x_2 + \ldots\ldots + b_kx_k$ and the merit of a plant is described by the function, $H = a_1G_1 + a_2G_2 + \ldots\ldots + a_kG_k$ where $x_1, x_2 \ldots\ldots x_k$ are the phenotypic values and $G_1, G_2 \ldots\ldots G_k$ are the genotypic values of the plants with respect to the characters $x_1, x_2 \ldots\ldots x_k$, and H is the genetic worth of the plant. It is assumed that economic weight assigned to each character is equal to unity *ie*., $a_1, a_2, \ldots\ldots, a_k = 1$ and b (regression) coefficients are determined such that correlation between H and I is maximum. The procedure will reduce to an equation of the form $b = P^{-1}Ga$ where P and G are the phenotypic and genotypic variance covariance matrices respectively.

3.3.2 Line x Tester Analysis

3.3.2.1 Combining ability

Based on screening trials, five lines and three testers were identified and carried over for crossing programme. Following the L x T method (Kempthorne, 1957), the general combining ability (GCA) of parents and the specific combining ability (SCA) of hybrids were estimated. The mean squares due to various sources of variation and their genetic expectations were computed as per Table 6.

Table 6. Anova for line x tester analysis

Source	df	Mean square	Expected MS
Replication	(r – 1)		
Line	(l – 1)	M_1	MSE + r (Cov F.S. – 2 Cov H.S.) + rt (Cov H.S.)
Tester	(t – 1)	M_2	MSE + r (Cov F.S. – 2 Cov H.S.) + rl (Cov H.S)
Line x Tester	(l – 1) (t – 1)	M_3	MSE + r (Cov F.S. – 2 Cov H.S.)
Error	(r – 1) (lt – 1)	M_4	MSE
Total	(rlt – 1)		

Where,

r = number of replications

g = number of genotypes

l = number of lines

t = number of testers

General combining ability (*gca*) effect of parents and specific combining ability (*sca*) effect of hybrids were estimated using the following model.

$X_{ijk} = \mu + g_i + g_j + s_{ij} + e_{ijk}$

Where,

μ = Population mean

g_i = *gca* effect of i^{th} line

g_j = *gca* effect of j^{th} tester

s_{ij} = *sca* effect of ij^{th} hybrid

e_{ijk} = error associated with ijk^{th} observation

i = 1,2,.....l

j = 1,2,.....t

k = 1,2,.....r

The individual effects were estimated as follows :

$$\text{Mean} = \frac{x...}{r_{lt}}$$

i. *gca* effect of lines

$$g_i = \frac{x_{i..}}{r_t} - \frac{x...}{r_{lt}} \quad i=1,2,....,l$$

ii. *gca* effect of testers

$$g_j = \frac{x_{.j.}}{r_l} - \frac{x...}{r_{lt}} \quad j= 1,2...,t$$

iii. *sca* effect of hybrids

$$s_{ij} = \frac{x_{ij.}}{r} - \frac{x_{i..}}{r_t} - \frac{x_{.j.}}{r_l} + \frac{x...}{r_{lt}}$$

Where,

$x_{...}$ = Total of all hybrids over 'r' number of replications

$x_{i..}$ = Total of all hybrids involving i^{th} line as one parent over 't' testers and 'r' replications

$x_{.j.}$ = Total of all hybrids involving j^{th} tester as one parent over 'l' lines and 'r' replications

$x_{ij.}$ = Total of the hybrids between i^{th} line and j^{th} tester over 'r' replications

Significance of combining ability effects was tested as follows :

1. SE of *gca* (lines) = $\sqrt{\frac{MSE}{rt}}$

2. SE of *gca* (testers) = $\sqrt{\frac{MSE}{rl}}$

3. SE of *sca* of hybrids = $\sqrt{\frac{MSE}{r}}$

The significance of these effects were tested by computing values as effect / (SE of the effect) and were compared with table 't' values at error df for 5 per cent level of significance.

3.3.2.2 Heterosis

Extent of heterosis was computed for all the fifteen hybrids as relative heterosis (RH), standard heterosis (SH), heterobeltiosis (HB) and best parent heterosis (HBP) using the following formulae and expressed as percentage. For estimating standard heterosis, Arka Anamika and Kiran (for YVM only) were used as the standard varieties.

i. Relative heterosis (RH) = $\frac{\overline{F}_1 - \overline{MP}}{\overline{MP}} \times 100$

ii. Standard heterosis (SH) = $\frac{\overline{F_1} - \overline{SV}}{\overline{SV}} \times 100$

iii. Heterobeltiosis (HB) = $\frac{\overline{F_1} - \overline{BP}}{\overline{BP}} \times 100$

iv. Best parent heterosis (HBP) = $\frac{\overline{F_1} - \overline{BAP}}{\overline{BAP}} \times 100$

Where,

$\overline{F_1}$ = Mean value of hybrid

$\overline{MP}$ = Mid parental value

$\overline{SV}$ = Mean of standard variety

$\overline{BP}$ = Mean of better parent in that particular cross

$\overline{BAP}$ = Mean value of the best parent among all the parents for each of the trait

The significance of different types of heterosis was tested by the 't' test.

't' for RH = $\frac{\left| \overline{F_1} - \overline{MP} \right|}{\sqrt{\frac{3\,MSE}{2r}}}$

't' for SH = $\frac{\left| \overline{F_1} - \overline{SV} \right|}{\sqrt{\frac{2\,MSE}{r}}}$

't' for HB = $\frac{\left| \overline{F_1} - \overline{BP} \right|}{\sqrt{\frac{2\,MSE}{r}}}$

$$\text{'t' for HBP} = \frac{\left| \overline{F_1} - \overline{BAP} \right|}{\sqrt{\frac{2\,MSE}{r}}}$$

Where,

MSE = estimate of error variance

r = number of replications

3.3.2.3 Proportional Contribution

Proportional contribution of lines, testers and their interaction to total variance was calculated (Singh and Chaudhary, 1985).

$$\text{Contribution of lines} = \frac{SS\ (lines)}{SS\ (hybrids)} \times 100$$

$$\text{Contribution of testers} = \frac{SS\ (testers)}{SS\ (hybrids)} \times 100$$

$$\text{Contribution of interaction} = \frac{SS\ (l \times t)}{SS\ (hybrids)} \times 100$$

3.3.3 Generation Mean Analysis

Six parameter model (Hayman, 1958) was used for the analysis which consisted of the following steps.

i. Development of scales

Using the scaling test proposed by Mather (1949), estimation of additive (D) and dominance (H) components of genetic variance were made using the mean and variance of six generations *viz.*, P_1, P_2, F_1, F_2, B_1 and B_2.

$$A = 2\bar{B}_1 - \bar{P}_1 - \bar{F}_1$$

$$V_A = 4\,V(\bar{B}_1) + V(\bar{P}_1) + V(\bar{F}_1)$$

$$B = 2\bar{B}_2 - \bar{P}_2 - \bar{F}_1$$

$$V_B = 4\,V(\bar{B}_2) + V(\bar{P}_2) + V(\bar{F}_1)$$

$$C = 4\bar{F}_2 - 2\bar{F}_1 - \bar{P}_1 - \bar{P}_2$$

$$V_C = 16\,V(\bar{F}_2) + 4\,V(\bar{F}_1) + V(\bar{P}_1) + V(\bar{P}_2)$$

$$D = 2\bar{F}_2 - \bar{B}_1 - \bar{B}_2$$

$$V_D = 4\,V(\bar{F}_2) + V(\bar{B}_1) + V(\bar{B}_2)$$

Where $\bar{P}_1$, $\bar{P}_2$, $\bar{F}_1$, $\bar{F}_2$, $\bar{B}_1$ and $\bar{B}_2$ are the means of respective generations over all replications and $V(P_1)$, $V(P_2)$, $V(F_1)$, $V(F_2)$, $V(B_1)$ and $V(B_2)$ are the respective variances. The standard errors of A, B, C and D obtained as square root of V_A, V_B, V_C and V_D.

ii. Testing for epistasis

Significance of any of the four scales indicates the inadequacy of additive-dominance model and presence of epistasis. For testing the significance of A, B, C and D scales, 't' test was employed.

$$t_A = \frac{A}{\sqrt{V_A}}$$

$$t_B = \frac{B}{\sqrt{V_B}}$$

$$t_C = \frac{C}{\sqrt{V_C}}$$

$$t_D = \frac{D}{\sqrt{V_D}}$$

If the calculated 't' value of these scales is higher than 1.96, it is considered as significant. Significance of each of these scales reveals the presence of specific type of epistasis as detailed below :

a. The significance of either one or both of A and B scales indicates the presence of all three types of digenic interaction *viz.*, additive x additive (i), additive x dominance (j) and dominance x dominance (l)
b. The significance of scale C denotes dominance x dominance type of non-allelic interaction
c. The significance of scale D reveals additive x additive type of gene interaction
d. The significance of both C and D scales depicts additive x additive and dominance x dominance type of epistasis.

iii. Estimation of genetic components

When the scales A, B, C and D were significantly different from zero, a digenic interaction model was assumed and the following six parameters were estimated (Jinks and Jones, 1958).

$$m = \bar{F}_2$$

$$d = \bar{B}_1 - \bar{B}_2$$

$$h = \bar{F}_1 - 4\bar{F}_2 - \tfrac{1}{2}\bar{P}_1 - \tfrac{1}{2}\bar{P}_2 + 2\bar{B}_1 + 2\bar{B}_2$$

$$i = 2\bar{B}_1 + 2\bar{B}_2 - 4\bar{F}_2$$

$$j = (\bar{B}_1 - \tfrac{1}{2}\bar{P}_1) - (\bar{B}_2 - \tfrac{1}{2}\bar{P}_2) = \bar{B}_1 - \tfrac{1}{2}\bar{P}_1 - B_2 + \tfrac{1}{2}\bar{P}_2$$

$$l = \bar{P}_1 + \bar{P}_2 + 2\bar{F}_1 + 4\bar{F}_2 - 4\bar{B}_1 - 4\bar{B}_2$$

Where,

m= mean

d= additive effect

h= dominance effect

i= additive x additive interaction

j= additive x dominance interaction

l= dominance x dominance interaction

The variances of these six genetic parameters were computed as follows :

$$V(m) = V(\bar{F}_2)$$

$$V(d) = V(\bar{B}_1) + V(\bar{B}_2)$$

$$V(h) = V(\bar{F}_1) + 16V(\bar{F}_2) + \tfrac{1}{4}V(\bar{P}_1) + \tfrac{1}{4}V(\bar{P}_2) + 4V(\bar{B}_1) + 4V(\bar{B}_2)$$

$$V(i) = 4V(\bar{B}_1) + 4V(\bar{B}_2) + 16V(\bar{F}_2)$$

$$V(j) = V(\bar{B}_1) + \tfrac{1}{4}V(\bar{P}_1) + V(\bar{B}_2) + \tfrac{1}{4}V(\bar{P}_2)$$

$$V(l) = V(\bar{P}_1) + V(\bar{P}_2) + 4V(\bar{F}_1) + 16V(\bar{F}_2) + 16V(\bar{B}_1) + 16V(\bar{B}_2)$$

The above genetic parameters were tested for significance using 't' test as in the case of scaling test.

iv. Transgressive segregants (%)

$$\text{Transgressive segregants (\%)} = \frac{\text{Number of plants better than superior parent}}{\text{Total number of } F_2 \text{ plants}} \times 100$$

Results

4. RESULTS

The results obtained from various experiments of the present investigation are furnished below:

4.1 GERMPLASM EVALUATION

4.1.1 Screening for YVM Disease Resistance

4.1.1.1 Analysis of Variance

4.1.1.1.1 YVM incidence

Symptoms of YVM disease are presented in Plate 1. The scores obtained as per YVM rating scale (Plate 2) for 101 genotypes under study during four crop stages *viz.*, 30 DAS, 50 DAS, 70 DAS and final harvest were subjected to ANOVA and the results are presented in Table 7.

Table 7. ANOVA for YVM disease incidence

Crop stage	Varietal mean square (df = 100)
30 DAS	0.022
50 DAS	1.602**
70 DAS	2.062**
Final harvest	3.095**

The genotypes varied significantly for YVM incidence during all the crop stages except at 30 DAS.

The mean scores of YVM disease in the genotypes in each crop stage are given in Table 8. Intensity of YVM incidence during various crop stages is presented in Fig. 1.

a. 30 DAS

Majority of the genotypes were highly resistant while a few of them exhibited resistance to the disease, as evident from Table 8. None of the genotypes showed susceptibility to YVM.

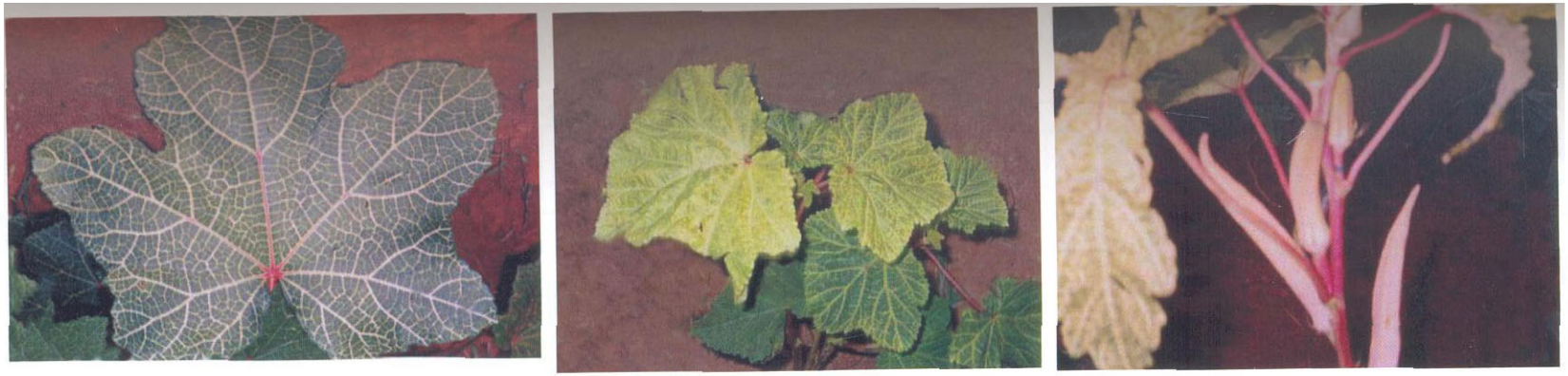


Plate 1. Symptoms of YVM

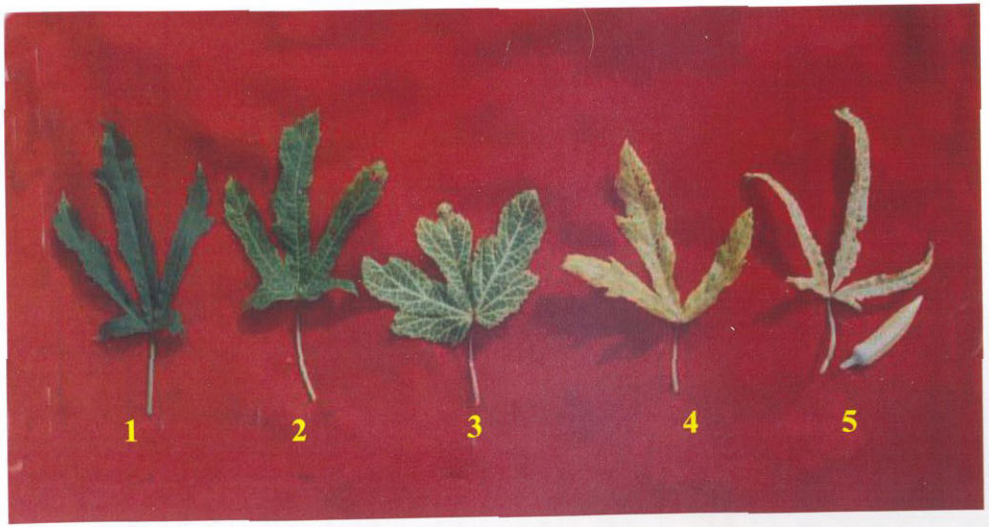


Plate 2. YVM rating scale

Plate 3. Okra fruit infected with fruit and shoot borer

Table 8. Scoring of yellow vein mosaic

Tr. No.	YVM score				Tr. No.	YVM score				Tr. No.	YVM score				Tr. No.	YVM score			
	30 DAS	50 DAS	70 DAS	Final harvest		30 DAS	50 DAS	70 DAS	Final harvest		30 DAS	50 DAS	70 DAS	Final harvest		30 DAS	50 DAS	70 DAS	Final harvest
1	1.3	2.8	3.7	4.7	**28**	1.0	3.8	4.2	5.0	**55**	1.0	4.0	4.0	5.0	**82**	1.0	1.1	1.3	1.9
2	1.0	3.5	3.7	5.0	**29**	1.0	2.5	2.9	4.5	**56**	1.0	2.7	4.2	5.0	**83**	1.0	2.0	2.9	4.2
3	1.0	1.8	3.0	4.7	**30**	1.0	3.3	3.9	5.0	**57**	1.0	2.5	3.2	4.5	**84**	1.0	2.2	2.9	3.9
4	1.0	1.5	2.5	4.0	**31**	1.0	2.1	2.9	4.4	**58**	1.0	3.0	3.3	4.2	**85**	1.0	1.0	1.0	1.0
5	1.0	2.3	4.5	5.0	**32**	1.0	2.4	3.3	4.9	**59**	1.0	2.3	2.7	4.0	**86**	1.0	1.0	1.0	1.0
6	1.0	2.8	3.2	4.7	**33**	1.1	2.6	3.4	4.5	**60**	1.0	1.5	2.5	4.2	**87**	1.1	2.8	4.3	4.8
7	1.0	2.1	3.5	4.7	**34**	1.0	1.0	1.0	1.0	**61**	1.0	3.0	3.0	4.7	**88**	1.0	3.0	3.8	5.0
8	1.0	3.0	3.3	4.6	**35**	1.0	2.9	3.6	4.8	**62**	1.0	5.0	5.0	5.0	**89**	1.0	1.0	1.5	2.3
9	1.0	1.5	3.0	5.0	**36**	1.0	2.0	2.7	3.8	**63**	1.0	1.0	4.0	5.0	**90**	1.0	1.0	1.0	1.1
10	1.0	4.0	4.5	5.0	**37**	1.0	2.0	2.5	5.0	**64**	1.0	1.5	3.5	5.0	**91**	1.0	1.0	1.0	1.0
11	1.0	2.0	4.6	5.0	**38**	1.0	3.1	3.9	4.7	**65**	1.0	2.1	2.2	3.1	**92**	1.0	1.1	1.5	2.1
12	1.0	3.8	4.2	5.0	**39**	1.0	2.0	2.3	3.9	**66**	1.0	1.0	1.5	1.9	**93**	1.0	1.0	1.9	3.2
13	1.0	2.0	2.9	5.0	**40**	1.0	2.3	3.1	4.5	**67**	1.0	2.5	3.7	4.9	**94**	1.0	2.1	3.4	5.0
14	1.0	2.8	3.6	4.8	**41**	1.0	3.3	4.0	5.0	**68**	1.1	3.3	4.4	5.0	**95**	1.0	1.5	2.0	4.0
15	1.0	2.0	2.5	3.9	**42**	1.0	1.3	1.3	1.3	**69**	1.0	1.0	1.5	1.9	**96**	1.0	1.0	3.0	5.0
16	1.0	2.0	3.0	4.8	**43**	1.0	1.5	1.9	2.6	**70**	1.0	2.9	3.3	3.5	**97**	1.0	3.0	3.0	5.0
17	1.0	1.5	3.0	4.7	**44**	1.0	2.0	2.6	3.9	**71**	1.0	1.0	1.0	1.1	**98**	1.0	1.5	3.0	4.5
18	1.0	1.8	3.2	5.0	**45**	1.0	2.0	3.5	5.0	**72**	1.0	1.0	1.0	1.2	**99**	1.0	4.0	4.5	5.0
19	1.0	2.5	3.5	5.0	**46**	1.0	3.0	3.9	4.8	**73**	1.0	1.8	3.0	4.7	**100**	1.0	4.0	3.9	5.0
20	1.1	2.8	3.5	4.5	**47**	1.1	2.7	4.0	5.0	**74**	1.0	1.3	1.7	2.2	**101**	1.0	2.5	5.0	5.0
21	1.0	3.4	3.6	5.0	**48**	1.0	2.0	3.5	5.0	**75**	1.0	2.3	2.4	2.6	**Mean**	1.0	2.2	3.0	4.1
22	1.0	2.3	2.7	4.7	**49**	1.0	3.5	4.3	5.0	**76**	1.0	2.3	3.5	4.4	**SE**	NS	0.7	0.6	0.6
23	1.0	1.7	2.0	2.6	**50**	1.2	3.5	4.2	5.0	**77**	1.0	1.0	1.0	1.1	**CD**	NS	1.8	1.7	1.5
24	1.0	2.3	3.0	4.7	**51**	1.0	3.0	1.9	5.0	**78**	1.1	1.4	1.7	3.6					
25	1.0	2.0	2.5	4.0	**52**	1.0	1.5	3.5	5.0	**79**	1.0	1.0	1.5	2.5					
26	1.0	2.5	4.0	5.0	**53**	1.0	1.3	2.5	4.3	**80**	1.1	2.2	3.5	4.3					
27	1.0	2.8	3.6	4.5	**54**	1.0	3.0	3.3	4.5	**81**	1.1	3.5	4.0	5.0					

b. 50 DAS

The genotypes exhibited significant variation for YVM incidence at this crop stage. High resistance was observed for 15 genotypes *viz.*, T34, T63, T66, T69, T71, T72, T77, T79, T85, T86, T89, T90, T91, T93 and T96 and they were on par with 60 other treatments. Thirty one treatments were resistant while moderate resistance was exhibited by 39 types. Susceptibility to YVM was noticed for fifteen genotypes. However, highly susceptible group included only one genotype *viz.*, T62.

c. 70 DAS

Eight treatments were highly resistant to YVM *viz.*, T34, T71, T72, T77, T85, T86, T90 and T91 and these were on par with other 23 treatments. Resistance and moderate resistance were shown by thirteen and 29 genotypes respectively. Susceptibility to YVM was noticed for 38 treatments whereas thirteen types were highly susceptible.

d. Final harvest

Highly resistant category included four genotypes *viz.*, T34, T85, T86 and T91. Eight types (T42, T66, T69, T71, T72, T77, T82, T90) were resistant whereas seven types (T23, T43, T74, T75, T79, T89 and T92) were moderately resistant to YVM. Most of the genotypes (70 numbers) exhibited high susceptibility while twelve types were susceptible to the disease.

Number of susceptible cultivars and intensity of disease increased gradually from 30 DAS to final harvest.

4.1.1.1.2 Vector population

The 101 genotypes of okra were scored for vector population of both white fly and leaf hopper in the morning and evening at 30, 50 and 70 DAS and the mean population of vectors is presented in Table 9.

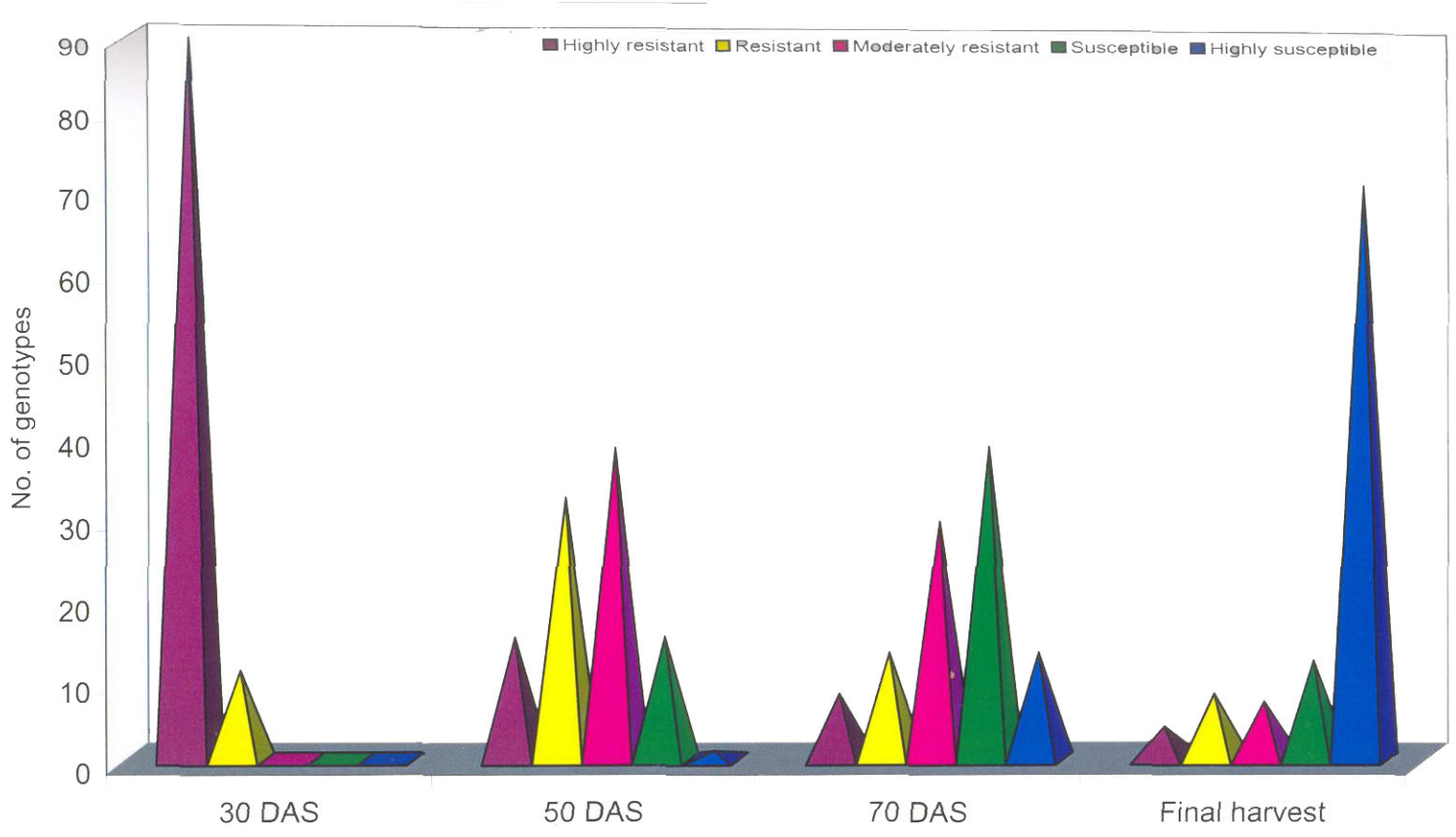


Fig. 1. Intensity of YVM incidence during four crop stages

Table 9. Mean population of vectors on okra genotypes during three crop stages

Treatment No.	White fly						Leaf hopper					
	30 DAS		50 DAS		70 DAS		30 DAS		50 DAS		70 DAS	
	M	E	M	E	M	E	M	E	M	E	M	E
	1	2	3	4	5	6	7	8	9	10	11	12
1	0.05	0.05	0.03	0.06	0.05	0.10	0.08	0.00	0.12	0.10	0.03	0.00
2	0.08	0.16	0.38	0.50	0.08	0.16	0.16	0.08	0.38	0.42	0.08	0.00
3	0.12	0.16	0.08	0.00	0.00	0.00	0.21	0.16	0.25	0.16	0.04	0.00
4	0.12	0.08	0.29	0.41	0.21	0.25	0.25	0.16	0.42	0.50	0.21	0.41
5	0.04	0.08	0.00	0.00	0.00	0.00	0.12	0.08	0.12	0.08	0.00	0.00
6	0.04	0.08	0.16	0.00	0.16	0.16	0.20	0.24	0.58	0.65	0.13	0.00
7	0.10	0.19	0.16	0.21	0.07	0.14	0.34	0.39	0.26	0.33	0.11	0.21
8	0.27	0.21	0.29	0.41	0.06	0.04	0.27	0.00	0.57	0.56	0.18	0.08
9	0.24	0.31	0.08	0.16	0.00	0.00	0.33	0.50	0.33	0.33	0.08	0.00
10	0.04	0.00	0.32	0.24	0.08	0.00	0.29	0.08	0.61	0.50	0.33	0.16
11	0.08	0.00	0.42	0.50	0.00	0.00	0.32	0.31	0.66	0.65	0.25	0.16
12	0.32	0.31	0.59	0.50	0.08	0.00	0.31	0.31	0.70	0.83	0.16	0.00
13	0.12	0.16	0.04	0.08	0.00	0.00	0.25	0.42	0.12	0.16	0.04	0.00
14	0.06	0.11	0.14	0.05	0.03	0.00	0.19	0.16	0.31	0.28	0.06	0.00
15	0.16	0.16	0.17	0.33	0.00	0.00	0.16	0.16	0.33	0.16	0.16	0.16
16	0.24	0.31	0.38	0.50	0.04	0.00	0.16	0.31	0.42	0.50	0.08	0.00
17	0.04	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.16	0.08	0.08	0.08
18	0.20	0.31	0.16	0.16	0.04	0.00	0.08	0.08	0.29	0.42	0.13	0.17
19	0.31	0.31	0.41	0.50	0.21	0.16	0.37	0.24	0.46	0.50	0.54	0.50
20	0.08	0.00	0.24	0.31	0.04	0.08	0.37	0.41	0.46	0.41	0.00	0.00
21	0.16	0.31	0.24	0.27	0.04	0.00	0.30	0.04	0.25	0.16	0.10	0.00
22	0.00	0.00	0.54	0.58	0.21	0.33	0.29	0.33	0.55	0.67	0.21	0.25
23	0.13	0.07	0.27	0.25	0.00	0.00	0.09	0.07	0.24	0.22	0.05	0.00

Table 9 (continued...)

	1	2	3	4	5	6	7	8	9	10	11	12
24	0.29	0.41	0.08	0.16	0.16	0.16	0.29	0.41	0.25	0.16	0.25	0.33
25	0.00	0.00	0.31	0.31	0.08	0.16	0.16	0.16	0.24	0.16	0.08	0.00
26	0.16	0.16	0.59	0.67	0.25	0.33	0.42	0.16	0.42	0.50	0.16	0.16
27	0.14	0.22	0.29	0.31	0.06	0.00	0.32	0.31	0.29	0.26	0.06	0.00
28	0.03	0.03	0.28	0.31	0.02	0.00	0.13	0.03	0.28	0.34	0.02	0.00
29	0.00	0.00	0.00	0.00	0.00	0.00	0.23	0.46	0.14	0.16	0.63	0.00
30	0.35	0.53	0.12	0.16	0.00	0.00	0.39	0.39	0.12	0.16	0.04	0.08
31	0.10	0.07	0.02	0.03	0.00	0.00	0.35	0.27	0.12	0.10	0.04	0.04
32	0.16	0.14	0.02	0.00	0.00	0.00	0.19	0.10	0.15	0.14	0.03	0.00
33	0.11	0.21	0.02	0.05	0.03	0.03	0.21	0.25	0.13	0.16	0.33	0.45
34	0.05	0.07	0.00	0.00	0.07	0.11	0.16	0.14	0.20	0.03	0.33	0.23
35	0.16	0.20	0.05	0.05	0.03	0.05	0.25	0.16	0.09	0.04	0.16	0.04
36	0.16	0.16	0.05	0.06	0.02	0.03	0.12	0.13	0.12	0.20	0.00	0.00
37	0.00	0.00	0.08	0.00	0.00	0.00	0.08	0.16	0.00	0.00	0.00	0.00
38	0.37	0.54	0.18	0.20	0.29	0.41	0.49	0.62	0.31	0.45	0.32	0.33
39	0.12	0.24	0.08	0.16	0.08	0.16	0.31	0.31	0.08	0.08	0.25	0.17
40	0.08	0.16	0.03	0.05	0.03	0.05	0.30	0.16	0.10	0.14	0.17	0.11
41	0.00	0.00	0.04	0.00	0.16	0.31	0.12	0.16	0.08	0.08	0.16	0.24
42	0.24	0.34	0.06	0.09	0.46	0.34	0.11	0.03	0.05	0.05	0.57	0.28
43	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.31	0.75	1.50
44	0.12	0.16	0.00	0.00	0.04	0.00	0.21	0.16	0.08	0.08	0.47	0.70
45	0.08	0.11	0.03	0.05	0.03	0.00	0.03	0.00	0.08	0.11	0.22	0.33
46	0.15	0.16	0.03	0.03	0.00	0.00	0.28	0.20	0.15	0.17	0.05	0.10
47	0.47	0.65	0.16	0.31	0.00	0.00	0.58	0.71	0.19	0.22	0.03	0.05
48	0.24	0.31	0.33	0.50	0.24	0.31	0.24	0.31	0.16	0.16	0.24	0.31
49	0.19	0.22	0.14	0.28	0.00	0.00	0.45	0.52	0.11	0.22	0.08	0.16
50	0.04	0.08	0.00	0.00	0.08	0.16	0.16	0.16	0.04	0.00	0.12	0.24
51	0.02	0.04	0.00	0.00	0.02	0.04	0.10	0.04	0.06	0.12	0.00	0.00

Table 9 (continued...)

	1	2	3	4	5	6	7	8	9	10	11	12
52	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
53	0.11	0.22	0.00	0.00	0.11	0.16	0.33	0.65	0.14	0.22	0.16	0.21
54	0.00	0.00	0.00	0.00	0.00	0.00	0.16	0.31	0.08	0.16	0.08	0.00
55	0.08	0.16	0.16	0.16	0.00	0.00	0.41	0.50	0.25	0.50	0.08	0.16
56	0.11	0.21	0.00	0.00	0.16	0.31	0.16	0.11	0.05	0.05	0.24	0.31
57	0.04	0.08	0.00	0.00	0.00	0.00	0.08	0.08	0.12	0.08	0.29	0.33
58	0.23	0.46	0.00	0.00	0.00	0.00	0.24	0.31	0.16	0.31	0.00	0.00
59	0.29	0.41	0.08	0.16	0.12	0.08	0.00	0.00	0.12	0.08	0.16	0.16
60	0.31	0.46	0.16	0.31	0.08	0.00	0.80	0.87	0.60	0.73	0.84	1.37
61	0.04	0.08	0.08	0.16	0.21	0.25	0.04	0.08	0.25	0.25	0.46	0.41
62	0.08	0.16	0.16	0.16	0.16	0.16	0.40	0.80	0.17	0.00	0.16	0.16
63	0.00	0.00	0.00	0.00	0.24	0.31	0.00	0.00	0.00	0.00	0.33	0.50
64	0.00	0.00	0.00	0.00	0.24	0.31	0.00	0.00	0.00	0.00	0.08	0.16
65	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.16	0.00	0.00
66	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.16	0.17	0.33	0.30	0.00
67	0.25	0.33	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.16	0.00	0.00
68	0.08	0.16	0.00	0.00	0.00	0.00	0.16	0.16	0.08	0.16	0.08	0.16
69	0.04	0.08	0.04	0.08	0.00	0.00	0.00	0.00	0.04	0.08	0.08	0.16
70	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
71	0.00	0.00	0.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.04
72	0.02	0.00	0.12	0.03	0.18	0.16	0.33	0.16	0.18	0.16	0.26	0.10
73	0.11	0.11	0.00	0.00	0.06	0.11	0.03	0.00	0.00	0.00	0.12	0.19
74	0.00	0.00	0.02	0.00	0.02	0.04	0.00	0.00	0.06	0.12	0.52	0.87
75	0.00	0.00	0.00	0.00	0.08	0.16	0.00	0.00	0.33	0.41	0.32	0.33
76	0.11	0.22	0.02	0.03	0.08	0.16	0.07	0.07	0.06	0.07	0.09	0.12
77	0.00	0.00	0.08	0.16	0.00	0.00	0.00	0.00	0.11	0.22	0.08	0.05
78	0.00	0.00	0.00	0.00	0.03	0.03	0.17	0.00	0.13	0.10	0.03	0.03
79	0.00	0.00	0.02	0.04	0.02	0.00	0.00	0.00	0.06	0.08	0.06	0.04

Table 9 (continued...)

	1	2	3	4	5	6	7	8	9	10	11	12
80	0.00	0.00	0.02	0.00	0.16	0.31	0.16	0.05	0.04	0.00	0.05	0.04
81	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.00	0.04	0.08	0.16	0.16
82	0.10	0.00	0.08	0.00	0.04	0.04	0.21	0.16	0.04	0.08	0.08	0.12
83	0.04	0.07	0.35	0.70	0.19	0.34	0.13	0.00	0.08	0.12	0.00	0.00
84	0.04	0.00	0.08	0.05	0.25	0.14	0.03	0.00	0.15	0.19	0.21	0.25
85	0.39	0.40	0.02	0.03	0.11	0.22	0.18	0.08	0.19	0.31	0.38	0.70
86	0.00	0.00	0.33	0.16	0.23	0.00	0.00	0.00	0.50	0.67	0.39	0.31
87	0.08	0.08	0.00	0.00	0.12	0.08	0.24	0.24	0.28	0.31	0.53	0.46
88	0.03	0.00	0.24	0.31	0.03	0.05	0.11	0.00	0.08	0.16	0.03	0.00
89	0.06	0.00	0.00	0.00	0.04	0.08	0.18	0.12	0.06	0.12	0.02	0.00
90	0.03	0.00	0.00	0.00	0.00	0.00	0.12	0.05	0.10	0.19	0.11	0.22
91	0.08	0.05	0.00	0.00	0.00	0.00	0.35	0.30	0.03	0.05	0.15	0.05
92	0.06	0.11	0.00	0.00	0.00	0.00	0.16	0.05	0.05	0.05	0.11	0.22
93	0.03	0.00	0.00	0.00	0.00	0.00	0.13	0.05	0.11	0.11	0.03	0.05
94	0.11	0.05	0.00	0.00	0.06	0.00	0.17	0.00	0.09	0.00	0.00	0.00
95	0.03	0.00	0.00	0.00	0.00	0.00	0.08	0.11	0.08	0.11	0.03	0.00
96	0.16	0.16	0.04	0.08	0.10	0.12	0.10	0.08	0.04	0.04	0.08	0.12
97	0.00	0.00	0.00	0.00	0.07	0.14	0.18	0.12	0.16	0.16	0.24	0.24
98	0.08	0.00	0.00	0.00	0.08	0.16	0.27	0.11	0.14	0.14	0.33	0.16
99	0.06	0.08	0.12	0.20	0.16	0.16	0.04	0.04	0.17	0.25	0.10	0.12
100	0.07	0.05	0.03	0.05	0.11	0.16	0.04	0.00	0.12	0.19	0.28	0.19
101	0.12	0.16	0.18	0.22	0.09	0.10	0.28	0.28	0.31	0.36	0.06	0.12
Mean	0.1	0.13	0.11	0.13	0.07	0.08	0.18	0.17	0.19	0.21	0.17	0.17
SE	-	-	0.15	0.19	-	-	-	-	0.19	0.24	-	-
CD	NS	NS	0.39	0.05	NS	NS	NS	NS	0.51	0.62	NS	NS

Interaction between the treatments and the populations of two vectors twice a day during the three stages of the crop was examined. Interaction mean squares were non-significant for both vectors during all the crop stages (Table 10).

The genotypes varied significantly for white fly population during all the three stages of the crop while leaf hopper count showed significance only during 50 DAS. At 30 DAS, time of infestation also differed significantly for white fly.

4.1.1.2 Association of YVM incidence with vector population

Correlation coefficients of YVM incidence with populations of white fly and leaf hopper were estimated at various stages of the crop *viz.*, 30 DAS, 50 DAS, 70 DAS and final harvest and are furnished in Table 11. YVM incidence at the three stages (except at 30 DAS) was significantly and positively correlated with the morning (0.209, 0.224 and 0.196 respectively) and evening (0.236, 0.251 and 0.210 respectively) populations of white fly at 30 DAS. YVM incidence during last harvest exhibited positively significant correlation with morning (0.208) and evening populations of white fly during 50 DAS also.

Morning population of leaf hopper at 30 DAS had significant positive correlation with disease incidence at 50 DAS (0.276) and 70 DAS (0.230) whereas evening count had influence on YVM incidence at 50 DAS (0.301), 70 DAS (0.278) and final harvest (0.257).

From this, it is clear that feeding by the vector during the initial stages of the crop especially at 30 DAS, is more important for the occurrence of YVM disease. As evident from the table, population of both vectors at 70 DAS and leaf hopper count also at 50 DAS had no correlation with the disease incidence.

Table 10. ANOVA for vectors and YVM incidence

Vector and crop stage	Mean square				
	Genotype (df=100)	Time (df=1)	Interaction (df=100)	Error (df=202)	Pooled error (df = 302)
White fly					
30 DAS	0.045**	0.329**	0.017	0.033	0.028
50 DAS	0.081**	0.152	0.014	0.031	0.025
70 DAS	0.032**	0.071	0.015	0.024	0.021
Leaf hopper					
30 DAS	0.094	0.069	0.044	0.073	0.064
50 DAS	0.110**	0.339	0.020	0.046	0.038
70 DAS	0.121	0.000	0.082	0.109	0.100

Table 11. Association of YVM incidence with vector population

Vectors	Correlation coefficients with YVM			
	30 DAS	50 DAS	70 DAS	Final harvest
a. White fly				
30 DAS				
Morning	0.045	0.209*	0.224*	0.196*
Evening	-0.002	0.236*	0.251*	0.210*
50 DAS				
Morning	-0.111	0.162	0.121	0.208*
Evening	-0.113	0.146	0.121	0.210*
70 DAS				
Morning	-0.030	-0.088	-0.071	-0.080
Evening	-0.025	-0.084	-0.014	-0.021
b. Leaf hopper				
30 DAS				
Morning	0.050	0.276**	0.230*	0.187
Evening	0.021	0.301**	0.278**	0.257**
50 DAS				
Morning	-0.042	0.146	0.074	0.171
Evening	-0.045	0.133	0.068	0.153
70 DAS				
Morning	-0.002	-0.096	-0.118	-0.082
Evening	-0.007	-0.052	-0.054	-0.029

4.1.2 Evaluation for Yield Traits

4.1.2.1 Analysis of Variance

The results of the analysis of variance for nineteen characters, which were used to compare the performance of 101 okra genotypes are presented in Table 12. The mean performance of genotypes with respect to various characters is furnished in Table 13.

Significant differences were detected among the genotypes with respect to all the characters studied.

a. Days to first flower

The mean performance of genotypes ranged from 34.8 (T90) to 92.1 (T101). T90 was the earliest flowering type, which was homogeneous with other 38 treatments. T101 took maximum days to produce the first flower.

b. Leaf axil bearing first flower

Six genotypes *viz.*, T15, T48, T51, T56, T82 and T86 possessed the lowest value (4.0) and these were on par with most of the other treatments. The highest value was recorded for T92 (7.9), which showed homogeneity with seventeen other genotypes.

c. Leaf area

Maximum leaf area of 325.63 cm^2 was recorded for T37 and minimum of 61.35 cm^2 for T45. High leaf area was recorded for T16, T83, T86, T90, T15, T82, T34, T95 and T85, which were on par with T37.

d. Pollen sterility

T15 exhibited the lowest pollen sterility (5.94 %) and T10 (48.72 %) the highest. More genotypes came under the low pollen sterility range compared to the genotypes which possessed high sterility.

e. Fruits $plant^{-1}$

Fruit number varied significantly among the genotypes and it ranged from 2.50 in T10 to 13.67 in T15. T10 was on par with other four

Table 12. ANOVA for nineteen characters in okra

Sl. No.	Character	Mean square	
		Treatment (df = 100)	Error (df = 100)
1.	Days to first flower	322.26**	47.13
2.	Leaf axil bearing first flower	1.52**	0.40
3.	Leaf area	5010.01**	604.78
4.	Pollen sterility	135.28**	47.82
5.	Fruits plant^{-1}	9.82**	0.41
6.	Average fruit weight	48.88**	7.32
7.	Fruit weight plant^{-1}	9374.69**	445.45
8.	Fruit length (cm)	23.41**	3.02
9.	Fruit girth (cm)	1.55**	0.26
10.	Ridges fruit^{-1}	1.15**	0.09
11.	Seeds fruit^{-1}	195.72**	35.21
12.	Plant duration	135.28**	35.87
13.	Crude fibre content	0.56**	0.07
14.	Protein content	0.50**	0.08
15.	Mucilage content	0.48**	0.07
16.	Fruit and shoot borer incidence	84.87**	31.69
17.	YVM incidence – 50 DAS	0.19**	0.10
18.	YVM incidence – 70 DAS	0.78**	0.34
19.	YVM incidence – Final harvest	1.27**	0.56

Table 13. Mean values of 22 characters in okra

Geno-type	Days to 1st flowering	Leaf axil of first flower	Leaf area	Pollen sterility	Fruits plant^{-1}	Average fruit weight	Fruit weight Plant^{-1}	Fruit length	Fruit girth	Ridges fruit^{-1}	Seeds fruit^{-1}	Plant duration	Crude fibre	Protein	Mucilage	Fruit and shoot borer	YVM 30 DAS	YVM 50 DAS	YVM 70 DAS	YVM Final harvest	Fruit colour	Fruit pubescence
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
T1	70.38	4.50	112.55	18.10	5.38	19.69	105.94	13.95	5.40	5.00	44.75	93.13	1.55	0.19	1.80	25.40	1.00	1.38	2.50	3.75	3.00	1.00
T2	46.50	4.50	134.85	30.69	4.75	19.93	93.43	14.88	5.46	5.33	40.25	92.50	1.95	0.20	1.50	31.67	1.00	1.25	2.75	3.75	3.00	1.00
T3	90.00	6.50	113.03	33.28	5.00	14.84	74.18	10.82	4.44	5.00	38.17	101.50	1.65	0.20	1.55	27.92	1.00	1.00	1.50	3.00	3.00	1.00
T4	87.00	6.50	63.50	23.38	5.50	14.35	78.48	11.73	5.17	5.00	48.17	103.00	1.75	1.77	1.50	40.97	1.00	1.50	3.00	4.00	6.00	1.00
T5	65.00	5.00	77.48	32.47	4.50	13.78	61.82	11.89	4.74	5.00	41.92	97.00	1.70	0.71	1.50	33.18	1.00	1.00	1.00	2.00	6.00	1.00
T6	54.25	5.00	121.88	42.68	4.00	16.46	64.85	12.04	4.57	5.00	41.34	90.25	1.85	0.46	1.30	32.19	1.00	1.25	1.50	2.25	2.00	1.00
T7	71.75	6.85	82.10	34.20	3.90	14.75	57.61	11.29	4.84	5.00	45.75	93.90	1.05	0.11	2.00	37.50	1.00	1.34	2.09	3.25	6.00	1.00
T8	49.80	4.50	71.60	27.92	4.10	14.25	58.32	12.38	5.13	5.00	44.00	90.10	1.55	0.30	1.80	31.11	1.00	1.20	1.60	2.50	2.00	1.00
T9	58.80	5.00	80.13	45.52	4.30	16.41	70.60	12.91	5.54	6.25	38.17	88.80	2.15	0.29	1.50	28.64	1.00	1.10	1.80	2.80	2.00	1.00
T10	60.00	5.50	79.53	48.72	2.50	13.89	34.52	11.65	4.45	5.67	46.00	89.50	1.90	0.20	1.90	27.89	1.00	1.00	1.50	2.50	3.00	1.00
T11	64.80	6.25	72.08	39.74	5.09	16.46	83.51	15.05	5.14	5.00	48.25	90.75	1.40	0.31	2.06	28.43	1.00	1.42	2.75	3.75	6.00	1.00
T12	60.50	5.50	178.05	27.33	5.50	25.91	144.96	16.78	5.56	5.00	45.38	98.50	2.20	1.50	1.30	23.72	1.00	1.00	2.50	3.50	6.00	1.00
T13	52.20	5.00	121.35	39.46	6.15	20.80	129.71	13.60	4.95	5.00	48.25	93.50	2.45	0.44	1.44	20.72	1.00	1.00	1.55	3.15	2.00	2.00
T14	72.00	7.00	120.20	23.54	5.00	20.75	103.75	8.99	5.94	5.00	58.67	98.00	2.90	0.07	1.50	29.02	1.00	2.50	3.50	4.50	2.00	1.00
T15	43.47	4.00	234.88	5.94	13.67	16.52	225.79	11.62	6.05	7.80	80.50	106.74	2.90	0.83	1.20	13.76	1.00	1.17	1.60	2.75	9.00	1.00
T16	39.90	5.00	258.75	6.22	10.97	24.85	272.26	17.65	5.80	5.13	58.05	106.44	1.45	0.92	1.49	11.31	1.00	1.67	2.74	3.59	2.00	1.00
T17	59.75	5.00	127.00	33.32	6.25	21.69	135.38	15.55	5.40	5.00	46.59	95.00	0.70	0.30	3.07	31.73	1.00	1.75	2.75	3.75	2.00	1.00
T18	55.64	4.87	95.30	41.54	4.47	12.18	54.30	11.24	5.47	5.00	34.04	94.63	3.65	1.49	1.00	4.17	1.00	1.37	2.10	3.30	2.00	3.00
T19	61.67	5.17	85.13	20.67	5.09	20.45	103.22	17.00	5.83	5.00	32.75	94.75	2.55	0.24	1.10	20.92	1.00	1.67	2.75	4.17	6.00	1.00
T20	47.84	4.50	115.60	32.30	5.54	17.66	97.99	15.05	5.06	5.00	30.92	92.21	1.85	0.51	1.40	33.24	1.00	1.20	2.24	3.70	2.00	1.00
T21	53.80	6.10	123.05	22.86	7.40	18.71	137.70	14.12	5.69	5.53	63.92	96.90	1.05	0.34	2.04	27.38	1.00	1.30	2.20	3.20	2.00	1.00
T22	46.17	4.34	136.13	23.89	6.67	17.72	118.59	13.45	5.48	5.00	41.00	95.34	1.70	0.56	1.20	37.06	1.00	1.00	2.00	2.84	6.00	1.00
T23	47.34	4.25	83.29	30.47	5.92	17.82	103.96	15.65	4.92	5.00	47.67	95.09	1.20	0.60	1.80	31.52	1.00	1.17	1.75	2.75	6.00	1.00
T24	54.10	4.20	146.28	29.66	5.45	17.02	92.78	14.23	5.04	5.00	32.17	92.90	2.00	0.72	1.35	26.79	1.00	1.85	2.75	3.85	6.00	1.00
T25	49.50	6.00	77.78	26.35	5.50	17.04	93.27	11.93	4.25	5.75	52.50	93.00	1.55	0.37	1.30	25.18	1.00	1.50	2.50	3.50	6.00	1.00
T26	68.67	6.17	104.65	29.38	5.34	17.10	90.44	13.78	4.20	5.00	38.00	95.17	2.15	0.09	0.90	26.10	1.00	1.37	2.50	3.20	3.00	1.00

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
T27	55.98	5.65	73.90	29.24	5.95	14.90	89.32	11.82	4.92	5.00	34.34	91.70	2.40	0.29	1.40	21.67	1.00	1.48	1.93	2.60	3.00	1.00
T28	44.00	6.25	77.13	28.35	5.30	18.88	99.45	15.34	5.54	5.00	37.50	90.10	2.30	0.17	1.50	16.67	1.10	1.30	1.90	3.10	7.00	1.00
T29	63.30	5.75	87.13	34.49	5.00	14.38	71.90	12.24	5.32	5.00	34.92	91.30	1.30	0.03	2.00	29.17	1.00	1.10	1.60	2.80	3.00	1.00
T30	63.00	5.50	81.95	29.86	5.67	18.37	103.89	15.30	4.85	5.00	26.50	85.67	1.15	0.38	2.25	26.92	1.00	1.17	1.84	2.84	3.00	1.00
T31	47.15	4.95	118.63	31.18	5.85	15.78	92.21	14.17	5.70	5.00	45.75	86.70	1.90	0.49	1.18	26.14	1.00	1.20	2.25	3.10	6.00	1.00
T32	47.00	4.70	209.15	14.93	8.00	27.77	222.97	16.95	6.02	5.50	51.00	90.00	2.10	0.21	1.30	22.50	1.00	1.10	1.80	2.80	2.00	1.00
T33	47.60	4.80	136.75	17.42	7.15	16.17	115.31	13.55	4.45	5.50	41.00	96.10	1.70	0.34	1.20	25.83	1.00	1.10	1.80	2.80	3.00	1.00
T34	47.80	5.40	216.13	16.38	12.10	23.86	288.89	17.80	5.63	5.25	48.00	116.30	3.10	0.53	1.40	28.21	1.00	1.00	1.00	1.00	2.00	1.00
T35	53.60	5.40	179.25	24.18	8.50	20.40	172.89	15.38	4.65	5.00	41.00	96.00	2.60	1.54	1.30	34.23	1.00	1.20	1.70	2.60	3.00	1.00
T36	45.60	4.80	179.44	24.82	8.20	22.44	182.28	15.35	5.89	5.00	49.09	92.40	2.40	2.20	1.30	30.39	1.00	1.20	1.70	2.50	2.00	1.00
T37	43.99	5.00	325.63	14.58	10.53	24.79	258.36	16.58	5.87	5.00	50.73	96.40	2.30	0.89	1.05	18.90	1.00	1.13	1.80	2.63	2.00	1.00
T38	58.30	5.00	170.48	22.41	7.70	20.71	160.31	16.52	5.02	5.00	40.50	93.40	2.30	0.10	1.30	28.90	1.00	1.20	1.70	2.40	6.00	1.00
T39	55.50	4.75	181.75	21.45	6.50	20.40	132.57	14.63	4.95	5.00	40.50	92.50	2.15	0.62	1.10	25.18	1.00	1.25	1.75	2.50	3.00	1.00
T40	45.30	4.25	149.40	18.38	7.13	22.15	157.85	19.65	4.93	5.00	44.17	98.57	1.80	0.33	1.40	30.68	1.00	1.00	1.10	1.55	3.00	1.00
T41	55.00	5.00	131.98	30.37	5.50	15.55	86.14	12.60	5.00	5.00	55.00	95.50	0.75	0.20	3.07	30.95	1.00	1.00	1.50	2.50	3.00	1.00
T42	66.25	6.25	157.31	21.59	5.75	19.26	110.32	12.99	7.69	6.92	47.17	98.45	2.35	0.66	1.30	26.93	1.00	1.00	1.00	1.75	2.00	1.00
T43	57.75	4.75	89.55	28.47	6.00	20.04	120.24	12.93	5.80	5.00	42.25	94.00	2.30	0.24	1.10	21.03	1.00	1.00	1.00	2.00	6.00	2.00
T44	60.00	5.40	87.25	25.58	5.80	18.40	123.90	15.53	4.85	6.90	53.50	87.20	2.55	1.03	1.40	33.52	1.00	1.60	2.25	3.15	6.00	1.00
T45	75.00	5.00	61.35	33.47	4.80	12.70	60.05	11.52	5.11	5.00	44.50	97.60	2.30	0.33	1.30	25.18	1.00	1.00	1.30	2.30	6.00	1.00
T46	56.15	4.85	168.48	32.59	5.25	22.43	117.73	17.99	5.85	5.00	48.17	88.60	2.55	1.09	1.10	29.17	1.00	1.00	1.25	2.38	2.00	1.00
T47	53.50	5.80	117.85	24.34	5.75	24.29	140.36	20.12	5.95	5.00	56.84	84.25	2.20	0.74	1.40	26.79	1.00	1.00	1.25	2.25	2.00	1.00
T48	45.80	4.00	182.33	14.31	9.15	23.66	215.81	14.81	6.03	5.00	48.17	101.90	0.85	0.37	3.60	15.48	1.00	1.00	1.87	2.77	2.00	1.00
T49	69.25	6.75	85.96	27.32	4.50	15.19	68.36	10.48	4.78	5.00	32.25	93.00	2.60	0.13	1.50	24.75	1.00	1.50	1.75	3.00	3.00	1.00
T50	59.87	5.75	107.28	42.56	4.94	12.88	62.73	12.64	5.47	5.00	31.42	95.46	2.40	0.40	1.20	22.50	1.00	1.84	2.30	3.57	3.00	1.00
T51	44.20	4.00	183.50	27.70	8.85	15.06	133.19	11.65	5.15	5.00	40.34	98.55	1.10	0.89	1.80	24.48	1.00	2.00	3.25	4.50	3.00	1.00
T52	64.00	5.50	133.00	25.91	6.50	19.04	123.11	14.38	5.78	5.00	51.00	95.00	2.20	1.06	1.30	24.04	1.00	1.00	1.00	2.00	6.00	1.00
T53	41.25	5.50	109.43	33.86	6.75	20.43	137.94	14.47	5.68	6.00	62.17	84.50	2.00	1.41	1.30	25.10	1.00	1.00	1.00	1.75	2.00	1.00
T54	60.00	5.50	96.35	38.45	6.00	15.39	91.47	10.93	5.40	5.00	39.75	97.00	2.15	0.76	1.40	37.86	1.00	1.00	1.00	2.00	3.00	1.00
T55	45.75	5.00	132.88	22.36	8.75	20.73	182.29	15.19	5.70	5.00	55.34	105.00	1.90	0.59	1.45	25.40	1.00	1.00	1.50	2.75	6.00	1.00
T56	45.60	4.00	114.68	27.35	8.20	17.79	142.78	14.29	5.02	5.00	43.59	97.80	1.60	0.61	1.30	21.33	1.00	1.30	2.00	3.20	3.00	1.00
T57	47.54	5.00	102.03	24.55	5.84	22.80	133.41	15.15	5.81	5.00	49.63	91.92	1.65	1.39	1.40	21.54	1.00	1.34	1.20	2.42	6.00	1.00
T58	64.59	7.17	70.90	47.13	4.13	15.91	65.60	11.33	4.73	5.00	32.50	92.63	1.40	0.20	1.70	30.72	1.00	1.29	1.88	2.75	7.00	1.00
T59	79.10	5.75	81.90	38.84	5.35	13.40	71.58	11.83	4.30	5.00	45.50	103.30	2.30	0.54	1.20	28.72	1.00	1.25	2.15	3.50	3.00	1.00
T60	65.00	5.50	107.28	31.11	6.00	15.12	92.28	1165	4.68	5.00	37.25	99.50	1.80	0.55	1.40	20.84	1.00	1.50	2.50	3.50	3.00	1.00

Table 13. (continued...)

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
T61	42.60	4.50	175.63	16.91	11.50	23.50	269.91	15.37	5.92	5.63	44.84	108.80	1.60	0.84	1.00	22.26	1.00	1.20	1.90	3.00	2.00	1.00
T62	39.64	4.90	134.35	20.19	9.43	20.18	190.87	14.92	5.29	5.00	41.17	90.24	1.50	0.57	1.10	23.34	1.00	1.57	2.20	3.30	3.00	1.00
T63	85.30	5.40	109.00	28.81	5.70	25.22	144.03	11.35	6.45	5.00	42.67	89.50	2.50	0.49	1.30	29.95	1.00	1.90	2.80	3.80	6.00	1.00
T64	74.92	6.59	150.85	25.48	6.09	16.10	100.48	10.70	4.73	5.00	39.25	101.84	2.00	0.77	1.50	35.42	1.00	1.50	2.25	3.42	2.00	1.00
T65	41.80	4.60	167.78	18.51	9.40	24.65	231.99	16.67	6.08	5.00	44.50	101.80	1.35	0.20	1.80	12.26	1.00	1.30	1.50	2.40	1.00	1.00
T66	62.67	5.00	100.44	27.73	5.67	22.19	125.73	16.14	4.94	5.25	43.25	94.17	2.65	0.65	1.10	21.98	1.00	1.17	1.50	2.34	6.00	1.00
T67	52.50	4.75	144.35	34.55	5.75	25.85	156.10	11.46	4.84	5.00	41.34	87.00	2.10	0.94	1.20	18.34	1.00	1.00	1.00	1.50	2.00	1.00
T68	49.10	5.20	116.55	22.11	6.50	19.40	125.29	22.17	5.58	5.00	40.25	84.00	1.50	1.80	1.70	31.11	1.00	1.40	2.00	3.10	2.00	1.00
T69	66.17	4.75	82.90	23.91	4.67	20.71	97.00	16.53	5.50	5.00	54.50	94.67	1.65	0.40	1.80	21.59	1.00	1.00	1.50	2.67	6.00	1.00
T70	58.00	5.13	111.68	27.41	5.38	27.26	146.83	20.62	6.09	5.00	46.42	89.75	2.10	0.35	1.60	24.75	1.00	1.13	1.50	2.38	2.00	1.00
T71	49.80	4.50	130.50	28.11	5.80	16.44	95.35	17.07	5.49	5.25	58.63	94.20	2.25	0.99	1.40	13.26	1.00	1.40	2.10	3.00	6.00	1.00
T72	82.88	6.33	183.95	19.73	6.10	34.47	210.23	15.49	9.91	8.00	68.09	106.03	2.25	1.33	1.50	15.08	1.00	1.00	1.25	1.70	9.00	1.00
T73	57.50	5.25	113.00	25.84	5.25	18.44	97.08	12.59	5.14	5.00	33.00	94.25	2.45	1.11	1.10	18.91	1.00	1.75	2.50	2.75	7.00	1.00
T74	59.75	6.50	84.40	16.33	5.25	19.67	103.38	13.53	10.08	7.75	62.00	94.00	2.35	0.88	1.40	27.15	1.00	1.00	1.25	2.50	7.00	1.00
T75	61.00	5.60	104.45	27.16	4.65	18.56	86.19	15.38	5.13	5.25	38.67	97.85	1.05	0.81	2.20	22.50	1.00	1.00	1.20	2.30	1.00	1.00
T76	64.00	6.17	158.43	30.35	5.50	22.22	121.94	16.59	6.89	8.17	85.17	95.50	2.65	0.94	1.10	26.25	1.00	1.10	1.74	2.80	6.00	1.00
T77	80.60	7.25	118.95	28.80	6.75	15.71	106.26	12.55	6.30	5.00	52.17	122.85	2.05	1.14	1.50	28.16	1.00	1.00	1.35	2.40	1.00	1.00
T78	45.90	4.30	128.25	12.44	10.70	28.34	303.17	18.49	6.63	5.17	56.83	107.10	2.40	0.51	1.30	18.34	1.00	1.00	1.00	2.20	7.00	1.00
T79	49.50	5.10	140.00	22.08	7.80	22.97	179.87	16.65	5.82	5.00	34.84	97.00	2.10	1.66	1.20	21.77	1.00	1.00	1.50	2.60	6.00	1.00
T80	54.80	4.70	147.35	19.85	7.80	24.84	193.80	18.97	5.69	5.00	45.59	102.60	1.95	0.33	1.30	19.05	1.00	1.00	1.00	1.40	2.00	1.00
T81	55.28	4.85	145.20	25.60	6.98	26.51	184.69	16.09	5.70	6.00	59.34	97.18	1.10	0.40	2.00	19.09	1.00	1.90	2.90	4.10	3.00	1.00
T82	38.80	4.00	218.03	12.48	12.40	23.70	293.28	19.14	5.96	5.00	58.50	109.80	1.55	1.20	1.00	12.26	1.00	1.80	2.70	3.60	2.00	1.00
T83	46.50	4.30	256.90	10.44	11.90	27.62	327.46	21.26	5.73	5.17	55.84	108.90	1.40	2.50	1.30	16.72	1.00	1.10	1.40	2.40	7.00	1.00
T84	53.75	4.25	180.30	28.69	7.75	20.71	160.72	14.96	6.65	6.25	42.84	96.75	2.15	0.40	1.10	26.62	1.00	1.00	1.75	3.00	2.00	1.00
T85	45.70	4.10	199.25	13.04	12.70	29.41	373.25	18.80	5.72	5.25	47.89	112.00	2.10	2.02	1.10	11.52	1.00	1.00	1.00	1.00	7.00	1.00
T86	41.62	4.00	245.63	11.49	12.65	27.58	348.44	19.31	5.54	5.34	52.90	112.92	2.00	0.48	1.30	15.63	1.00	1.00	1.00	1.00	2.00	1.00
T87	66.69	6.12	157.9	26.98	5.17	24.56	125.97	21.16	5.62	5.00	38.13	91.59	1.90	0.58	1.80	27.21	1.00	1.79	2.79	4.47	6.00	1.00
T88	57.50	5.80	178.80	26.85	5.90	25.60	150.73	19.66	4.95	5.00	50.17	96.50	2.10	0.46	1.50	25.84	1.00	1.30	2.10	3.10	4.00	1.00
T89	49.75	5.50	165.35	23.05	5.50	23.80	130.88	17.05	5.84	5.00	50.17	87.50	2.20	1.00	1.50	21.71	1.00	1.00	1.25	2.25	2.00	1.00
T90	34.80	5.40	245.00	18.25	6.70	28.85	192.17	21.63	6.25	5.00	42.00	93.50	2.20	0.39	1.70	22.71	1.00	1.00	1.40	2.30	2.00	1.00
T91	51.90	5.10	122.15	30.83	5.90	30.28	178.53	19.10	5.62	5.50	42.25	102.60	1.30	0.38	2.20	21.33	1.00	1.00	1.00	1.00	2.00	1.00
T92	73.45	7.90	184.80	27.18	4.50	30.78	136.85	23.87	6.14	7.34	52.50	104.50	2.25	0.26	1.50	19.88	1.00	1.00	1.10	1.65	2.00	1.00
T93	79.75	7.00	170.43	29.26	4.75	29.78	140.43	27.18	6.35	8.00	70.09	100.00	2.10	0.99	1.40	34.85	1.00	1.25	2.25	3.00	6.00	1.00
T94	54.90	5.10	132.45	21.74	5.80	24.94	144.65	17.57	5.13	5.00	52.00	88.20	1.70	0.62	1.40	31.25	1.00	2.30	3.70	4.80	6.00	1.00

Table 13. (continued...

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
T95	51.90	5.30	206.75	19.79	5.80	29.92	172.38	22.25	5.57	6.00	56.25	91.50	1.80	0.25	2.04	16.03	1.00	1.20	2.10	3.20	4.00	1.00
T96	61.30	5.65	120.03	27.60	5.35	15.59	99.19	12.50	5.23	5.00	43.00	93.80	1.85	1.16	1.40	22.50	1.00	1.25	1.85	3.50	2.00	1.00
T97	65.34	6.42	137.10	24.39	5.09	18.78	94.53	13.25	5.38	5.00	50.00	95.75	1.85	0.46	1.40	21.11	1.00	1.25	2.09	3.59	1.00	1.00
T98	88.25	5.75	138.30	28.04	6.00	15.43	94.74	12.63	5.38	5.00	47.25	110.50	0.75	1.21	4.00	29.17	1.00	1.00	1.25	2.00	6.00	1.00
T99	87.50	7.00	87.35	34.08	5.00	14.08	35.44	11.05	4.48	5.00	40.25	118.50	2.35	0.67	1.50	27.50	1.00	1.25	2.00	2.75	1.00	1.00
T100	82.80	6.20	136.55	29.48	4.60	15.63	71.59	12.18	4.63	5.00	49.75	111.30	2.25	0.92	1.40	25.76	1.00	1.20	1.90	2.90	6.00	1.00
T101	92.10	7.27	125.28	32.58	4.44	28.37	125.41	22.75	6.03	7.50	50.50	129.95	2.15	0.26	1.50	23.38	1.00	1.00	1.00	1.54	2.00	1.00
Mean	57.18	5.34	136.38	26.43	6.49	20.43	136.45	15.18	5.52	5.31	46.44	97.06	1.95	0.69	1.52	24.88	1.00	1.26	1.84	2.80	3.80	1.04
SE	6.86	0.63	24.59	6.92	0.64	2.71	21.11	1.74	0.51	0.31	5.93	5.99	0.26	0.28	0.27	5.63	–	0.32	0.59	0.75	–	–
CD	17.97	1.65	64.43	18.13	1.68	7.10	55.31	4.56	1.34	0.81	15.54	15.69	0.68	0.73	0.71	14.75	–	0.84	1.55	1.97	–	–

genotypes *viz.* T7, T6, T8 and T58 whereas T15 was homogeneous with T85, T86, T82 and T84.

f. Average fruit weight

Average fruit weight showed wide range of variation among the genotypes from 12.18 (T18) to 34.47 (T72). Forty six genotypes were homogeneous with T18 while T72 was on par with T92, T91, T95, T93, T85, T90, T101, T78, T32, T83 and T86.

g. Fruit weight plant^{-1}

T85 was the best yielder having a fruit yield of 373.25 g plant^{-1} whereas the lowest fruit yielder was T10 with 34.52 g plant^{-1}. However, only two genotypes *viz.*, T83 and T86 were on par with T85 whereas several genotypes were low yielders similar to T10.

h. Fruit length

The length of fruit exhibited wide range of variation among the various genotypes (Plate 4). The longest (27.18 cm) and the shortest (8.99 cm) fruits were produced by T93 and T14 respectively. The length of fruits of T92 and T101 was on par with that of T93.

i. Fruit girth

The fruits with maximum girth (10.08 cm) were produced by T74 and it was on par with T72. Girth of fruits was minimum (4.20 cm) in T26, which exhibited homogenity with several other genotypes.

j. Ridges fruit^{-1}

Ridges fruit^{-1} among the various genotypes ranged from 5.00 to 8.17 (Plate 5). The genotype with fruits having the highest number of ridges was T76 (8.17), which was on par with T72, T93, T15, T74, T101, T92, T44, T9, T84 and T42. Though most of the treatments had fruits with five ridges, 28 treatments possessed fruits having more than five ridges.

Plate 4. Variability in okra fruits

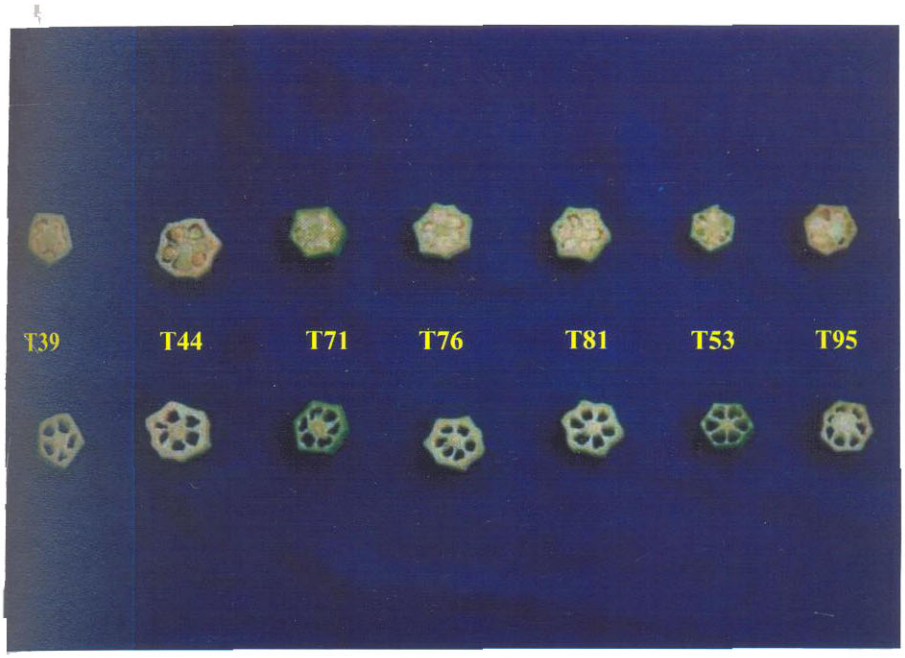


Plate 5. Variability in ridges and locules

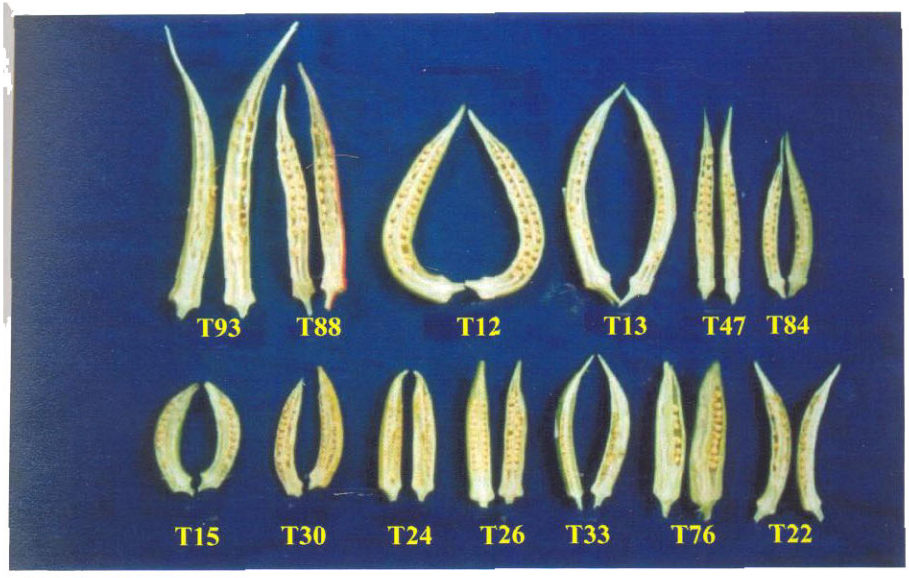


Plate 6. Variability in seeds

k. Seeds fruit^{-1}

Seeds fruit^{-1} varied from 26.50 in T30 to 85.17 in T76 (Plate 6). T15 and T93 were found to be on par with T76 with respect to this character.

l. Plant duration

Wide variation was observed among the okra genotypes under study for plant duration. The lowest (84 days) and the highest (130 days) durations were exhibited by T68 and T101 respectively. The duration of T77, T99 and T34 were found to be on par with T101 while most of the other treatments were found to conform to the lowest duration genotypes.

m. Crude fibre content (%)

Among the significantly varying genotypes, T18 had the highest fibre content (3.65 %), which was on par with T34. Fibre content was the lowest in T17 (0.70 %) and it was on par with twelve other treatments.

n. Protein content (g 100g^{-1})

Protein content was the highest (2.50 g) in the fruits of T83 and it was on par with T4, T36, T68 and T85. T29 had the lowest protein content (0.03 g), which showed homogenity with most of the other genotypes.

o. Mucilage content (%)

The highest mucilaginous type was T98 (4.0 %) and it was on par with T48. T26 (0.9 %) had the lowest mucilage content and most of the other types were on par with it.

p. Fruit and shoot borer incidence (%)

Incidence of fruit and shoot borer (Plate 3) was the highest in T4 (41.0 %) and several other genotypes conformed to the highest incidence group being on par with T4. T18 (4.2 %) was the least preferred type by borer and low infestation percentage was noticed for sixteen other genotypes.

q. YVM incidence at 30 DAS

No significant variation was noticed among varieties for the incidence of YVM disease at 30 DAS. Except T28 (1.1), all the genotypes had the minimum score (1.0) indicating the absence of disease symptoms during this stage of crop growth.

r. YVM incidence at 50 DAS

The highest value of disease incidence was noticed for T14 (2.5). Disease score was minimum for 36 genotypes and they were on par with all the other genotypes except six (T14, T24, T51, T63, T81 and T94).

s. YVM incidence at 70 DAS

At 70 DAS, the most susceptible genotype to the disease was T94 (3.7) which was on par with several other treatments. Fourteen treatments were with minimum score (1.0) and these were on par with most of the other treatments.

t. YVM incidence during final harvest

YVM incidence scored during final harvest of the crop revealed that the most susceptible genotype was T94 (4.8) which exhibited homogenity with many other treatments. Highly resistant types with a score of 1.0 *viz.*, T34, T85, T86 and T91 were on par with many of the genotypes which exhibited only very mild symptoms of the disease.

u. Fruit colour

The maximum score of 9 for fruit colour was observed for T15 and T72 whereas T65, T75, T77, T97 and T99 secured the minimum score (1).

v. Fruit pubescence

The highest value of fruit pubescence was observed for T18 (3) and two treatments (T13 and T43) possessed medium value (2) while all the others exhibited minimum value (1) for this trait.

Table 14. Genetic parameters in okra

Sl. No.	Character	PCV	GCV	H^2 (%)	GA (% of mean)
1.	Days to first flower	23.53	20.31	74.49	36.46
2.	Leaf axil bearing first flower	18.36	14.00	58.17	22.10
3.	Leaf area	38.85	34.41	78.46	62.80
4.	Pollen sterility	36.20	25.02	47.76	35.60
5.	Fruits $plant^{-1}$	34.83	33.42	92.06	66.10
6.	Average fruit weight	25.95	22.31	73.94	39.50
7.	Fruit weight $plant^{-1}$	51.35	48.97	90.93	96.19
8.	Fruit length	23.95	21.03	77.12	38.08
9.	Fruit girth	17.25	14.60	71.62	25.36
10.	Ridges $fruit^{-1}$	14.84	13.66	84.75	25.99
11.	Seeds $fruit^{-1}$	23.03	19.20	69.50	32.98
12	Plant duration	9.53	7.26	58.07	11.41
13.	Crude fibre content	28.74	25.37	77.90	46.15
14	Protein content	78.41	66.60	72.14	115.94
15.	Mucilage content	34.68	29.77	74.70	52.63
16.	Fruit and shoot borer incidence	30.69	20.73	45.63	28.86
17.	YVM incidence – final harvest	34.11	21.26	38.87	27.50

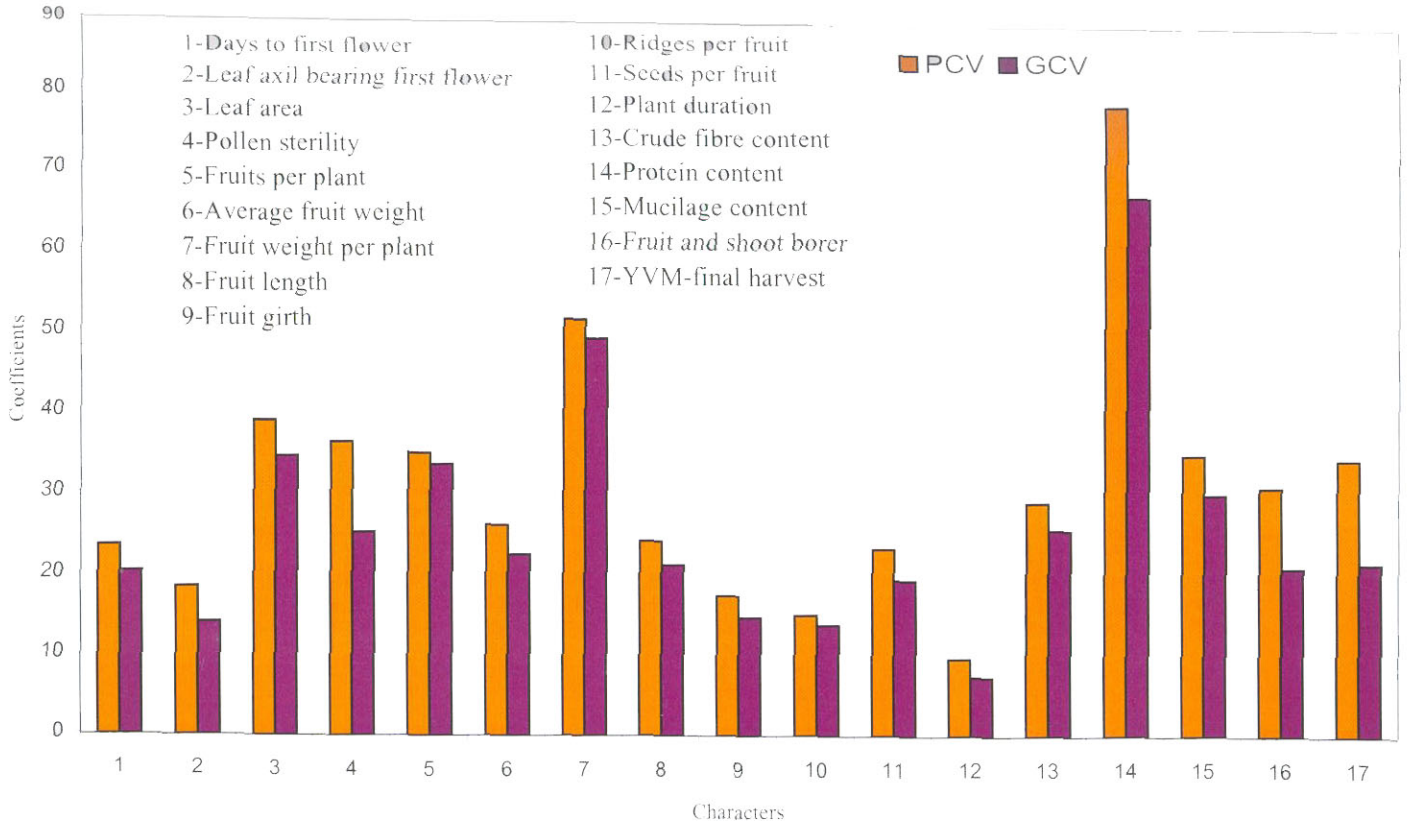


Fig. 2. Phenotypic and genotypic coefficients of variation

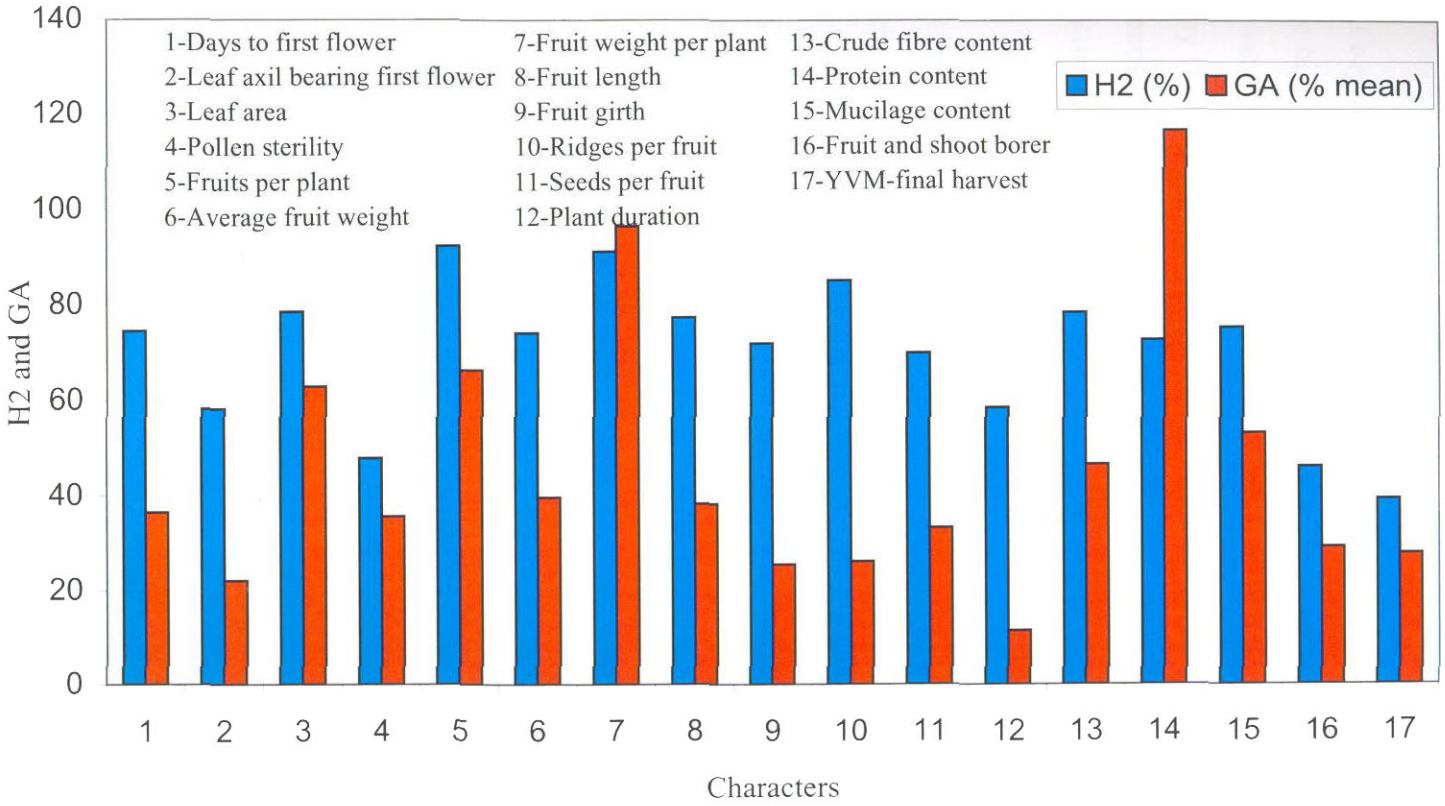


Fig. 3. Heritability and genetic advance

4.1.2.2 Genetic Parameters

The genetic parameters *viz.*, the phenotypic and genotypic coefficients of variation, heritability and genetic advance for each character under study were estimated and are presented in Table 14.

4.1.2.2.1 Coefficients of variation

The highest values of phenotypic as well as genotypic coefficients of variation were observed for protein content (78.41 and 66.60 respectively) followed by fruit weight plant^{-1} (51.35 and 48.97 respectively) (Fig. 2).

Phenotypic and genotypic coefficients of variation were the least for plant duration (9.53 and 7.26 respectively) followed by ridges fruit^{-1} (14.84 and 13.66 respectively).

4.1.2.2.2 Heritability and genetic advance

High heritability (broad sense) was exhibited by majority of the characters (Fig. 3). Very high heritability was exhibited by fruits plant^{-1} (92.06 %), fruit weight plant^{-1} (90.93 %) and ridges fruit^{-1} (84.75 %). The other traits which expressed high heritability were days to first flower, leaf area, average fruit weight, fruit length, fruit girth, seeds fruit^{-1}, and contents of crude fibre, protein and mucilage.

Maximum genetic advance (% mean) was observed for protein content (115.94 %) followed by fruit weight plant^{-1} (96.19 %) and fruits plant^{-1} (Fig. 3). The character with moderate genetic advance was plant duration (11.41 %).

4.1.2.3 Association Analyses

4.1.2.3.1 Correlations

a. Phenotypic correlation

Phenotypic correlation coefficients estimated for the nineteen characters are furnished in Table 15.

Days to first flower had positive association with leaf axil bearing first flower, pollen sterility, plant duration and incidence of fruit and shoot

Table 15. Phenotypic correlation among nineteen characters in okra

Character	Days to first flower	Leaf axil of first flower	Leaf area	Pollen sterility	Fruit plant^{-1}	Average fruit weight	Fruit weight plant^{-1}	Fruit length	Fruit girth	Ridges fruit^{-1}	Seeds fruit^{-1}	Plant duration	Crude fibre	Protein	Mucilage	Fruit and shoot borer	YVM-50 DAS	YVM-70 DAS
Leaf axil	0.68**																	
Leaf area	0.37**	-0.25*																
Pollen sterility	0.32**	0.28**	-0.54**															
Fruits plant^{-1}	-0.50**	-0.43**	0.66**	-0.64**														
Average fruit weight	-0.19	-0.06	0.58**	-0.42**	0.33**													
Fruit weight plant^{-1}	-0.47**	-0.36**	0.73**	-0.64**	0.88**	0.71**												
Fruit length	-0.18	-0.06	0.43**	-0.34**	0.23*	0.73**	0.50**											
Fruit girth	-0.03	0.06	0.26**	-0.30**	0.15	0.47**	0.32**	0.28**										
Ridges fruit^{-1}	0.19	0.24*	0.11	-0.07	-0.01	0.26**	-0.09	0.22*	0.52**									
Seeds fruit^{-1}	-0.02	0.05	0.31**	-0.34**	0.26**	0.35**	0.32**	0.29**	0.45**	0.53**								
Plant duration	0.30**	0.15	0.25*	-0.22*	0.38**	0.16	0.35**	0.11	0.13	0.20*	0.20*							
Crude fibre	0.04	0.12	0.07	-0.02	-0.02	0.06	0.01	-0.01	0.17	0.21*	0.07	0.04						
Protein	-0.06	-0.06	0.25*	-0.20*	0.27**	0.11	0.26**	0.10	0.17	0.04	0.17	0.09	0.07					
Mucilage	0.15	0.04	-0.11	0.08	-0.14	-0.07	-0.13	-0.05	-0.05	-0.10	0.08	0.02	-0.66**	-0.16				
Fruit and shoot borer	0.26**	0.21*	-0.31**	0.24*	-0.34**	-0.32**	-0.41**	-0.19	-0.22*	-0.05	-0.11	-0.17	-0.11	-0.08	0.10			
YVM-50 DAS	-0.01	0.01	-0.05	0.02	-0.03	-0.11	-0.09	-0.15	-0.14	-0.14	-0.06	-0.10	0.01	-0.07	-0.02	0.02		
YVM-70 DAS	0.03	0.02	-0.06	0.05	-0.07	-0.15	-0.15	-0.13	-0.18	-0.14	-0.06	-0.12	-0.09	-0.08	0.04	0.09	0.84**	
YVM-final harvest	0.39**	0.03	-0.12	0.10	-0.14	-0.25*	-0.25*	-0.19	-0.17	-0.17	-0.09	-0.20*	-0.10	-0.09	0.04	0.13	0.75**	0.92**

*-Significant at 5 % level **-Significant at 1 % level

borer and YVM disease during final harvest whereas it was negatively associated with leaf area, fruits and fruit weight plant^{-1}. Positive correlation was noticed for leaf axil bearing first flower with pollen sterility, ridges fruit^{-1} and fruit and shoot borer incidence while its correlation was negative with leaf area, fruits and fruit weight plant^{-1}.

The association of leaf area with number and weight of fruits plant^{-1}, average fruit weight, length, girth, seeds and protein content of fruits and plant duration was positive whereas it was negative with pollen sterility and incidence of fruit and shoot borer. Pollen sterility was associated positively with fruit pubescence and fruit and shoot borer incidence whereas negatively with number, average weight, total weight, length, girth, seeds and protein content of fruits and plant duration.

Positive association was observed for fruits plant^{-1}with average fruit weight, fruit weight plant^{-1}, fruit length, seeds fruit^{-1}, plant duration and protein content and negative association with incidence of fruit and shoot borer. Average fruit weight had positive correlation with fruit weight plant^{-1}, length and girth of fruits and ridges and seeds fruit^{-1} whereas it was negatively associated with incidence of fruit and shoot borer and YVM incidence during final harvest.

Association of fruit weight plant^{-1} with length, girth, seeds and protein content of fruits and plant duration was positive while it was negative with incidence of fruit and shoot borer and YVM disease during final harvest. Fruit length was observed to be correlated positively with fruit girth as well as ridges and seeds fruit^{-1}. Fruit girth followed the same trend of correlations as that of fruit length except in the case of fruit and shoot borer incidence (negative association).

Correlation observed for ridges fruit^{-1} was positive with seeds fruit^{-1}, plant duration and crude fibre content. Seeds fruit^{-1} was associated positively with plant duration alone. Plant duration exhibited negative correlation with YVM incidence during final harvest whereas contents of crude fibre and mucilage were negatively correlated with each other.

Incidence of disease during all the crop stages were positively correlated among themselves.

b. Genotypic correlation

Genotypic correlation coefficients among the nineteen characters were estimated and are presented in Table 16.

Days to first flower was associated significantly and positively with leaf axil bearing first flower, pollen sterility, ridges fruit^{-1}, plant duration, mucilage content and incidence of fruit and shoot borer and negatively with leaf area, fruits plant^{-1}, average fruit weight, fruit weight plant^{-1} and fruit length. Significant positive correlation was recorded for leaf axil bearing first flower with pollen sterility (%), ridges fruit^{-1} and incidence of fruit and shoot borer while it was negatively correlated with leaf area, fruits plant^{-1} and fruit weight plant^{-1}.

Leaf area had significant positive association with fruits plant^{-1}, average fruit weight, fruit weight plant^{-1}, fruit length, fruit girth, seeds fruit^{-1}, plant duration and protein content and significant negative association with pollen sterility, fruit and shoot borer incidence and YVM incidence during final harvest. Correlation of pollen sterility with incidence of fruit and shoot borer was significant and positive whereas it was negative with fruits plant^{-1}, average fruit weight, fruit weight plant^{-1}, fruit length, fruit girth, seeds fruit^{-1}, plant duration and protein content.

Fruits plant^{-1}, average fruit weight and fruit weight plant^{-1} had significant positive association with other fruit characters *viz.*, length, girth and seeds of fruit and plant duration. Moreover, fruit number and fruit weight plant^{-1} showed significant positive correlation with protein content also while average fruit weight had negative correlation also with ridges fruit^{-1}. Fruits plant^{-1} had significant negative association with incidence of fruit and shoot borer as well as YVM at all the stages except at 50 DAS.

Table 16. Genotypic correlation among nineteen characters in okra

Character	Days to first flower	Leaf axil of first flower	Leaf area	Pollen sterility	Fruit plant^{-1}	Average fruit weight	Fruit weight plant^{-1}	Fruit length	Fruit girth	Ridges fruit^{-1}	Seeds fruit^{-1}	Plant duration	Crude fibre	Protein	Mucilage	Fruit and shoot borer incidence	YVM incidence-50 DAS	YVM incidence-70 DAS
Leaf axil	0.77**																	
Leaf area	-0.45**	-0.38**																
Pollen sterility	0.51**	0.45**	-0.83**															
Fruits plant^{-1}	-0.63**	-0.65**	0.73**	-0.92**														
Average fruit weight	-0.31**	-0.15	0.65**	-0.67**	0.42**													
Fruit weight plant^{-1}	-0.60**	-0.55**	0.80**	-0.96**	0.92**	0.72**												
Fruit length	-0.28**	-0.12	0.54**	-0.50**	0.30**	0.82**	0.55**											
Fruit girth	-0.04	0.12	0.30**	-0.50**	0.22*	0.52**	0.35**	0.26**										
Ridges fruit^{-1}	0.27**	0.34**	0.16	-0.18	0.01	-0.33**	0.10	0.28**	0.64**									
Seeds fruit^{-1}	-0.04	0.07	0.43**	-0.46**	0.34**	0.43**	0.40**	0.29**	0.52**	0.63**								
Plant duration	0.33**	0.16	0.37**	-0.45**	0.49**	0.20*	0.43**	0.14	0.16	0.25*	0.28**							
Crude fibre	0.11	0.18	0.05	0.00	-0.01	0.04	0.01	-0.03	0.21*	0.27**	0.04	0.01						
Protein	-0.06	-0.13	0.32**	-0.23*	0.30**	0.14	0.30**	0.15	0.19	0.04	0.23*	0.20*	0.14					
Mucilage	0.20*	0.10	-0.11	0.12	-0.18	-0.04	-0.15	-0.01	-0.06	-0.12	0.02	0.06	-0.69**	-0.21*				
Fruit and shoot borer	0.47**	0.46**	-0.53**	0.70**	-0.57**	-0.46**	-0.63**	-0.28**	-0.28**	-0.03	-0.27**	-0.31**	-0.27**	-0.09	0.21*			
YVM -50 DAS	0.01	0.15	-0.16	-0.06	-0.12	-0.18	-0.16	-0.22*	-0.23*	-0.29**	-0.20	-0.34**	-0.11	-0.08	-0.09	0.10		
YVM-70 DAS	0.05	0.07	-0.17	-0.01	-0.20*	-0.26**	-0.28**	-0.22*	-0.31**	-0.23*	-0.16	-0.36**	-0.19	-0.11	-0.05	0.27**	0.92**	
YVM-final harvest	0.11	0.11	-0.29**	0.14	-0.32**	-0.39**	-0.42**	-0.32**	-0.28**	-0.25*	-0.16	-0.47**	-0.20*	-0.11	-0.03	0.26**	0.81**	0.94**

*-Significant at 5 % level **-Significant at 1 % level

Length and girth of fruit were correlated significantly and positively with each other and also with ridges and seeds fruit^{-1} whereas negatively correlated with incidence of fruit and shoot borer as well as YVM at 50 DAS, 70 DAS and final harvest. Fruit girth displayed significant positive correlation with fibre content also.

Ridges fruit^{-1} showed significant positive correlation with seeds fruit^{-1}, crude fibre content and plant duration but negative correlation with YVM incidence at all the three stages. Significant positive association was observed for seeds fruit^{-1} with plant duration and protein content whereas it had negative correlation with incidence of fruit and shoot borer.

Plant duration was observed to be correlated significantly and positively with protein content while negatively with incidence of fruit and shoot borer and YVM disease (at all the three stages). Crude fibre content showed negative association with mucilage content and incidence of fruit and shoot borer as well as YVM during final harvest.

Protein content exhibited significant negative correlation with mucilage content which had significant positive association with incidence of fruit and shoot borer.

Incidence of fruit and shoot borer exhibited significant positive association with YVM incidence at 70 DAS as well as during final harvest. YVM incidence at 50 DAS, 70 DAS and final harvest were associated significantly and positively among themselves.

c. Environmental correlation

Environmental correlation coefficients were estimated for the nineteen characters and are presented in Table 17.

Days to first flower had positive correlation with leaf axil bearing first flower and plant duration. Leaf axil bearing first flower was correlated positively with number as well as weight of fruits plant^{-1}.

For leaf area, positive association was noticed with the three important yield traits *viz.*, fruits, average fruit weight and fruit weight

Table 17. Environmental correlation among nineteen characters in okra

Character	Days to first flower	Leaf axil of first flower	Leaf area	Pollen sterility	Fruit plant^{-1}	Average fruit weight	Fruit weight plant^{-1}	Fruit length	Fruit girth	Ridges fruit^{-1}	Seeds fruit^{-1}	Plant duration	Crude fibre	Protein	Mucilage	Fruit and shoot borer	YVM-50 DAS	YVM-70 DAS
Leaf axil	0.53																	
Leaf area	0.12	0.03																
Pollen sterility	0.06	0.09	-0.10															
Fruits plant^{-1}	0.11	0.24	0.27	-0.13														
Average fruit weight	0.14	0.11	0.35	-0.07	-0.14													
Fruit weight plant^{-1}	0.17	0.21	0.44	-0.05	0.43	0.74												
Fruit length	0.12	0.09	0.08	-0.10	-0.18	0.46	0.29											
Fruit girth	0.01	-0.06	0.13	-0.02	-0.14	0.33	0.21	0.33										
Ridges fruit^{-1}	-0.12	0.07	-0.09	0.16	0.01	-0.04	-0.01	-0.04	0.07									
Seeds fruit^{-1}	0.01	-0.01	-0.03	-0.19	-0.06	0.15	0.02	0.27	0.30	0.20								
Plant duration	0.24	0.15	-0.01	0.04	0.11	0.07	0.19	0.05	0.08	0.10	0.08							
Crude firbre	-0.17	-0.02	0.10	0.05	-0.08	0.12	0.04	0.05	0.05	-0.03	0.17	0.14						
Protein	-0.05	0.07	0.04	-0.18	0.18	0.28	0.07	-0.05	0.13	0.07	0.01	-0.11	-0.15					
Mucilage	-0.01	-0.08	-0.09	0.02	0.08	-0.15	-0.09	-0.17	-0.04	-0.03	-0.04	-0.06	-0.57	-0.03				
Fruit and shoot borer	-0.04	0.06	0.01	-0.17	0.14	-0.15	-0.03	-0.08	-0.17	-0.11	0.09	-0.02	0.16	-0.08	-0.07			
YVM -50 DAS	-0.04	-0.11	0.07	0.07	0.11	-0.06	-0.04	-0.10	0.07	0.01	0.06	0.07	0.16	-0.08	0.05	-0.02		
YVM-70 DAS	0.00	-0.03	0.11	0.08	0.24	-0.03	0.08	-0.02	-0.04	-0.03	0.05	0.09	0.05	-0.04	0.17	0.04	0.80	
YVM -final harvest	-0.04	-0.04	0.10	0.07	0.24	-0.11	0.00	-0.04	-0.07	-0.09	-0.00	0.04	0.03	-0.08	0.14	0.03	0.73	0.91

plant^{-1}. Fruit number exhibited positive association with fruit weight plant^{-1} and YVM incidence at 70 DAS and during final harvest while average fruit weight had positive association with fruit weight plant^{-1} and length, girth and protein content of fruits.

Weight of fruits plant^{-1} was associated positively with length and girth of fruits. Besides being positively correlated with each other, association of fruit length and fruit girth with seeds fruit^{-1} also were positive. Ridges and seeds fruit^{-1} had positive association with each other.

The only negative environmental association observed was between the contents of crude fibre and mucilage of fruits. YVM incidence at all the crop stages were correlated positively among themselves.

4.1.2.3.2 Path analysis

The characters which exhibited high correlation with fruit weight plant^{-1} (yield) were selected for path coefficient analysis. The direct and indirect effects of selected thirteen component characters on fruit yield were estimated and are presented in Table 18.

Days to first flower had the highest negative direct effect (-1.067) with yield. The highest positive indirect effect was exerted through plant duration (0.439) followed by pollen sterility (0.418). Negative indirect effect was maximum through leaf axil bearing first flower (-0.325) and the minimum through protein content (-0.001).

Leaf axil bearing first flower had negative direct effect (-0.422) with yield. Negative indirect effect was the highest through days to first flower (-0.823) followed by average fruit weight (-0.117) while the lowest was through protein content (-0.001). Maximum and minimum positive indirect effects were exerted through pollen sterility (0.368) and seeds fruit^{-1} (0.004) respectively.

Positive direct effect (0.106) was exerted by leaf area on yield. The highest positive indirect effect was through average fruit weight (0.522) followed by plant duration (0.494), days to first flower (0.482), leaf axil

Table 18. Path analysis

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	X_{11}	X_{12}	X_{13}	Total correlation coefficient
X_1	**-1.067**	-0.325	-0.048	0.418	0.052	-0.247	0.036	-0.015	-0.002	0.439	-0.001	0.101	0.060	-0.599
X_2	-0.823	**-0.422**	-0.040	0.368	0.054	-0.117	0.016	0.040	0.004	0.206	-0.001	0.100	0.061	-0.554
X_3	0.482	0.159	**0.106**	-0.682	-0.061	0.522	-0.068	0.103	0.022	0.494	0.003	-0.115	-0.167	0.798
X_4	-0.543	-0.189	-0.088	**0.823**	0.077	-0.535	0.064	-0.170	-0.023	-0.598	-0.002	0.150	0.980	-0.954
X_5	0.669	0.272	0.077	-0.759	**-0.083**	0.340	-0.038	0.073	0.017	0.654	0.003	-0.123	-0.182	0.920
X_6	0.328	0.061	0.069	-0.548	-0.035	**0.803**	-0.104	0.177	0.022	0.271	0.002	-0.098	-0.223	0.725
X_7	0.296	0.052	0.057	-0.409	-0.025	0.656	**-0.128**	0.089	0.015	0.183	0.002	-0.060	-0.180	0.548
X_8	0.046	-0.050	0.032	-0.411	-0.018	0.419	-0.033	**0.340**	0.026	0.215	0.002	-0.060	-0.157	0.351
X_9	0.037	-0.033	0.045	-0.376	-0.028	0.345	-0.037	0.177	**0.051**	0.368	0.002	-0.057	-0.093	0.401
X_{10}	-0.351	-0.065	0.039	-0.369	-0.041	0.163	-0.018	0.055	0.014	**1.334**	0.002	-0.068	-0.265	0.430
X_{11}	0.068	0.054	0.034	-0.191	-0.025	0.114	-0.019	0.064	0.012	0.270	**0.010**	-0.020	-0.063	0.308
X_{12}	-0.500	-0.195	-0.056	0.572	0.047	-0.366	0.035	-0.094	-0.014	-0.419	-0.001	**0.215**	0.147	-0.629
X_{13}	-0.112	-0.045	-0.031	0.115	0.027	-0.316	0.041	-0.094	-0.008	-0.623	-0.001	0.056	**0.568**	-0.423

R^2-0.052 Values on principal diagonal are direct effects

X_1 - Days to first flower
X_2 - Leaf axil bearing first flower
X_3 - Leaf area
X_4 - Pollen sterility
X_5 - Fruits plant^{-1}
X_6 - Average fruit weight
X_7 - Fruit length
X_8 - Fruit girth
X_9 - Seeds fruit^{-1}
X_{10} - Plant duration
X_{11} - Protein content
X_{12} - Fruit and shoot borer incidence
X_{13} - YVM incidence during final harvest

bearing first flower (0.159) and fruit girth (0.103) while the lowest was through protein content (0.003). Negative indirect effect was maximum through pollen sterility (-0.682) and minimum through fruits plant^{-1} (-0.061).

Pollen sterility exerted positive direct effect (0.823) on yield. Negative indirect effects were exerted mainly through plant duration (-0.598), days to first flower (-0.543), average fruit weight (-0.535), leaf axil bearing first flower (-0.189) and fruit girth (-0.170), the minimum being through protein content (-0.002).

The direct effect manifested by fruits plant^{-1} on yield was in negative direction (-0.083). The highest positive indirect effect was exerted through days to first flower (0.669) followed by plant duration (0.654), average fruit weight (0.340) and leaf axil bearing first flower (0.272) while the highest and the lowest negative indirect effects were through pollen sterility (-0.759) and fruit length (-0.038).

Average fruit weight exerted positive direct effect (0.803) on yield. The highest positive indirect effect was manifested through days to first flower (0.328) followed by plant duration (0.271) and fruit girth (0.177) and the lowest was through protein content (0.002) whereas the maximum and minimum negative indirect effects were through pollen sterility (-0.548) and fruits plant^{-1} (-0.035).

The direct effect on yield by fruit length was negative (-0.128). Positive indirect effect was exerted mainly through average fruit weight (0.656), days to first flower (0.296) and plant duration (0.183) while the highest negative indirect effect was through pollen sterility (-0.409).

Fruit girth exerted positive direct effect (0.340) on yield. The highest positive indirect effect was exerted through average fruit weight (0.419), followed by plant duration (0.215) and the lowest was through protein content (0.002) whereas the maximum and minimum negative indirect effects were through pollen sterility (-0.411) and fruits plant^{-1} (-0.018) respectively.

Positive direct effect (0.051) was noticed for seeds fruit^{-1} on yield. Among its positive indirect effects, maximum was through plant duration (0.368) followed by average fruit weight (0.345) and minimum was through protein content (0.002). Negative indirect effect was maximum through pollen sterility (-0.376) and minimum through fruits plant^{-1} (-0.028).

Plant duration exerted the highest positive direct effect (1.334) on yield. Its negative indirect effect was the highest through pollen sterility (-0.369) followed by days to first flower (-0.351) and YVM incidence during final harvest (-0.265) and the lowest was through fruit length (-0.018). The maximum and minimum positive indirect effects were exerted through average fruit weight (0.163) and protein content (0.002).

The direct effect (0.010) exerted by protein content on yield was positive and the lowest among all the component traits. Among the positive indirect effects, the highest was through plant duration (0.270) followed by average fruit weight (0.114). Manifestation of negative indirect effect was maximum through pollen sterility (-0.191) and minimum through fruit length (-0.019).

Incidence of fruit and shoot borer had positive direct effect (0.215) on yield. Negative indirect effect was the highest through days to first flower (-0.500) followed by plant duration (-0.419), average fruit weight (-0.366) and leaf axil bearing first flower (-0.195), the minimum being through protein content (-0.001). Maximum and minimum positive indirect effects were through pollen sterility (0.572) and fruit length (0.035) respectively.

Positive direct effect (0.568) was exerted by YVM incidence during final harvest on yield. Most of the indirect effects were in negative direction, with the highest being through plant duration (-0.623) followed by average fruit weight (-0.316), days to first flower (-0.112) and fruit girth (-0.094) and the lowest was through protein content (-0.001). Positive indirect effect was maximum through pollen sterility (0.115) and minimum through fruits plant^{-1} (0.027).

4.2.2.4 Selection Index

Selection indices were estimated for 101 genotypes (Table 19) based on yield and thirteen component characters which exhibited high correlation with yield (fruit weight.plant^{-1}) in the desirable direction.

The component characters considered for formulating the selection index were days to first flower, leaf axil bearing first flower, leaf area, pollen sterility, fruit number, average fruit weight, fruit length, fruit girth, seed number, plant duration, protein content, incidence of fruit and shoot borer and YVM during final harvest.

Among the genotypes under evaluation, T83 (1318.49) ranked first with the highest index value, followed by T86, T85, T37, T82, T15, T16, T34, T78 and T61. The most inferior genotypes with the lowest selection index value was T10 (430.87).

From the superior genotypes with high selection indices, eight types (Plate 7) were selected for hybridisation programme to develop F_1 hybrids. Among these, five types (T83, T37, T82, T15 and T16) belonging to the high yielding and YVM susceptible category were used as female parents (lines) and the remaining three (T86, T85 and T34) which were highly resistant to YVM were taken as male parents (testers).

4.2.2.5 Confirmation of disease resistance

4.2.2.5.1 Grafting

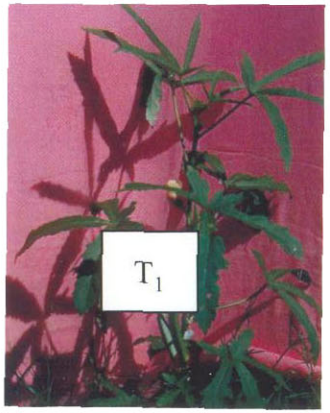
Disease resistance in the highly resistant genotypes and hybrids was confirmed by grafting them on susceptible root stock. No symptom could be noticed on the subsequent growth of the scion in all the cases.

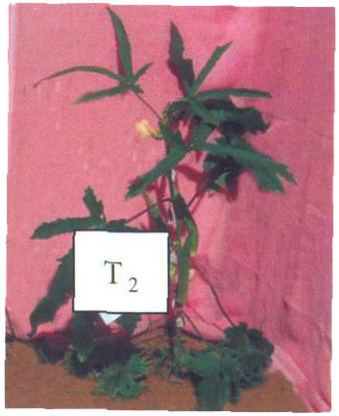
4.2.2.5.2 Vector transmission

Artificial feeding on the highly resistant plants was carried out using viruliferous white flies (Plate 8). The plants did not develop any symptom even one month after inoculation.

Table 19.Selection indices for 101 genotypes

Genotypes	Rank	Index value	Genotypes	Rank	Index value	Genotypes	Rank	Index value
1	63	648.07	41	61	656.96	81	25	834.43
2	75	607.72	42	48	733.14	82	5	1195.00
3	80	584.38	43	65	640.25	83	1	1318.49
4	82	572.74	44	60	657.62	84	27	829.30
5	91	532.38	45	92	522.94	85	3	1291.90
6	87	547.83	46	38	760.34	86	2	1314.14
7	96	498.84	47	40	754.12	87	50	724.49
8	98	491.24	48	14	950.44	88	26	829.96
9	97	497.56	49	99	488.49	89	37	778.19
10	101	430.87	50	93	512.63	90	13	958.31
11	89	542.31	51	36	780.37	91	33	805.36
12	34	802.07	52	41	751.23	92	21	865.58
13	57	681.47	53	46	734.01	93	17	906.11
14	72	616.86	54	78	588.87	94	51	722.95
15	6	1187.16	55	22	853.86	95	16	916.32
16	7	1177.14	56	44	736.65	96	67	636.70
17	54	702.88	57	32	810.86	97	62	655.39
18	95	508.16	58	100	443.32	98	43	738.49
19	81	579.68	59	84	562.52	99	86	549.49
20	79	585.73	60	76	600.85	100	59	664.42
21	39	759.17	61	10	1037.59	101	29	818.66
22	55	689.46	62	31	811.75			
23	70	626.77	63	68	633.48			
24	69	630.12	64	58	670.34			
25	83	565.72	65	15	949.77			
26	77	590.24	66	56	684.49			
27	90	538.74	67	47	733.51			
28	88	547.56	68	49	725.35			
29	94	512.51	69	64	641.74			
30	85	560.11	70	45	735.08			
31	71	618.12	71	52	720.43			
32	12	967.85	72	11	992.23			
33	53	705.78	73	74	608.02			
34	8	1174.52	74	66	640.16			
35	20	869.69	75	73	611.92			
36	19	895.63	76	24	834.60			
37	4	1207.58	77	42	740.28			
38	28	826.80	78	9	1061.42			
39	35	783.67	79	30	816.55			
40	23	835.67	80	18	900.27			





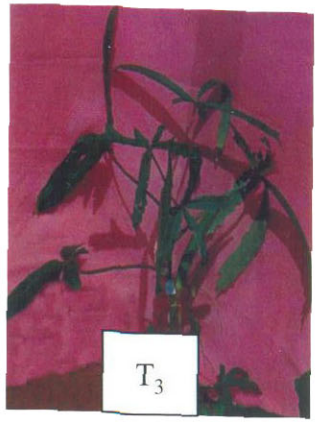


Plate 7. Selected lines and testers

L_1-NBPGR/TCR-2020
L_2-NBPGR/TCR-1498
L_3- NBPGR/TCR-2019
L_4- MDU-1
L_5- NBPGR/TCR-985
T_1-NBPGR/TCR-2060
T_2-Parbhani Kranti
T_3-Varsha Uphar

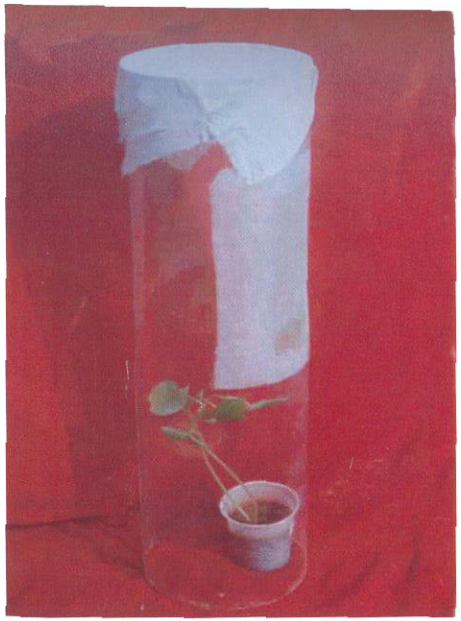


Plate 8. Artificial inoculation of YVM

a.Susceptible genotype

b.Resistant genotype

Plate 9. Difference in leaf pubescence

Table 20. Phenol content in selected parents

Sl. No	Parent	Disease reaction	Phenol content (mg $100g^{-1}$)
Lines			
L_1	NBPGR/TCR-2020 (T15)	Susceptible (S)	2
L_2	NBPGR/TCR –1498 (T16)	S	1
L_3	NBPGR/TCR-2019(T37)	S	5
L_4	MDU-1(T82)	S	2
L_5	NBPGR/TCR-985(T83)	S	3
Testers			
T_1	NBPGR/TCR-2060 (T34)	Resistant (R)	24
T_2	Parbhani Kranti(T85)	R	21
T_3	Varsha Uphar(T86)	R	20

4.2.2.5.3 Leaf pubescence

Leaf pubescence of highly resistant and susceptible genotypes was observed using digital microscope (Plate 9). The number and length of leaf hairs were more in highly resistant types than the susceptible ones.

4.2.2.5.4 Phenol Content in Parents

Phenol content in the leaves of selected parents were estimated and the results are presented in Table 20.

The susceptible types (lines) recorded lower content of phenol compared to resistant types (testers). Among the lines, L_3 (5 mg) and L_2 (1 mg) possessed the maximum and minimum phenol content respectively.

Testers exhibited higher phenol content. The highest value was observed for T_1 (24 mg) whereas the lowest value was for T_3 (20 mg).

4.2 LINE X TESTER ANALYSIS

Results of line x tester analysis are presented in Table 21. Significant variation was observed among treatments for all the characters studied.

Parents varied significantly with respect to all traits except days to first flower and plant duration while crosses had significant variation except for YVM incidence at various stages. Interaction effect of parents and hybrids was significant for traits other than leaf area, fruits plant^{-1}, ridges fruit^{-1} and plant duration.

Line x tester interaction mean square was significant for most of the characters. However, non-significance was observed with respect to YVM incidence at various stages. Lines varied significantly for leaf axil bearing first flower and ridges fruit^{-1} while testers exhibited significant variation for leaf axil bearing first flower.

Table 21. ANOVA for line x tester analysis in okra

Source	Df	Mean square														
		Days to first flower	Leaf axil bearing first flower	Leaf area	Pollen sterility	Fruits plant^{-1}	Average fruit weight	Fruit weight plant^{-1}	Fruit length	Fruit girth	Ridges fruit^{-1}	Seeds fruit^{-1}	Plant duration	Fruit and shoot borer incidence	YVM incidence		
															50 DAS	70 DAS	Final harvest
Replications	2	71.19**	0.11	80.00	11.90	0.26	6.10	1228.75	4.87*	0.38	0.25	90.84	35.06	6.60	0.01	0.04	0.03
Treatments	22	80.34**	0.86**	2973.68**	40.95**	2.31**	91.73**	16046.14**	17.17**	0.70**	4.10**	416.27**	258.67**	32.87**	0.02*	0.32**	1.91**
Parents	7	21.57	0.93**	3988.38**	35.11**	1.89**	53.45**	8987.29**	5.32**	0.38*	4.66**	206.22**	24.61	7.51*	0.03*	0.50**	2.97**
Crosses	14	99.96**	0.67**	2639.25**	44.04**	2.66**	110.36**	19625.95**	23.67**	0.66**	3.98**	264.40**	392.56**	36.91**	0.00	0.01	0.03
Parents x crosses	1	217.02**	2.96**	552.88	41.43**	0.23	98.87**	15340.75**	9.06*	3.58**	1.93	4012.85**	22.56	153.74**	0.18**	3.33**	20.92**
Lines	4	100.07	2.00**	4205.00	82.04	1.54	236.99	36476.81	23.94	0.47	13.57**	196.15	116.65	53.59	0.00	0.01	0.02
Testers	2	82.38	0.37*	1101.00	27.59	1.70	47.73	9728.63	4.86	0.15	0.08	180.11	325.69	40.57	0.00	0.01	0.02
Lines x Testers	8	104.30**	0.08	2240.94**	28.78**	3.46**	62.70**	13674.84**	28.24**	0.88**	0.16	319.60**	547.24**	27.66**	0.00	0.01	0.03
Error	44	10.29	0.07	250.41	4.17	0.27	2.62	385.76	1.29	0.14	0.09	37.80	30.90	2.50	0.01	0.04	0.12

*-Significant at 5 % level **-Significant at 1 % level

4.2.1 *Per se* Performance of Parents and Hybrids

Per se performance of five lines, three testers and their fifteen hybrids with respect to nineteen characters is presented in Tables 22 and 23.

a. Days to first flower

The earliest flowering line and tester were L_2 (45.37 days) and T_3 (51.17 days) respectively while L_1 (49.57 days) and T_1 (53.40 days) took maximum days for flowering within their respective groups. Among the hybrids minimum days for flowering was observed for $L_3 \times T_2$ (42.27 days) which was on par with $L_2 \times T_1$ (44.00 days) whereas the maximum days was recorded for $L_3 \times T_3$ (62.77 days).

b. Leaf axil bearing first flower

L_5 (4.80) and L_1 (6.50) possessed the lowest and the highest leaf axils bearing first flower respectively among lines while these positions among testers were occupied by T_3 (4.80) and T_1 (5.27) respectively. Minimum value of this trait among hybrids was observed for $L_2 \times T_1$ (5.00) and it was on par with $L_2 \times T_2$ (5.13), $L_5 \times T_2$ (5.20), $L_3 \times T_2$ (5.23) and $L_5 \times T_1$ (5.33) where as maximum value was exhibited by $L_1 \times T_1$ (6.53).

c. Leaf area

Leaf area was maximum for L_3 (317.50 cm^2) and minimum for L_4 (211.83cm^2) among lines while these positions among testers were occupied by T_3 (232.03 cm^2) and T_2 (202.33 cm^2) respectively. The highest leaf area was noticed for $L_2 \times T_1$ (296.17 cm^2) which was homogeneous with $L_3 \times T_2$ (283.60 cm^2) and $L_3 \times T_3$ (278.77 cm^2) among hybrids while the lowest value was for $L_5 \times T_3$ (201.20 cm^2).

d. Pollen sterility

Minimum and maximum values of pollen sterility were observed respectively for L_2 (9.48 %) and L_3 (19.17 %) among lines and for T_3 (15.14 %) and T_1 (17.43 %) for testers. When the hybrids were considered. the lowest pollen sterility was recorded for $L_5 \times T_1$ (8.46 %) whereas L_5 X

Table 22. *Per se* performance of parents for nineteen characters

Parents	Days to first flower	Leaf axil bearing of first flower	Leaf area cm^2	Pollen sterility, %	Fruits plant^{-1}	Average fruit weight, g	Fruit weight plant^{-1}, g	Fruit length, cm	Fruit girth, cm	Ridges fruit^{-1}	Seeds fruit^{-1}	Plant duration	Fruit and shoot borer incidence, %	YVM incidence				Fruit colour	Fruit pubescence
														30 DAS	50 DAS	70 DAS	Final harvest		
Lines																			
L_1	49.57	6.50	223.10	10.32	10.33	15.33	158.20	11.17	6.02	8.56	72.33	105.67	14.76	1.00	1.13	1.80	2.93	9.00	1.00
L_2	45.37	5.13	253.13	9.48	9.93	24.17	239.08	16.70	6.37	5.00	63.43	111.83	14.02	1.00	1.27	1.83	3.13	2.00	1.00
L_3	48.60	5.33	317.50	19.17	8.60	22.37	192.00	16.27	6.28	5.07	52.80	109.27	15.97	1.00	1.20	1.80	3.00	2.00	1.00
L_4	47.03	4.87	211.83	16.85	10.33	25.70	266.07	17.53	6.37	5.00	50.62	107.03	14.70	1.00	1.13	1.67	2.73	2.00	1.00
L_5	48.30	4.80	227.93	15.42	10.57	27.40	289.38	18.57	6.37	5.10	60.83	106.77	14.22	1.00	1.20	1.67	2.73	7.00	1.00
Mean	47.77	5.33	246.70	14.25	9.95	22.99	228.95	16.05	6.28	5.75	60.00	108.11	14.73	1.00	1.19	1.77	2.90	4.00	1.00
SE	1.07	0.09	5.27	0.68	0.17	0.54	6.55	0.38	0.13	0.10	2.05	1.85	0.53	1.00	0.03	0.07	0.12	4.00	-
CD 5%	2.27	0.19	11.19	1.44	0.37	1.15	13.87	0.80	0.27	0.21	4.35	3.93	1.12	-	0.07	0.14	0.25	-	-
CD 1%	3.05	0.25	15.03	1.94	0.49	1.54	18.67	1.08	0.36	0.29	5.84	5.28	1.50	-	0.09	0.19	0.33	-	-
Testers																			
T_1	53.40	5.27	215.80	17.43	10.97	25.37	278.22	17.62	5.54	5.07	48.07	114.13	12.12	1.00	1.00	1.00	1.00	2.00	1.00
T_2	52.13	5.07	202.33	16.63	11.13	28.17	314.20	18.72	5.73	5.00	51.93	109.80	13.27	1.00	1.00	1.00	1.00	2.00	1.00
T_3	51.17	4.80	232.03	15.14	10.73	27.97	300.05	17.93	5.63	5.00	51.67	107.47	17.29	1.00	1.00	1.00	1.00	2.00	1.00
Mean	52.23	5.05	216.72	16.40	10.94	27.17	297.49	18.09	5.63	5.02	50.56	110.47	14.23	1.00	1.00	1.00	1.00	2.00	1.00
SE	0.83	0.07	4.09	0.53	0.13	0.42	5.07	0.29	0.10	0.08	1.59	1.44	0.41	-	0.03	0.05	0.09	-	-
CD 5%	1.76	0.14	8.67	1.12	0.28	0.89	10.77	0.62	0.21	0.17	3.37	3.04	0.87	-	0.05	0.11	0.19	-	-
CD 1%	2.36	0.19	11.64	1.50	0.38	1.19	14.45	0.84	0.28	0.22	4.52	4.09	1.16	-	0.07	0.15	0.26	-	-

Table 23. *Per se* performance of hybrids for nineteen characters

Hybrids	Days to first flower	Leaf axil bearing of first flower	Leaf area, cm^2	Pollen sterility, %	Fruits $plant^{-1}$	Average fruit weight, g	Fruit weight $plant^{-1}$, g	Fruit length, cm	Fruit girth, cm	Ridges $fruit^{-1}$	Seeds $fruit^{-1}$	Plant duration	Fruit and shoot borer incidence, %	YVM incidence				Fruit colour	Fruit pubes-cence
														30 DAS	50 DAS	70 DAS	Final har-vest		
L_1XT_1	54.20	6.53	225.57	15.75	9.40	24.40	229.15	14.46	5.47	8.13	46.00	95.13	8.11	1.0	1.0	1.0	1.0	9.00	1.00
L_1XT_2	59.47	6.37	207.87	17.31	9.67	15.73	152.57	11.96	5.08	7.75	35.90	103.87	12.26	1.0	1.07	1.13	1.2	9.00	1.00
L_1XT_3	55.80	6.43	216.90	18.54	10.65	15.87	169.16	12.90	5.12	8.11	49.42	117.17	16.49	1.0	1.0	1.0	1.0	9.00	1.00
L_2XT_1	44.00	5.00	296.17	9.17	11.43	34.24	391.43	20.24	6.44	5.53	62.48	122.97	8.49	1.0	1.0	1.0	1.0	2.00	1.00
L_2XT_2	49.30	5.13	262.57	10.44	10.42	29.60	308.04	16.32	5.54	5.47	44.57	114.10	9.04	1.0	1.0	1.0	1.0	2.00	1.00
L_2XT_3	51.11	5.50	224.90	12.89	9.87	22.59	222.62	13.25	5.23	5.43	33.48	85.60	13.42	1.0	1.07	1.2	1.33	2.00	1.00
L_3XT_1	62.13	5.60	237.57	21.53	8.23	21.29	175.02	12.71	4.69	5.63	28.57	91.83	7.13	1.0	1.0	1.0	1.0	2.00	1.00
L_3XT_2	42.27	5.23	283.60	12.31	11.27	30.62	344.30	17.39	6.35	5.42	46.07	116.27	8.28	1.0	1.0	1.0	1.0	2.00	1.00
L_3XT_3	62.77	5.77	278.77	13.49	10.93	25.92	283.37	15.95	5.71	5.17	35.33	101.80	9.29	1.0	1.0	1.0	1.0	2.00	1.00
L_4XT_1	52.00	5.73	202.43	16.19	10.87	27.41	298.22	16.67	5.85	5.08	42.12	107.77	15.71	1.0	1.0	1.0	1.0	2.00	1.00
L_4XT_2	52.37	5.60	238.13	10.48	11.17	32.18	358.97	15.33	5.62	5.00	29.80	110.57	9.53	1.0	1.0	1.0	1.0	2.00	1.00
L_4XT_3	51.50	5.67	242.60	12.45	10.77	33.14	356.86	16.73	5.92	5.00	44.39	116.87	8.91	1.0	1.0	1.0	1.0	2.00	1.00
L_5XT_1	51.93	5.33	244.83	8.46	11.00	33.03	363.61	16.34	5.33	5.00	42.26	117.50	14.10	1.0	1.0	1.0	1.0	2.00	1.00
L_5XT_2	51.60	5.20	257.87	8.78	11.61	32.50	377.14	19.05	5.72	5.63	40.61	119.13	12.07	1.0	1.0	1.0	1.0	2.00	1.00
L_5XT_3	57.10	5.73	201.20	13.65	9.40	27.57	358.89	14.67	5.33	5.00	25.57	96.37	18.34	1.0	1.0	1.0	1.0	2.00	1.00
Mean	53.17	5.65	241.40	13.43	10.45	27.07	285.96	15.60	5.56	5.82	40.45	107.80	11.41	1.0	1.0	1.02	1.04	3.40	1.00
SE	1.85	0.15	9.14	1.18	0.30	0.94	11.34	0.66	0.22	0.17	3.55	3.21	0.91	-	0.06	0.12	0.20	-	-
CD 5%	3.92	0.32	19.38	2.50	0.63	1.98	24.05	1.39	0.47	0.37	7.53	6.81	1.94	-	0.12	0.25	0.43	-	-
CD 1%	5.28	0.43	26.04	3.36	0.85	2.67	32.31	1.87	0.63	0.50	10.12	9.15	2.60	-	0.16	0.33	0.58	-	-

T_2 (8.78 %), L_2 x T_1 (9.17 %), L_2 x T_2 (10.44 %) and L_4 x T_2 (10.48 %) were on par with it and the highest per cent of sterile pollen grains was in L_3 x T_1 (21.53 %).

e. Fruits plant^{-1}

Among lines, the highest and the lowest number of fruits plant^{-1} was noticed for L_5 (10.57) and L_3 (8.60) respectively . T_2 (11.13) and T_3 (10.73) produced the maximum and minimum number of fruits among testers. The best hybrid with respect to fruit production was L_5 x T_2 (11.61) which was on par with L_2 x T_1 (11.43), L_3 x T_2 (11.27), L_4 x T_2 (11.17) L_5 x T_1 (11.00), L_3 x T_3 (10.93) L_4 x T_1 (10.87) and L_4 x T_3 (10.77) whereas the lowest producer was L_3 x T_1 (8.23).

f. Average fruit weight

Among the lines, L_5 (27.40 g) had the highest average fruit weight while L_1 (15.33 g) had the lowest value. T_2 (28.17g) and T_1 (25.37 g) respectively were the testers which possessed the maximum and minimum values within their group. Average fruit weight among hybrids was maximum for L_2 x T_1 (34.24 g) which was on par with L_4 x T_3 (33.14 g), L_5 x T_1 (33.03 g), L_5 x T_2 (32.50 g) and L_4 x T_2 (32.18 g) while it was minimum for L_1 x T_2 (15.73 g).

g. Fruit weight plant^{-1}

The best yielding line and tester were L_5 (289.38 g) and T_2 (314.20 g) respectively while L_3 (192.00 g) and T_1 (278.22 g) were the lowest yielders among their respective groups. Fruit weight plant^{-1} among the hybrids was maximum for L_2 x T_1 (391.43 g) which was homogeneous with L_5 x T_2 (377.14 g) and L_5 x T_1 (363.61 g) whereas the minimum yielding hybrid was L_1 x T_2 (152.57 g).

h. Fruit length

The lines which produced the longest and the shortest fruits were L_5 (18.57 cm) and L_1 (11.17 cm) respectively while among testers, these

positions were occupied by T_2 (18.72 cm) and T_1 (17.62 cm) respectively. Fruit length among the hybrids was maximum for $L_2 \times T_1$ (20.24 cm), which was on par with $L_5 \times T_2$ (19.05 cm), and minimum observed was for $L_1 \times T_2$ (11.96 cm).

i. Fruit girth

Fruit girth was maximum for three lines *viz.*, L_2, L_4 and L_5 (6.37 cm) while minimum value was for L_1 (6.02 cm). Among testers, T_2 (5.73 cm) and T_1 (5.54 cm,) respectively possessed the highest and the lowest values for this character. The hybrid with maximum fruit girth was $L_2 \times T_1$ (6.44 cm) and the crosses $L_3 \times T_2$ (6.35 cm), $L_4 \times T_3$ (5.92 cm) and $L_4 \times T_1$ (5.85 cm) were on par with it while minimum fruit girth was displayed by $L_3 \times T_1$ (4.69 cm).

j. Ridges fruit^{-1}

Maximum ridges fruit^{-1} was displayed by L_1 (8.56) among lines while L_2, L_4, T_2 and T_3 had the minimum ridges (5.00). Among the hybrids, crosses involving L_1 had high values with $L_1 \times T_1$ being the highest (8.13) which was homogeneous with $L_1 \times T_3$ (8.11) and $L_1 \times T_2$ (7.75). Minimum value (5.00) was observed for $L_4 \times T_2$, $L_4 \times T_3$, $L_5 \times T_1$ and $L_5 \times T_3$.

k. Seeds fruit^{-1}

L_1 (72.33) and L_4 (50.62) were the lines with maximum and minimum seeds per fruit respectively while among testers, T_2 (51.93) and T_1 (48.07) were with the highest and lowest values in the respective order. Considering the hybrids, maximum seeds fruit^{-1} was produced by $L_2 \times T_1$ (62.48) whereas $L_5 \times T_3$ (25.57) had the minimum.

l. Plant duration

Plant duration was the shortest and the longest for L_1 (105.70 days) and L_2 (111.83 days) among lines, T_3 (107.47 days) and T_1 (114.13 days) among testers and $L_2 \times T_3$ (85.60 days) and $L_2 \times T_1$ (123.00 days) among hybrids respectively.

m. Fruit and shoot borer incidence

The minimum and maximum incidence of fruit and shoot borer was observed respectively for L_2 (14.02 %) and L_3 (15.97 %) among lines, T_1 (12.12 %) and T_3 (17.29 %) among testers. Among the hybrids, borer incidence was minimum on $L_3 \times T_1$ (7.13 %) which was on par with $L_1 \times T_1$ (8.11 %), $L_3 \times T_2$ (8.28 %), $L_2 \times T_1$ (8.49 %), $L_4 \times T_3$ (8.91 %), $L_2 \times T_2$ (9.04 %), $L_3 \times T_3$ (9.29 %) and $L_4 \times T_2$ (9.53 %) while it was maximum on $L_5 \times T_3$ (18.34 %).

n. YVM incidence at 30 DAS

All the lines, testers and hybrids were free from YVM disease incidence (score 1) during this stage.

o. YVM incidence at 50 DAS

Among the lines, minimum score of 1.13 for YVM incidence was observed in L_1 and L_4 while maximum score of 1.27 was noticed in L_2. All the testers and most of the hybrids except two ($L_1 \times T_2$ and $L_2 \times T_3$) were free from disease.

p. YVM incidence at 70 DAS

Minimum score for YVM incidence among lines was observed for L_4 and L_5 (1.67) while maximum was for L_2 (1.83). All the testers and hybrids except $L_1 \times T_2$ (1.13) and $L_2 \times L_3$ (1.20) did not exhibit any symptom of YVM.

q. YVM incidence during final harvest

L_4 and L_5 (2.73) were the least susceptible types among lines while L_2 (3.13) was the most susceptible one. Similarly, all the testers and the hybrids other than $L_1 \times T_2$ (1.20) and $L_2 \times T_3$ (1.33) maintained their high resistance during final harvest also.

r. Fruit colour

For fruit colour, the highest score of 9 was observed for L_1 and its three hybrids (L_1 x T_1, L_1 x T_2, L_1 x T_3) followed by L_5 (7) while rest of the lines, testers and hybrids had a score of 2.

s. Fruit pubescence

Score of fruit pubescence was uniform (score 1) for all the treatments *viz.*, lines, testers and hybrids.

4.2.2 Heterosis

Relative heterosis, standard heterosis, heterobeltiosis and heterosis over best parent were estimated for fifteen hybrids with respect to 14 characters under study and the results are furnished in Tables 24 to 37 and Fig. 4. Standard heterosis was calculated for each character based on the check variety Arka Anamika while it was estimated for YVM incidence during final harvest over the check variety Kiran also.

a. Days to first flower

The hybrids L_2 x T_1 and L_3 x T_2 exhibited the desirable negative and significant relative heterosis of -10.90 % and –16.08 % respectively (Table 24). L_1 x T_2, L_1 x T_3, L_3 x T_1, L_3 x T_3 and L_5 x T_3 showed positively significant heterosis over mid parent. Significant standard heterosis was recorded for five hybrids. The highest negative heterosis was noticed for L_3 x T_2 (-21.10 %), followed by L_2 x T_1 (-17 .86 %) whereas L_1 x T_2, L_3 x T_1 and L_3 x T_3 had positively significant standard heterosis.

Among the eight hybrids with significant heterobeltiosis, only L_3 x T_2 had negative value (-13.03 %) while L_1 x T_2, L_1 x T_3, L_2 x T_3, L_3 x T_1, L_3 x T_3, L_4 x T_2 and L_5 x T_3 had positive values. The highest percentage of heterosis was noticed for L_3 x T_3 (29.15 %). Though majority of the hybrids showed significant heterosis over the best parent for days to first flower, all of them were in positive direction. The only cross with negative (but non-significant) heterosis was L_2 x T_1 (-3.01 %).

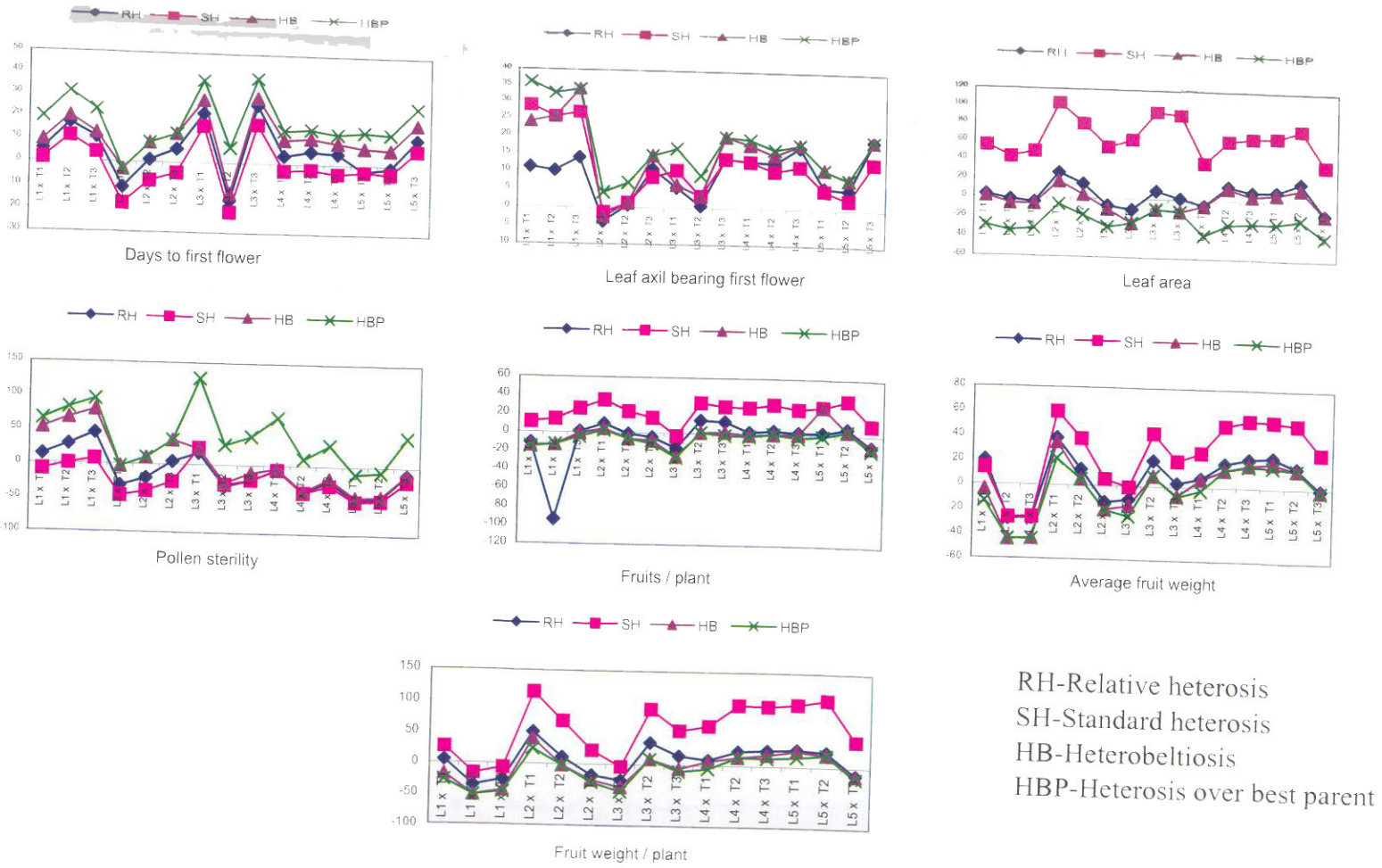
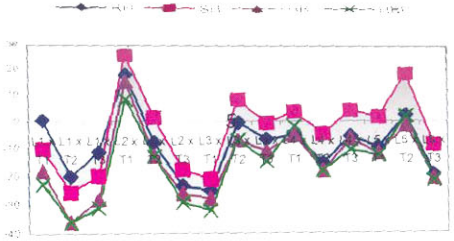
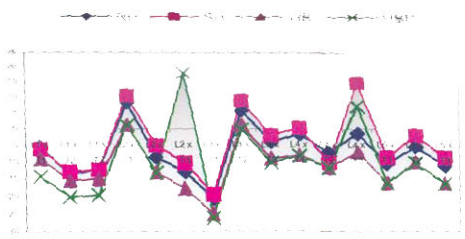


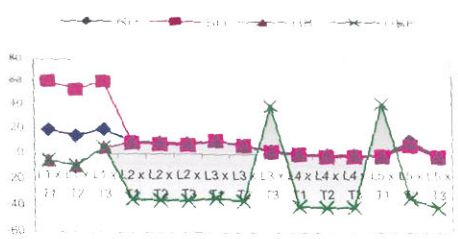
Fig. 4. Heterosis for various characters in fifteen hybrids



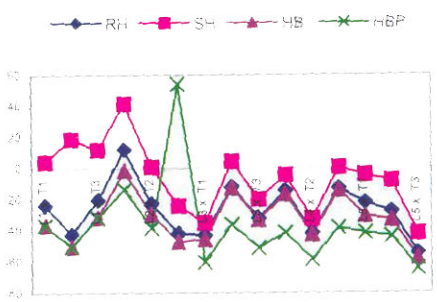
Fruit length



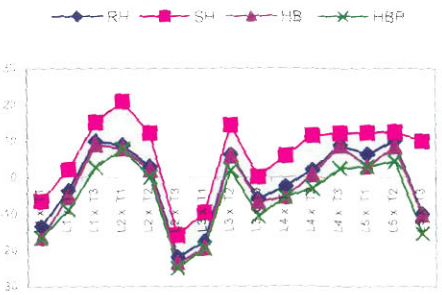
Fruit girth



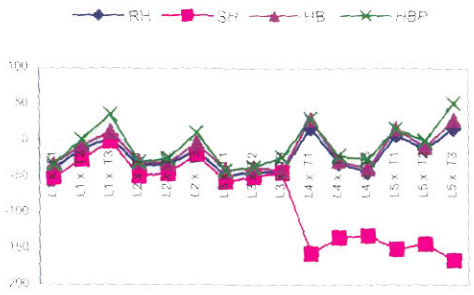
Ridges / fruit



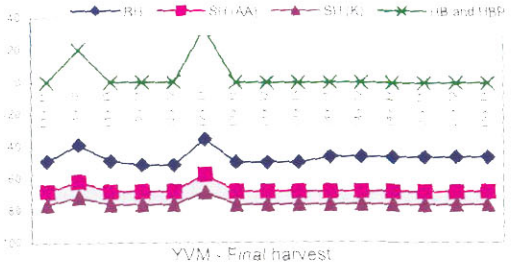
Seeds / fruit



Plant duration



Fruit and shoot borer incidence



YVM - Final harvest

RH-Relative heterosis
SH-Standard heterosis
HB-Heterobeltiosis
HBP-Heterosis over best parent

Fig. 4. Continued....

Table 24. Heterosis (%) for days to first flower

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)	Heterosis over best parent (HBP)
L_1 x T_1	5.28	1.18	9.35	19.47**
L_1 x T_2	16.95**	11.01*	19.97**	31.08**
L_1 x T_3	10.79*	4.16	12.58**	23.00**
L_2 x T_1	-10.90	-17.86**	-3.01	-3.01
L_2 x T_2	1.13	-7.97	8.67	8.67
L_2 x T_3	5.89	-4.59	12.66**	12.66*
L_3 x T_1	21.83**	15.99**	27.85**	36.96**
L_3 x T_2	-16.08**	-21.10**	-13.03*	6.83
L_3 x T_3	25.83**	17.17**	29.15**	38.35**
L_4 x T_1	3.55	-2.93	10.56	14.62*
L_4 x T_2	5.61	-2.25	11.34*	15.43*
L_4 x T_3	4.89	-3.86	9.50	13.52*
L_5 x T_1	-2.75	-3.06	7.52	14.47*
L_5 x T_2	-1.02	-3.68	6.83	13.74*
L_5 x T_3	11.60**	6.59	18.22**	25.86**

Table 25. Heterosis (%) for leaf axil bearing first flower

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)	Heterosis over best parent (HBP)
L_1 x T_1	11.05**	28.86**	24.05**	36.11**
L_1 x T_2	10.09**	25.58**	25.65**	32.64**
L_1 x T_3	13.86**	26.89**	34.03**	34.03**
L_2 x T_1	-3.85	-1.38	-2.60	4.17
L_2 x T_2	0.65	1.25	1.32	6.94
L_2 x T_3	10.74**	8.48	14.58**	14.58**
L_3 x T_1	5.66	10.45*	6.33	16.67**
L_3 x T_2	0.64	3.22	3.29	9.03
L_3 x T_3	13.82**	13.74**	20.14**	20.14**
L_4 x T_1	13.16**	13.08**	17.81**	19.44**
L_4 x T_2	12.75**	10.45*	15.06**	16.67**
L_4 x T_3	17.24**	11.77**	18.06**	18.06**
L_5 x T_1	5.96	5.19	11.11*	11.11*
L_5 x T_2	5.41	2.56	8.33	8.33
L_5 x T_3	19.44**	13.08**	19.44**	19.44**

b. Leaf axil bearing first flower

None of the hybrids exhibited the desirable negatively significant heterosis over mid parent, standard parent, better parent and best parent for leaf axil bearing first flower (Table 25). However, $L_2 \times T_1$ possessed negative but non-significant values for all categories of heterosis except over best parent. Eight hybrids *viz.*, $L_1 \times T_1$, $L_1 \times T_2$, $L_1 \times T_3$, $L_3 \times T_3$, $L_4 \times T_1$, $L_4 \times T_2$, $L_4 \times T_3$ and $L_5 \times T_3$ had positively significant heterosis in all the four types. The highest positive values were observed for $L_5 \times T_3$ (relative heterosis), $L_1 \times T_1$ (heterosis over both standard and best parents) and $L_1 \times T_3$ (heterobeltiosis).

c. Leaf area

Significant relative heterosis was exhibited by seven hybrids of which five were positive (Table 26). The highest percentage of positive heterosis over mid parent was observed for $L_2 \times T_1$ (26.32 %) followed by $L_5 \times T_2$ (19.86 %), $L_2 \times T_2$ (15.30 %), $L_4 \times T_2$ (14.99 %) and $L_5 \times T_1$ (10.35 %). $L_3 \times T_1$ and $L_5 \times T_3$ possessed significant negative relative heterosis (-10.91 % and –12.52 % respectively). All the hybrids exhibited significant and positive standard heterosis and among these $L_2 \times T_1$ and $L_5 \times T_3$ had the maximum (103.45 %) and minimum (38.22 %) values respectively. Other hybrids with high standard heterosis were $L_3 \times T_2$ (94.82 %), $L_3 \times T_3$ (91.50 %), $L_2 \times T_2$ (80.37 %) and $L_5 \times T_2$ (77.14 %).

Heterobeltiosis was significant and positive for $L_2 \times T_1$ (17.00 %), $L_5 \times T_2$ (13.13 %) and $L_4 \times T_2$ (12.42 %). Five hybrids possessed negatively significant heterobeltiosis for this character. Among the fourteen negatively and significantly heterotic hybrids, the maximum heterosis over best parent was noticed for $L_5 \times T_3$ (-36.63 %).

d. Pollen sterility

Relative heterosis was negatively significant for $L_5 \times T_1$ (-48.52 %), $L_5 \times T_2$ (-45.23 %), $L_4 \times T_2$ (-37.40 %), $L_2 \times T_1$ (-31.82 %), $L_3 \times T_2$ (-31.21 %), $L_4 \times T_3$ (-22.18 %) and $L_3 \times T_3$ (-21.37 %) while it was positively

Table 26. Heterosis (%) for leaf area

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)	Heterosis over best parent (HBP)
L_1 x T_1	2.79	54.95**	1.11	-28.96**
L_1 x T_2	-2.28	42.80**	-6.83	-34.53**
L_1 x T_3	-4.69	49.00**	-6.52	-31.69**
L_2 x T_1	26.32**	103.45**	17.00**	-6.72
L_2 x T_2	15.30**	80.37**	3.73	-17.30**
L_2 x T_3	-7.29	54.50**	-11.15*	-29.17**
L_3 x T_1	-10.91*	63.20**	-25.18**	-25.18**
L_3 x T_2	9.11	94.82**	-10.68*	-10.68*
L_3 x T_3	1.46	91.50**	-12.20**	-12.20**
L_4 x T_1	-5.32	39.06**	-6.19	-36.24**
L_4 x T_2	14.99**	63.59**	12.42*	-25.00**
L_4 x T_3	9.31	66.66**	4.55	-23.59**
L_5 x T_1	10.35*	68.19**	7.41	-22.89**
L_5 x T_2	19.86**	77.14**	13.13*	-18.78**
L_5 x T_3	-12.52*	38.22**	-13.29*	-36.63**

Table 27. Heterosis (%) for pollen sterility

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)	Heterosis over best parent (HBP)
L_1 x T_1	13.51	-8.59	52.62**	66.14**
L_1 x T_2	28.45*	0.45	67.70**	82.56**
L_1 x T_3	45.64**	7.60	79.65**	95.57**
L_2 x T_1	-31.82**	-46.76**	-3.23	-3.23
L_2 x T_2	-20.05	-39.43**	10.09	10.09
L_2 x T_3	4.69	-25.21*	35.94*	35.94**
L_3 x T_1	17.66	24.98*	23.54*	127.14**
L_3 x T_2	-31.21**	-28.54**	-25.94*	29.89
L_3 x T_3	-21.37*	-21.71*	-10.90	42.30*
L_4 x T_1	-5.55	-6.06	-3.92	70.75**
L_4 x T_2	-37.40**	-39.20**	-36.99**	10.51
L_4 x T_3	-22.18*	-27.76**	-17.79	31.29
L_5 x T_1	-48.52**	-50.92**	-45.17**	-10.79
L_5 x T_2	-45.23**	-49.06**	-43.09**	-7.42
L_5 x T_3	-10.70	-20.80*	-9.86	43.95*

significant for L_1 x T_3 (45.64 %) and L_1 x T_2 (28.45 %) (Table 27). While ten hybrids exhibited desirable negatively significant heterosis over the standard variety, only L_3 x T_1 showed positive heterosis. The highest value of negative standard heterosis was observed for L_5 x T_1 (-50.92 %) followed by L_5 x T_2 (-49.06 %) and L_2 x T_1 (-46.76 %).

Heterobeltiosis was negatively significant for four hybrids *viz.*, L_5 x T_1 (-45.17 %), L_5 x T_2 (-43.09 %), L_4 x T_2 (-36.99 %) and L_3 x T_2 (-25.94 %) whereas it was positively significant for five crosses. Significant negative heterosis over best parent was observed for none of the hybrids. Eight hybrids possessed significant positive heterosis.

e. Fruits plant^{-1}

Significant positive and negative relative heterosis for fruits plant^{-1} were observed for four hybrids each (Table 28). Maximum positive relative heterosis was possessed by L_3 x T_2 (14.19 %) followed by L_3 x T_3 (13.10 %), L_2 x T_1 (9.41 %) and L_5 x T_2 (7.01 %) whereas significant negative values were shown by L_1 x T_1, L_1 x T_2, L_3 x T_1 and L_5 x T_3.

All the hybrids except L_3 x T_1 exhibited significant positive heterosis over standard variety for fruit number. The highest standard heterosis was noticed for the hybrid L_5 x T_2 (37.07 %) followed by L_2 x T_1 (34.99 %), L_3 x T_2 (33.02 %) and L_4 x T_2 (31.84 %). Though five hybrids possessed significant heterosis over both better and best parents, all of them were in negative direction. However, positive but non-significant values were noticed for L_2 x T_1, L_3 x T_2, L_4 x T_2 and L_5 x T_2.

f. Average fruit weight

Relative heterosis was positively significant for eight hybrids with respect to average fruit weight (Table 29). Among these, the maximum value was noticed for L_2 x T_1 (38.24 %) followed by L_5 x T_1 (25.21 %) and L_4 x T_3 (23.50 %) whereas the minimum heterosis was for L_2 x T_2 (13.12 %). Four crosses *viz.*, L_1 x T_2, L_1 x T_3, L_2 x T_3 and L_3 x T_1 possessed negatively significant heterosis for this trait. Positively significant

Table 28. Heterosis (%) for fruits plant^{-1}

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)	Heterosis over best parent (HBP)
L_1 x T_1	-11.74**	10.98*	-14.29**	-15.57**
L_1 x T_2	-9.94**	14.13**	-13.17**	-13.17**
L_1 x T_3	1.11	25.74**	-0.78	-4.34
L_2 x T_1	9.41*	34.99**	4.26	2.69
L_2 x T_2	-1.11	22.98**	-6.44	-6.44
L_2 x T_3	-4.52	16.49**	-8.08*	-11.38**
L_3 x T_1	-15.84**	-2.79	-24.92**	-26.05**
L_3 x T_2	14.19**	33.02**	1.20	1.20
L_3 x T_3	13.10**	29.08**	1.86	-1.80
L_4 x T_1	2.03	28.30**	-0.91	-2.40
L_4 x T_2	4.04	31.84**	0.30	0.30
L_4 x T_3	2.22	27.12**	0.31	-3.29
L_5 x T_1	2.17	29.87**	0.30	-1.20
L_5 x T_2	7.01*	37.07**	4.28	4.28
L_5 x T_3	-11.74**	10.98*	-12.42**	-15.57**

Table 29. Heterosis (%) for average fruit weight

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)	Heterosis over best parent (HBP)
L_1 x T_1	19.90**	13.86*	-3.81	-13.37**
L_1 x T_2	-27.66**	-26.58**	-44.14**	-44.14**
L_1 x T_3	-26.71**	-25.96**	-43.27**	-43.67**
L_2 x T_1	38.24**	59.76**	34.97**	21.55**
L_2 x T_2	13.12**	38.12**	5.09	5.09
L_2 x T_3	-13.43**	5.30	-19.31**	-19.88**
L_3 x T_1	-10.81*	-0.67	-16.08**	-24.43**
L_3 x T_2	21.24**	42.95**	8.76	8.76
L_3 x T_3	2.99	20.95**	-7.32	-7.98
L_4 x T_1	7.36	27.92**	6.67	-2.67
L_4 x T_2	19.47**	50.15**	14.24**	14.24**
L_4 x T_3	23.50**	54.64**	18.50**	17.66**
L_5 x T_1	25.21**	54.15**	20.56**	17.28**
L_5 x T_2	16.98**	51.66**	15.39**	15.39**
L_5 x T_3	-0.42	28.64**	-1.43	-2.13

heterosis over standard variety was observed for most of the hybrids with the maximum value for $L_2 \times T_1$ (59.76 %) followed by $L_4 \times T_3$ (54.64 %), $L_5 \times T_1$ (54.15 %), $L_5 \times T_2$ (51.66 %) and $L_4 \times T_2$ (50.15 %). Two hybrids *viz.*, $L_1 \times T_2$ and $L_1 \times T_3$ had negatively significant standard heterosis.

Positively significant heterosis over better and best parents were noticed for five hybrids *viz.*, $L_2 \times T_1$, $L_4 \times T_2$, $L_4 \times T_3$, $L_5 \times T_1$ and $L_5 \times T_2$ with the highest values of both types being recorded by $L_2 \times T_1$ (34.97 % and 21.55 % respectively). The crosses $L_1 \times T_2$, $L_1 \times T_3$, $L_2 \times T_3$ and $L_3 \times T_1$ exhibited significant negative values for both the above types of heterosis.

g. Fruit weight plant^{-1}

Eight hybrids possessed positively significant heterosis over mid parent for fruit weight plant^{-1} (Table 30). Among these, $L_2 \times T_1$ (51.34 %) was the most heterotic, followed by $L_3 \times T_2$ (36.03 %), $L_5 \times T_1$ (28.12 %), $L_4 \times T_3$ (26.07 %) and $L_5 \times T_2$ (24.97 %). Negatively significant relative heterosis was observed for $L_1 \times T_2$, $L_1 \times T_3$, $L_2 \times T_3$, $L_3 \times T_1$ and $L_5 \times T_3$.

Majority of the hybrids exhibited positively significant standard heterosis for this character. The maximum value was observed for $L_2 \times T_1$ (115.46 %) followed by $L_5 \times T_2$ (107.60 %), $L_5 \times T_1$ (100.15 %), $L_4 \times T_2$ (97.60 %) and $L_4 \times T_3$ (96.43 %). None of the hybrids had significant negative heterosis.

The expression pattern of both heterobeltiosis and heterosis over best parent was similar among the hybrids. Five hybrids exhibited significant positive heterosis over these parents. The maximum values for both types of heterosis were recorded for $L_2 \times T_1$ (40.69 % and 24.58 % respectively) whereas negatively significant heterosis was noticed for $L_1 \times T_1$, $L_1 \times T_2$, $L_1 \times T_3$, $L_2 \times T_3$, $L_3 \times T_1$ and $L_5 \times T_3$.

h. Fruit length

Only one hybrid *ie.*, $L_2 \times T_1$ (17.95 %) possessed desirable positively significant heterosis for fruit length over mid parent whereas seven hybrids

Table 30. Heterosis (%) for fruit weight plant^{-1}

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)	Heterosis over best parent (HBP)
L_1 x T_1	5.01	26.13**	-17.64**	-27.07**
L_1 x T_2	-35.41**	-16.02	-51.44**	-51.44**
L_1 x T_3	-26.17**	-6.89	-43.62**	-46.16**
L_2 x T_1	51.34**	115.46**	40.69**	24.58**
L_2 x T_2	11.35*	69.56**	-1.96	-1.96
L_2 x T_3	-17.42**	22.54**	-25.81**	-29.15**
L_3 x T_1	-25.56**	-3.66	-37.09**	-44.30**
L_3 x T_2	36.03**	89.52**	9.58	9.58
L_3 x T_3	15.18*	55.98**	-5.56	-9.81
L_4 x T_1	9.58	64.15**	7.19	-5.09
L_4 x T_2	23.73**	97.60**	14.25**	14.25**
L_4 x T_3	26.07**	96.43**	18.93**	13.58*
L_5 x T_1	28.12**	100.15**	25.65**	15.73**
L_5 x T_2	24.97**	107.60**	20.03**	20.03**
L_5 x T_3	-12.16*	42.51**	-13.72*	-17.60**

Table 31. Heterosis (%) for fruit length

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)	Heterosis over best parent (HBP)
L_1 x T_1	0.46	-10.13	-17.93**	-22.74**
L_1 x T_2	-19.96**	-25.67	-36.10**	-36.10**
L_1 x T_3	-11.34*	-19.85**	-28.06**	-31.10**
L_2 x T_1	17.95**	25.79**	14.87**	8.14
L_2 x T_2	-7.86	1.41	-12.82**	-12.82*
L_2 x T_3	-23.47**	-17.65**	-26.09**	-29.21**
L_3 x T_1	-24.99**	-21.01**	-27.87**	-32.09**
L_3 x T_2	-0.59	8.08	-7.09	-7.09
L_3 x T_3	-6.70	-0.85	-11.09*	-14.76**
L_4 x T_1	-5.18	3.58	-5.41	-10.95*
L_4 x T_2	-15.44**	-4.74	-18.11**	-18.11**
L_4 x T_3	-5.64	3.98	-6.68	-10.61*
L_5 x T_1	-9.67*	1.57	-11.98*	-12.68**
L_5 x T_2	2.19	18.40**	1.78	1.78
L_5 x T_3	-19.60**	-8.83	-20.99**	-21.62**

viz., $L_1 \times T_2$, $L_1 \times T_3$, $L_2 \times T_3$, $L_3 \times T_1$, $L_4 \times T_2$, $L_5 \times T_1$ and $L_5 \times T_3$ showed significant negative heterosis (Table 31).

Positively significant heterosis over check variety was exhibited by two hybrids *viz.*, $L_2 \times T_1$ (25.79 %) and $L_5 \times T_2$ (18.40 %) while $L_1 \times T_2$, $L_1 \times T_3$, $L_2 \times T_3$ and $L_3 \times T_1$ showed negatively significant standard heterosis. Out of the eleven hybrids which exhibited significant heterobeltiosis, the only cross with positive heterosis was $L_2 \times T_1$ (14.87 %) while non-significant positive heterosis was noticed for $L_5 \times T_2$.

None of the hybrids exhibited positively significant heterosis over best parent. However, $L_2 \times T_1$ and $L_5 \times T_2$ exhibited positive non-significant heterosis and twelve hybrids showed significant negative heterosis.

i. Fruit girth

Only two hybrids *viz.*, $L_2 \times T_1$ (8.14 %) and $L_3 \times T_2$ (5.74 %) had positive but non-significant heterosis for fruit girth over mid parent (Table 32). The hybrids which possessed negatively significant heterosis were $L_1 \times T_2$, $L_1 \times T_3$, $L_2 \times T_3$, $L_3 \times T_1$, $L_5 \times T_1$ and $L_5 \times T_3$.

$L_4 \times T_3$ was the only hybrid with positively significant standard heterosis (14.87 %) for fruit girth. Positive but non-significant heterosis was observed for $L_2 \times T_1$, $L_3 \times T_2$ and $L_4 \times T_1$ while $L_1 \times T_2$, $L_1 \times T_3$ and $L_3 \times T_1$ were with negatively significant heterosis.

Nine and eleven hybrids exhibited significant negative heterobeltiosis and heterosis over best parent respectively. Non-significant positive values were noticed for $L_3 \times T_2$ with respect to heterobeltiosis and $L_2 \times T_1$ for both types of heterosis.

j. Ridges fruit^{-1}

Positively significant relative heterosis was exhibited by nine hybrids (Table 33). The highest value was noticed for $L_1 \times T_3$ (19.70 %) followed by $L_1 \times T_1$ (19.40 %) and $L_1 \times T_2$ (14.34 %) whereas $L_5 \times T_3$ showed negatively significant relative heterosis (-0.99 %).

Table 32. Heterosis (%) for fruit girth

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)	Heterosis over best parent (HBP)
L_1 x T_1	-5.31	-6.12	-9.03	-14.12**
L_1 x T_2	-13.48**	-12.81*	-15.51**	-20.24**
L_1 x T_3	-12.16*	-12.24*	-14.96**	-19.72**
L_2 x T_1	8.14	10.52	1.10	1.10
L_2 x T_2	-8.54	-5.03	-13.13*	-13.13*
L_2 x T_3	-12.83**	-10.23	-17.89**	-17.89**
L_3 x T_1	-20.63**	-19.50**	-25.31**	-26.36**
L_3 x T_2	5.74	8.98	1.11	-0.31
L_3 x T_3	-4.11	-2.00	-9.07	-10.36*
L_4 x T_1	-1.76	0.34	-8.12	-8.21
L_4 x T_2	-7.11	-10.23	-11.73*	-11.82*
L_4 x T_3	-1.39	14.87**	-7.07	7.17
L_5 x T_1	-10.44*	-8.52	-16.23**	-16.32**
L_5 x T_2	-5.46	-1.89	-10.16*	-10.25*
L_5 x T_3	-11.11*	-8.52	-16.23**	-16.32**

Table 33. Heterosis (%) for ridges fruit^{-1}

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)	Heterosis over best parent (HBP)
L_1 x T_1	19.40**	60.42**	-4.95	-4.95
L_1 x T_2	14.34**	52.86**	-9.43**	-9.43**
L_1 x T_3	19.70**	60.02**	-5.18	-5.18
L_2 x T_1	9.93*	9.14	9.21	-35.33**
L_2 x T_2	9.47*	7.96	9.47	-36.03**
L_2 x T_3	8.67*	7.17	8.67	-36.50**
L_3 x T_1	11.18*	11.11	11.18*	-34.16**
L_3 x T_2	7.75	6.97	7.04	-36.62**
L_3 x T_3	2.65	1.91	1.97	39.62**
L_4 x T_1	0.99*	0.26	0.33	-40.59**
L_4 x T_2	0.00	-1.38	0.00	-41.57**
L_4 x T_3	0.00	-1.38	0.00	-41.57**
L_5 x T_1	-1.64	-1.38	-1.96	-41.57**
L_5 x T_2	11.55**	6.97	10.46*	-34.16**
L_5 x T_3	-0.99*	-1.38	-1.96	-41.57**

Only the three hybrids of L_1 displayed significant standard heterosis for ridges fruit^{-1} and all of them were in positive direction. $L_1 \times T_1$ had the maximum value (60.42 %) while $L_1 \times T_3$ and $L_1 \times T_2$ had 60.02 per cent and 52.86 per cent respectively.

Heterobeltiosis was significant and positive for $L_3 \times T_1$ (11.18 %) and $L_5 \times T_2$ (10.46 %) whereas negative for $L_1 \times T_2$ (-9.43 %). All the hybrids exhibited negative heterosis over best parent and significance also was observed for these except $L_1 \times T_1$ and $L_1 \times T_3$. Maximum value (-41.57 %) was noticed for four crosses *viz.*, $L_4 \times T_2$, $L_4 \times T_3$, $L_5 \times T_1$ and $L_5 \times T_3$.

k. Seeds fruit^{-1}

$L_2 \times T_1$ (12.07 %) alone displayed the desirable positive (non-significant) relative heterosis while all the other hybrids exhibited negative heterosis for this trait (Table 34). Among these, the maximum and minimum values were observed for $L_5 \times T_3$ (-54.55 %) and $L_3 \times T_2$ (-12.03 %) respectively.

Positively significant standard heterosis was noticed for $L_2 \times T_1$ (41.45 %) whereas $L_1 \times T_1$, $L_1 \times T_2$, $L_1 \times T_3$, $L_2 \times T_2$, $L_3 \times T_2$ and $L_4 \times T_3$ showed positive but non-significant heterosis. Expression of standard heterosis was negatively significant for $L_2 \times T_3$, $L_3 \times T_1$, $L_4 \times T_2$ and $L_5 \times T_3$.

All the fifteen hybrids had negative heterosis over both better and best parents among which both types of heterosis were significant for eleven hybrids.

l. Plant duration

Negatively significant relative heterosis was maximum for $L_2 \times T_3$ (-21.93 %) followed by $L_3 \times T_1$ (-17.79 %), $L_1 \times T_1$ (-13.44 %) and $L_5 \times T_3$ (-10.04 %) while standard heterosis was negatively significant for $L_2 \times T_3$ (-15.86 %) and $L_3 \times T_1$ (-9.73 %) (Table 35). Heterobeltiosis and heterosis over best parent were negatively significant and maximum for $L_2 \times T_3$ followed by $L_3 \times T_1$, $L_1 \times T_1$ and $L_5 \times T_3$.

Table 34. Heterosis (%) for seeds fruit^{-1}

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)	Heterosis over best parent (HBP)
$L_1 \times T_1$	-23.59**	4.14	-36.41**	-36.41**
$L_1 \times T_2$	-42.22**	18.72	-50.37**	-50.37**
$L_1 \times T_3$	-20.29**	11.89	-31.68**	-31.68**
$L_2 \times T_1$	12.07	41.45**	-1.51	-13.63
$L_2 \times T_2$	-22.74**	0.90	-29.74**	-38.39**
$L_2 \times T_3$	-41.83**	-24.21*	-47.23**	53.72**
$L_3 \times T_1$	-42.99**	-34.91**	-45.55**	-60.25**
$L_3 \times T_2$	-12.03	4.29	-12.75	-36.31**
$L_3 \times T_3$	-32.36**	-20.01	-33.08**	-51.15**
$L_4 \times T_1$	-14.64	-4.65	-16.79	-41.77**
$L_4 \times T_2$	-41.88**	-32.53**	-42.62**	-58.80**
$L_4 \times T_3$	-13.20	0.50	-14.08	-38.63**
$L_5 \times T_1$	-22.39**	-4.33	-30.54**	-41.58**
$L_5 \times T_2$	-27.98**	-8.06	-33.24**	-43.86**
$L_5 \times T_3$	-54.55**	-42.12**	-57.97**	-64.65**

Table 35. Heterosis (%) for plant duration

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)	Heterosis over best parent (HBP)
$L_1 \times T_1$	-13.44**	-6.48	-16.65**	-16.65**
$L_1 \times T_2$	-3.59	2.10	-5.40	-9.00*
$L_1 \times T_3$	9.95*	15.17**	9.03	2.66
$L_2 \times T_1$	8.84*	20.88**	7.74	7.74
$L_2 \times T_2$	2.96	12.16**	2.03	-0.03
$L_2 \times T_3$	-21.93**	-15.86**	-23.46**	-25.00**
$L_3 \times T_1$	-17.79**	-9.73*	-19.54**	-19.54**
$L_3 \times T_2$	6.15	14.29**	5.89	1.87
$L_3 \times T_3$	-6.06	0.07	-6.83	-10.81**
$L_4 \times T_1$	-2.55	5.93	-5.58	-5.58
$L_4 \times T_2$	1.98	11.51*	0.70	-3.12
$L_4 \times T_3$	8.97*	12.23**	8.75	2.39
$L_5 \times T_1$	6.38	12.30**	2.95	2.95
$L_5 \times T_2$	10.02*	12.49**	8.50	4.38
$L_5 \times T_3$	-10.04*	9.91*	-10.33*	-15.57**

Table 36. Heterosis (%) for fruit and shoot borer incidence

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)	Heterosis over best parent (HBP)
$L_1 \times T_1$	-39.65**	-51.73**	-33.09**	-33.09**
$L_1 \times T_2$	-12.52	-27.02**	-7.63	1.16
$L_1 \times T_3$	2.92	-1.83	11.77	36.08**
$L_2 \times T_1$	-35.05**	-49.46**	-29.95**	-29.95**
$L_2 \times T_2$	-33.77**	-46.19**	-31.89**	-25.41*
$L_2 \times T_3$	-14.32	-20.14*	-4.33	10.7
$L_3 \times T_1$	-49.26**	-57.58**	-41.20**	-41.20**
$L_3 \times T_2$	-43.37**	-50.71**	-37.62**	-31.68**
$L_3 \times T_3$	-44.16**	-44.72**	-41.85**	-23.38*
$L_4 \times T_1$	17.14*	-156.26**	29.62**	29.62**
$L_4 \times T_2$	-31.85**	-134.14**	-28.18**	-21.34
$L_4 \times T_3$	-44.29**	-131.92**	-39.38**	-26.46**
$L_5 \times T_1$	7.05	-150.50**	16.34	16.34
$L_5 \times T_2$	-12.23	-143.22**	-9.09	-0.44
$L_5 \times T_3$	16.40*	-165.69**	28.97**	51.35**

Table 37. Heterosis for YVM incidence during final harvest

Hybrids	Relative heterosis (RH)	Standard heterosis		Heterobeltiosis (HB)	Heterosis over best parent (HBP)
		Arka Anamika	Kiran		
$L_1 \times T_1$	-49.15**	-68.05	-76.58**	0.00	0.00
$L_1 \times T_2$	-38.98**	-61.66	-71.90**	20.00	20.00
$L_1 \times T_3$	-49.15**	-68.05	-76.58**	0.00	0.00
$L_2 \times T_1$	-51.61**	-68.05	-76.58**	0.00	0.00
$L_2 \times T_2$	-51.61**	-68.05	-76.58**	0.00	0.00
$L_2 \times T_3$	-35.48**	-57.40	-68.77**	33.33	33.33
$L_3 \times T_1$	-50.00**	-68.05	-76.58**	0.00	0.00
$L_3 \times T_2$	-50.00**	-68.05	-76.58**	0.00	0.00
$L_3 \times T_3$	-50.00**	-68.05	-76.58**	0.00	0.00
$L_4 \times T_1$	-46.43**	-68.05	-76.58**	0.00	0.00
$L_4 \times T_2$	-46.43**	-68.05	-76.58**	0.00	0.00
$L_4 \times T_3$	-46.43**	-68.05	-76.58**	0.00	0.00
$L_5 \times T_1$	-46.43**	-68.05	-76.58**	0.00	0.00
$L_5 \times T_2$	-46.43**	-68.05	-76.58**	0.00	0.00
$L_5 \times T_3$	-46.43**	-68.05	-76.58**	0.00	0.00

m. Fruit and shoot borer incidence

Relative heterosis was negatively significant for eight hybrids *viz.*, L_3 x T_1 (-49.26 %), L_4 x T_3 (-44.29 %), L_3 x T_3 (-44.16 %), L_3 x T_2 (-43.37 %), L_1 x T_1 (-39.65 %), L_2 x T_1 (-35.05 %), L_2 x T_2 (-33.77 %) and L_4 x T_2 (-31.85 %) (Table 36). Positive and significant relative heterosis was exhibited by L_4 x T_1 and L_5 x T_3.

All the hybrids displayed significant negative standard heterosis for this trait except L_1 x T_3 which was non-significant. L_5 x T_3 was the most heterotic (-165.69 %) followed by L_4 x T_1 (-156.26 %) and L_5 x T_1 (-150.50 %). Significant heterosis over both better and best parents were noticed for ten hybrids of which heterosis for eight and seven crosses respectively were in negative direction. For heterobeltiosis, the highest value was observed in the case of L_3 x T_3 (-41.85 %).

n. YVM incidence during final harvest

All the fifteen hybrids under study possessed significant negative heterosis over mid parent as well as both standard varieties (Arka Anamika and Kiran) for YVM incidence during final harvest (Table 37). For relative heterosis, the values ranged from -35.48 per cent (L_2 x T_3) to -51.61 per cent (L_2 x T_1 and L_2 x T_2) whereas standard heterosis over Arka Anamika ranged from –57.40 per cent (L_2 x T_3) to –68.05 per cent and was non-significant. Standard heterosis over Kiran was negatively significant for all the hybrids and it ranged from -68.77 to –76.58 per cent.

Heterobeltiosis as well as heterosis over best parent was absent for all the hybrids except L_1 x T_2 and L_2 x T_3. Moreover, L_1 x T_2 and L_2 x T_3 had equal values for both types of heterosis *i.e.*, 20 per cent for the former and 33.33 per cent for the latter hybrid.

4.2.3 Combining Ability

General combining ability (*gca*) effects of lines and testers are presented in Table 38 and Fig. 5 and 6 and specific combining ability (*sca*) effects of hybrids are furnished in Table 39 and Fig. 7.

Table 38. General combining ability effects of parents for fourteen characters

Parents	Days to first flower	Leaf axil bearing of first flower	Leaf area. cm^2	Pollen sterility. %	Fruits $plant^{-1}$	Average fruit weight. g	Fruit weight $plant^{-1}$. g	Fruit length. cm	Fruit girth. cm	Ridges $fruit^{-1}$	Seeds $fruit^{-1}$	Plant duration	Fruit and shoot borer incidence. %	YVM-Final harvest
Lines														
L_1	3.32**	0.79**	-24.62**	3.77**	-0.54**	-8.40**	-102.33**	-2.49**	-0.34*	2.17**	3.32	-2.41	0.88	0.03
L_2	-5.03**	-0.44**	19.81**	-2.60**	0.13	1.73**	21.41**	1.00*	0.18	-0.35**	6.39**	-0.24	-1.10*	0.08
L_3	2.55*	-0.12	25.25**	2.35**	-0.30	-1.12**	-18.39**	-0.25	0.03	-0.42**	-3.73	-4.50*	-3.18**	-0.04
L_4	-1.21	-0.01	-13.68*	-0.39	0.49**	3.84**	52.06**	0.64	0.23	-0.80**	-1.68	3.94*	-0.03	-0.04
L_5	0.37	-0.23*	-6.76	-3.13**	0.22	3.96**	47.26**	1.09**	-0.10	-0.61**	-4.30*	3.20	3.43**	-0.04
SE	1.07	0.09	5.28	0.68	0.17	0.54	6.55	0.38	0.13	0.10	2.05	1.85	0.53	0.12
Testers														
T_1	-0.32	-0.02	-0.08	0.79	-0.25	1.00*	5.53	0.49	0.00	0.05	3.87*	-0.76	-0.70	-0.04
T_2	-2.17*	-0.15*	8.61*	-1.57*	0.38**	1.06*	22.25**	0.41	0.10	0.03	-1.06	4.99**	-1.18**	0.00
T_3	2.49**	0.16*	-8.52*	0.77	-0.12	-2.06**	-27.78**	-0.90**	-0.10	-0.08	-2.81	-4.24**	1.88**	0.03
SE	0.83	0.07	4.09	0.52	0.13	0.42	5.07	0.29	0.10	0.08	1.59	1.44	0.41	0.09

*-Significant at 5 % level **-Significant at 1 % level

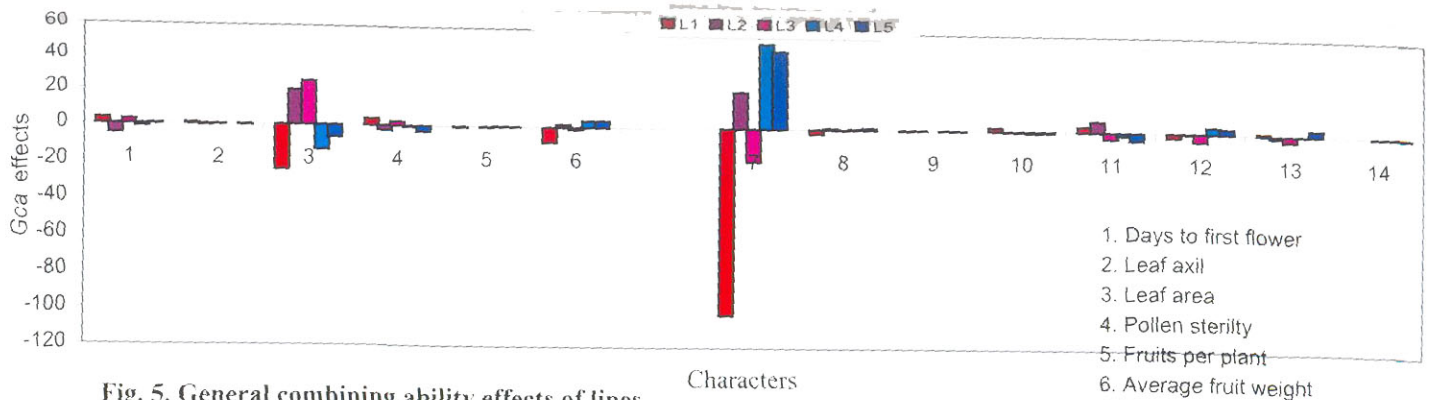


Fig. 5. General combining ability effects of lines

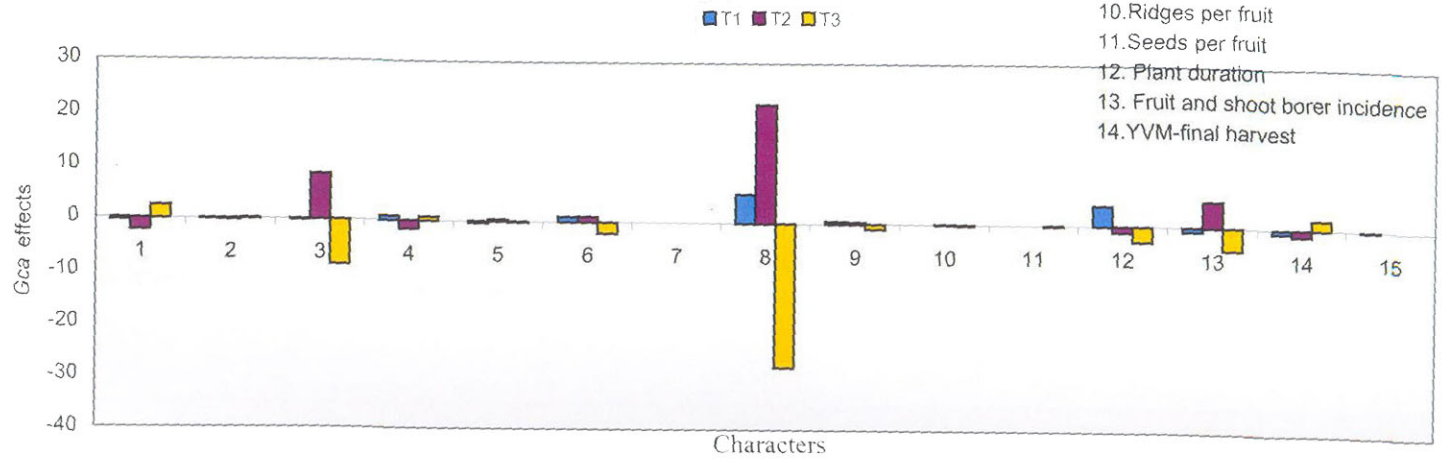


Fig. 6. General combining ability effects of testers

Table 39. Specific combining ability effects of fifteen hybrids for fourteen characters

Hybrids	Days to first flower	Leaf axil bearing of first flower	Leaf area. cm^2	Pollen sterility. %	Fruits $plant^{-1}$	Average fruit weight. g	Fruit weight $plant^{-1}$. g	Fruit length. cm	Fruit girth. cm	Ridges/ fruit	Seeds/ fruit	Plant duration	Fruit and shoot borer incidence. %	YVM -Final harvest
L_1xT_1	-1.97	0.10	8.87	-2.24	-0.25	4.73**	39.99**	0.87	0.25	0.08	-1.64	-9.50**	-3.47**	-0.03
L_1xT_2	5.15*	0.07	-17.52	1.67	-0.62**	-3.99**	-53.30**	-1.56**	-0.24	-0.28	-6.81	-6.51*	1.15	0.13
L_1xT_3	-3.17	-0.18	8.65	0.57	0.87**	-0.74	13.31	0.69	-0.01	0.20	8.46*	16.01**	2.33**	-0.10
L_2xT_1	-3.82*	-0.20	35.04**	-2.45*	1.12**	4.43**	78.54**	3.15**	0.71**	0.00	11.77**	16.17**	-1.12	-0.08
L_2xT_2	3.33	0.07	-7.25	1.17	-0.54	-0.26	-21.57	-0.70	-0.30	-0.04	-1.21	1.55	-0.10	-0.12
L_2xT_3	0.49	0.12	-27.79**	1.28	-0.58	-4.18**	-56.97**	-2.45**	-0.41	0.04	-10.55**	-17.72**	1.22	0.19
L_3xT_1	6.73**	0.08	-28.99**	4.96**	-1.65**	-5.66**	-98.07**	-3.13**	-0.89**	0.17	-11.84**	-10.71**	-0.40	0.04
L_3xT_2	-11.29**	-0.15	8.35	-1.90	0.74*	3.63**	54.49**	1.63*	0.67**	-1.53	10.41**	7.98*	1.22	0.00
L_3xT_3	4.56*	0.07	20.65*	-3.06*	0.91**	2.03*	43.58**	1.50*	0.23	-0.16	1.43	2.74	-0.82	-0.03
L_4xT_1	0.36	0.08	-25.20*	2.36	0.19	-4.50**	-45.33**	-0.06	0.06	0.00	-0.52	-3.21	5.03**	0.04
L_4xT_2	2.58	0.08	1.80	-0.99	-0.15	0.21	-1.29	-1.33*	-0.28	-0.06	-7.91*	-6.16	-0.68	0.00
L_4xT_3	-2.94	-0.16	23.40*	-1.36	-0.04	4.29**	46.62**	1.39*	0.22	0.05	8.43*	9.37**	-4.35**	-0.03
L_5xT_1	-1.29	-0.07	10.28	-2.63*	0.59	1.00	24.87*	-0.83	-0.13	-0.26	2.24	7.26*	-0.03	-0.04
L_5xT_2	0.23	0.07	14.62	0.05	0.56	0.41	24.68*	1.95**	0.16	0.39*	5.53	3.14	-1.59	0.00
L_5xT_3	1.07	0.15	-24.91*	2.58*	-1.15**	-1.41	-46.54**	-1.12	-0.03	-0.13	-7.77*	-10.40**	1.63	-0.03
SE	1.852	0.152	9.136	1.178	0.299	0.935	11.340	0.656	0.219	0.175	3.550	3.210	0.912	0.203

*-Significant at 5 % level **-Significant at 1 % level

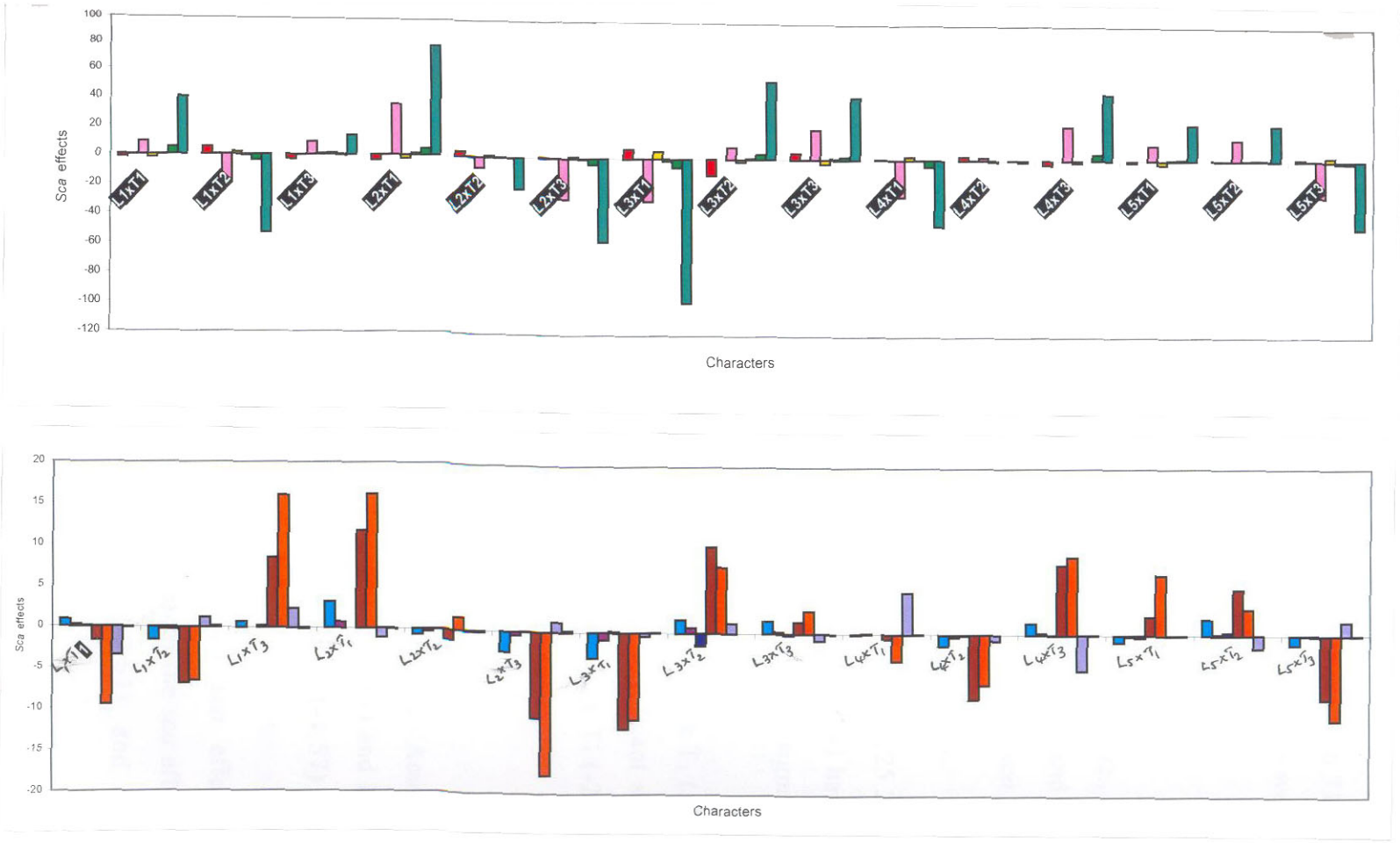


Fig. 7. Specific combining ability effects of hybrids

a. Days to first flower

Among the lines, significant *gca* effects were observed for L_1 (3.32), L_2 (-5.03), L_3 (2.55) and among the testers, T_2 (-2.17) and T_3 (2.49). Significant positive *sca* effects were exhibited by L_3 x T_1 (6.73), L_1 x T_2 (5.15), L_3 x T_3 (4.56) whereas significant negative *sca* effects were noticed for L_3 x T_2 (-11.29) and L_2 x T_1 (-3.82).

b. Leaf axil bearing first flower

Significant *gca* effects were exhibited by three lines *viz.*, L_1 (0.79), L_2 (-0.44) and L_5 (-0.23) among the lines and T_2 (-0.15) and T_3 (0.16) among the testers. None of the hybrids possessed significant *sca* effect.

c. Leaf area

Among the four lines with significant *gca* effects, L_3 (25.25) and L_2 (19.81) had positive values while L_1 (-24.62) and L_4 (-13.68) had negative values. In the tester group, T_2 (8.61) and T_3 (-8.52), had significant *gca* effects.

Positive significant *sca* effects were observed for L_2 x T_1 (35.04), L_4 x T_3 (23.40) and L_3 x T_3 (20.65) whereas negative significant *sca* effects were expressed by L_3 x T_1 (-28.99), L_2 x T_3 (-27.79), L_4 x T_1 (-25.20) and L_5 x T_3 (-24.91).

d. Pollen sterility

All the lines except L_4 exerted significant *gca* effects. Among these, L_1 (3.77) and L_3 (2.35) had positive values while L_5 (-3.13) and L_2 (-2.60) had negative values. Out of the three testers, only T_2 (-1.57) exhibited significant *gca* effect.

In the hybrid category, positively significant *sca* effects were observed for L_3 x T_1 (4.96) and L_5 x T_3 (2.58) whereas the *sca* effects were negatively significant for L_3 x T_3 (-3.06), L_5 x T_1 (-2.63) and L_2 x T_1 (-2.45).

e. Fruits plant^{-1}

Two lines *viz*., L_1 (-0.54) and L_4 (0.49) and only one tester, T_2 (0.38) possessed significant *gca* effects for fruits plant^{-1}. *Sca* effects were significant and positive for L_2 x T_1 (1.12), L_3 x T_3 (0.91), L_1x T_3 (0.87) and L_3 x T_2 (0.74) and negative for L_3 x T_1 (-1.65), L_5 x T_3 (-1.15) and L_1 x T_2 (-0.62).

f. Average fruit weight

All the lines displayed significant *gca* effects and among these, the highest positive value was noticed for L_5 (3.96) followed by L_4 (3.84) and L_2 (1.73) whereas L_1 (-8.40) and L_3 (-1.12) had negative values, T_2 (1.06) and T_1 (1.00) had positively significant *gca* effects whereas T_3 (-2.06) had negatively significant *gca* effect.

Significant positive *sca* effect was expressed by five hybrids, of which the highest was observed for L_1 x T_1 (4.73) followed by L_2 x T_1 (4.43), L_4 x T_3 (4.29), L_3 x T_2 (3.63) and L_3 x T_3 (2.03). Out of the four hybrids with significant negative *sca* effects, maximum was noticed for L_3 x T_1 (-5.66) followed by L_4 x T_1 (-4.50), L_2 x T_3 (-4.18) and L_1 x T_2 (-3.99).

g. Fruit weight plant^{-1}

For fruit weight plant^{-1} also, all the lines exhibited significant *gca* effects of which those of L_4 (52.06), L_5 (47.26) and L_2 (21.41) were in positive direction while those of L_1 (-102.33) and L_3 (-18.39) were in negative direction. T_2 (22.25) and T_3 (-27.78) exerted significant *gca* effects in opposite directions.

All the hybrids except L_1 x T_3, L_2 x T_2 and L_4 x T_2 exhibited significant *sca* effects. Among these, maximum positive *sca* effect was exhibited by L_2 x T_1 (78.54) followed by L_3 x T_2 (54.49), L_4 x T_3 (46.62), L_3 x T_3 (43.58), L_1 x T_1 (39.99), L_5 x T_1 (24.87) and minimum by L_5 x T_2 (24.68) whereas maximum negative *sca* effect was noticed for L_3 x T_1 (-98.07) followed by L_2 x T_3 (-56.97), L_1 x T_2 (-53.30), L_5 x T_3 (-46.54), L_4 x T_1 (-45.33) and L_2 x T_2 (-21.57).

h. Fruit length

Gca effect was significant and positive for L_5 (1.09) and L_2 (1.00) whereas negative for L_1 (-2.49). Among the testers, T3 (-0.90) alone exhibited significant *gca* effect.

Significant positive *sca* effect was displayed by five hybrids with the maximum being $L_2 \times T_1$ (3.15) followed by $L_5 \times T_2$ (1.95), $L_3 \times T_2$ (1.63), $L_3 \times T_3$ (1.50) and $L_4 \times T_3$ (1.39) and the hybrids with negative values were $L_3 \times T_1$ (-3.13), $L_2 \times T_3$ (-2.45), $L_1 \times T_2$ (-1.56) and $L_4 \times T_2$ (-1.33).

i. Fruit girth

Among the lines and testers, only L_1 (-0.34) displayed significant *gca* effect.

Sca effect was significant and positive for $L_2 \times T_1$ (0.71) and $L_3 \times T_2$ (0.67) and negative for $L_3 \times T_1$ (-0.89).

j. Ridges fruit^{-1}

All the lines displayed significant *gca* effects of which only L_1 (2.17) had positive value whereas maximum and minimum negative values were noticed for L_4 (-0.80) and L_2 (-0.35) respectively. Non-significant *gca* effect was observed for all the testers. The hybrids with significant *sca* effect were $L_5 \times T_2$ (0.39) and $L_3 \times T_2$ (-1.53).

k. Seeds fruit^{-1}

Significant *gca* effect was noticed for L_2 (6.39) and L_5 (-4.30) among the lines and for T_1 (3.87) among the testers.

Four hybrids *viz.*, $L_2 \times T_1$ (11.77), $L_3 \times T_2$ (10.41), $L_1 \times T_3$ (8.46) and $L_4 \times T_3$ (8.43) displayed positively significant *sca* effects whereas negative *sca* effect was observed for four crosses *viz.*, $L_3 \times T_1$ (-11.84), $L_2 \times T_3$ (-10.55), $L_4 \times T_2$ (-7.91) and $L_5 \times T_3$ (-7.77).

l. Plant duration

L_3 (-4.50) and L_4 (3.94) exhibited significant *gca* effects among the five lines while T_2 (4.99) and T_3 (-4.24) had significant *gca* effect within

the tester group. Out of the five crosses with significant negative *sca* effects, maximum and minimum values were noticed for L_2 x T_3 (-17.72) and L_1 x T_2 (-6.51) respectively whereas among the five crosses with positively significant *sca* effects, these positions were occupied by L_2 x T_1 (16.17) and L_5 x T_1 (7.26) in the respective order.

m. Fruit and shoot borer incidence

Among the three lines with significant *gca* effects, positive value was observed for L_5 (3.43), while the values were negative for L_3 (-3.18) and L_2 (-1.10). Among the testers, *gca* effect was significant and positive for L_3 (1.88) but negative for L_2 (-1.18).

The hybrids, L_4 x T_3 (-4.35) and L_1 x T_1 (-3.47) displayed negatively significant *sca* effects whereas L_4 x T_1 (5.03) and L_1 x T_3 (2.33) had positively significant *sca* effects.

n. YVM incidence during final harvest

Non-significance was observed for *gca* effects of both lines and testers and *sca* effects of hybrids for YVM incidence during final harvest. However L_1, L_2 and T_3 generally exhibited positive *gca* effects whereas L_3, L_4, L_5 and T_1 had negative *gca* effects.

4.2.4 Proportional Contribution of Parents and Hybrids

Proportional contribution of lines, testers and hybrids to the total variation in each of the fourteen characters under study are presented in Table 40 and Fig. 8.

Hybrids (59.62 %) contributed the maximum towards total variability in days to first flower while testers (11.78 %) contributed the minimum. Contribution to total variation in leaf axil bearing first flower was the highest by lines (85.29 %) while those of testers and hybrids were almost equal (7.90 % and 6.81 % respectively).

With regard to the variation in leaf area, maximum proportional contribution was observed for hybrids (48.52 %), closely followed by lines

Table 40. Proportional contribution of parents and hybrids

Sl. No.	Character	Proportional contribution		
		Lines	Testers	Hybrids
1	Days to first flower	28.60	11.78	59.62
2	Leaf axil bearing first flower	85.29	7.90	6.81
3	Leaf area	45.52	5.96	48.52
4	Pollen sterility	53.48	8.99	37.53
5	Fruits plant^{-1}	16.59	9.11	74.30
6	Average fruit weight	61.35	6.18	32.47
7	Fruit weight plant^{-1}	53.10	7.08	39.82
8	Fruit length	28.90	2.93	68.17
9	Fruit girth	20.54	3.27	76.19
10	Ridges fruit^{-1}	97.42	0.28	2.30
11	Seeds fruit^{-1}	21.20	9.73	69.07
12	Plant duration	8.49	11.85	79.66
13	Fruit and shoot borer incidence	41.48	15.70	42.82
14	YVM incidence – final harvest	23.77	8.52	67.71

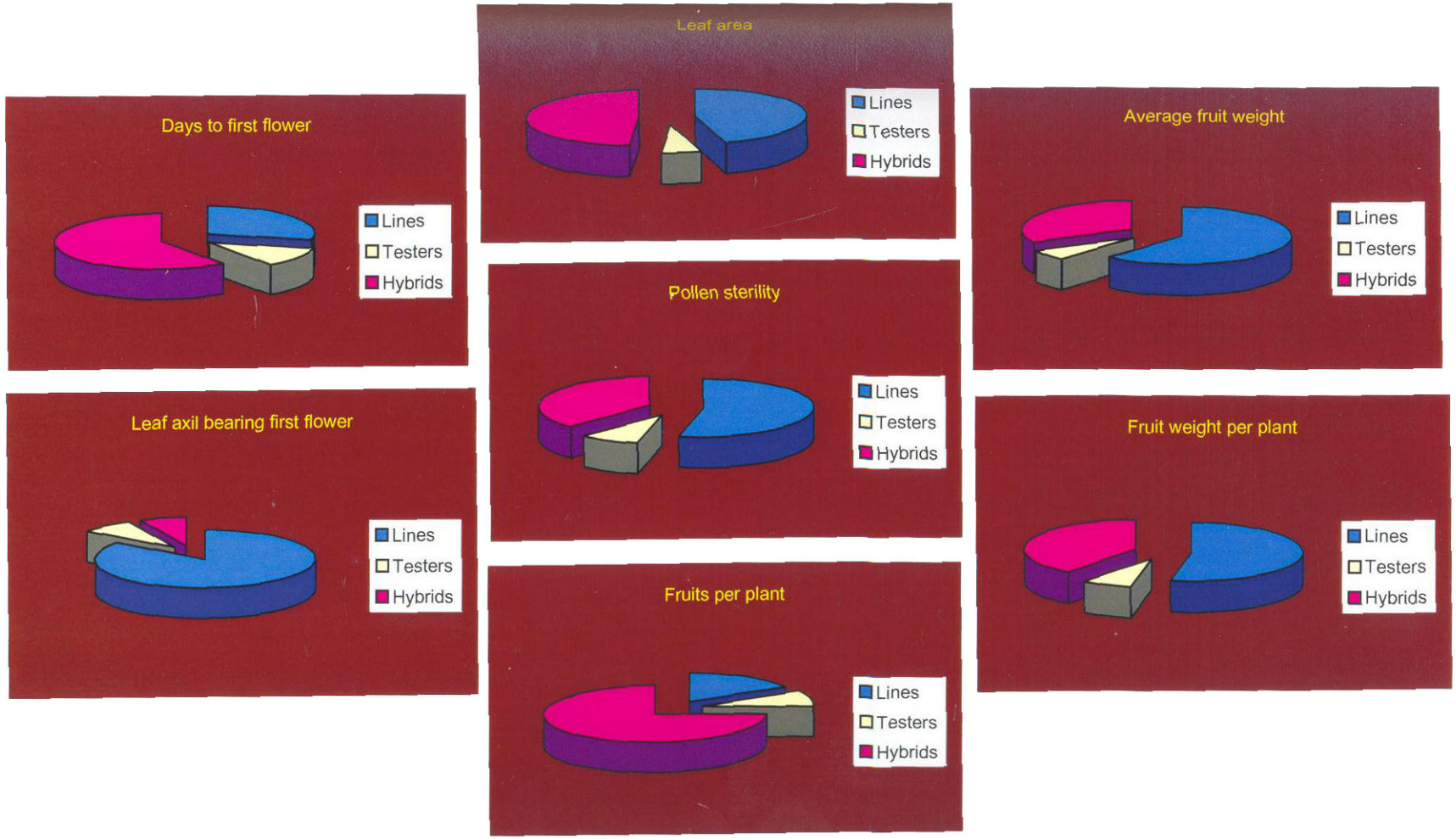


Fig. 8. Proportional contribution of parents and hybrids

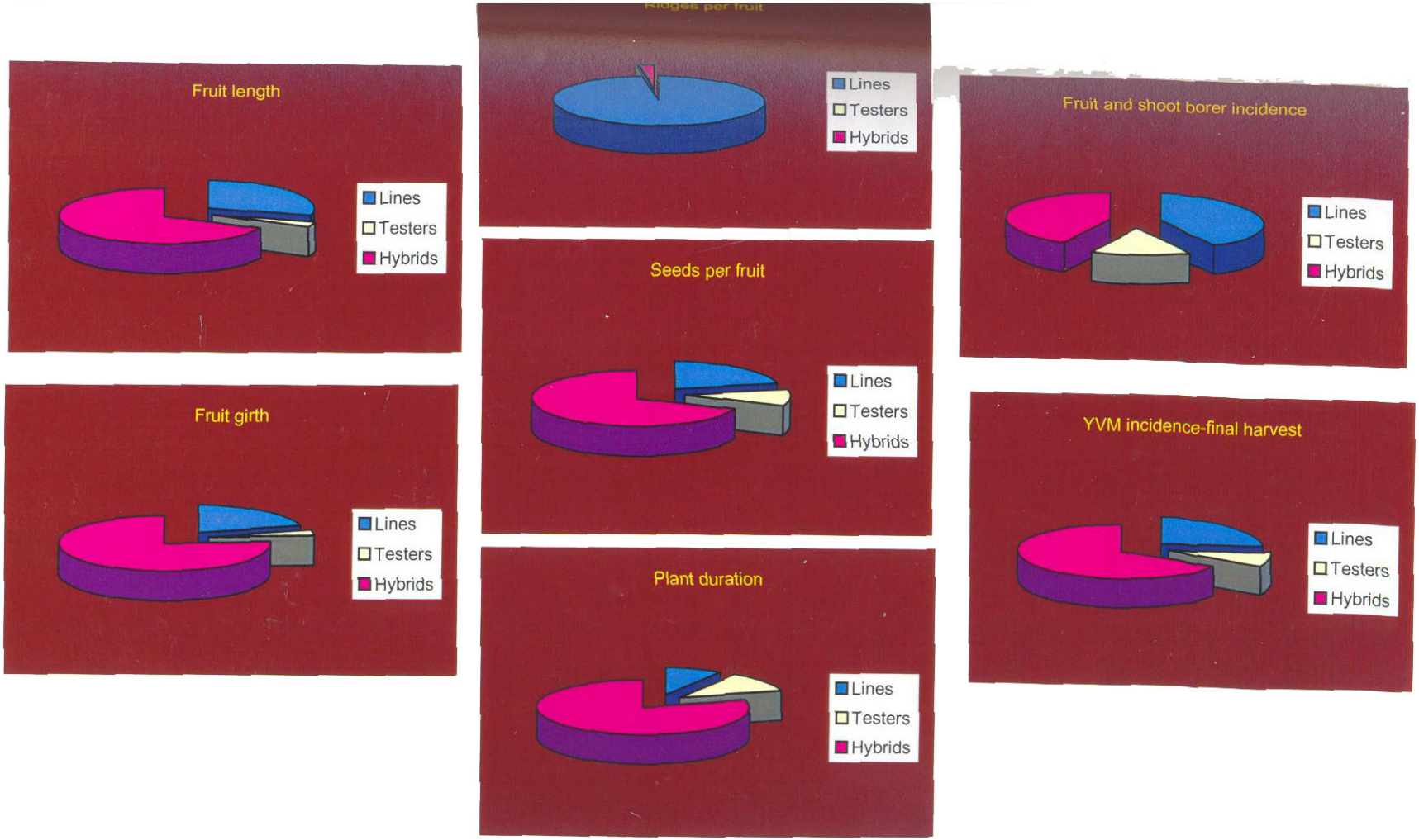


Fig. 8. Proportional contribution of parents and hybrids (Continued...)

(45.52 %) while that of testers (5.96 %) was the minimum. Half of the total variability in pollen sterility was accounted by the lines (53.48 %) followed by hybrids (37.53 %) whereas testers had the minimum proportion (8.99 %).

In the case of fruits plant^{-1}, the highest and the lowest proportions were contributed by hybrids (74.30 %) and testers (9.11 %) respectively. Proportional contribution towards the total variation in average fruit weight was maximum by the lines (61.35 %) and minimum by the testers (6.18 %) while hybrids accounted for 32.47 per cent.

For the total variability in fruit weight plant^{-1} half was the contribution of lines (53.10 %) whereas hybrids and testers had 39.82 per cent and 7.08 per cent respectively.

Regarding fruit length, hybrids (68.17 %) expressed the highest per cent contribution followed by lines (28.90 %) while testers (2.93 %) had the minimum. Of the total variability in fruit girth, 76.19 per cent was contributed by hybrids and those of lines and testers were 20.54 per cent and 3.27 per cent respectively.

In the case of ridges fruit^{-1}, most of the total variation was accounted by lines (97.42 %) while hybrids and testers contributed 2.30 per cent and 0.28 per cent respectively. Maximum proportional contribution towards the total variation in seeds fruit^{-1} was exhibited by hybrids (69.07 %) followed by lines (21.20 %) and testers (9.73 %).

Hybrids contributed maximum (79.66 %) and lines contributed minimum (8.49 %) towards the variability present in plant duration. In the case of fruit and shoot borer incidence, hybrids (42.82 %) and lines (41.48 %) exhibited almost equal proportional contribution while testers (15.70 %) had the minimum.

For YVM incidence during final harvest, maximum proportional contribution was observed for hybrids (67.71 %) followed by lines (23.77 %) and minimum for testers (8.52 %).

4.3 GENERATION MEAN ANALYSIS

Generation mean analysis was performed for the four selected crosses (Plate 10) with respect to 22 characters. The traits, fruit colour and fruit pubescence were exempted from this analysis owing to the lack of variability in them whereas two new traits *viz.*, incidence of leaf roller and leaf spot were included among the list of characters.

The results of generation mean analysis are presented in the Table 41. The fruits of six generations of the selected crosses are presented in Plate 11.

a. Days to first flower

Among the generations, the lowest and the highest means were recorded by P_2 and B_2 in cross 1, B_1 and F_2 in crosses 2 and 3 and P_1 and B_1 in cross 4. Generally, the mean values of F_1 were less than those of F_2.

Scale A was non-significant in all the crosses. Scale B exhibited significance in cross 1 indicating the presence of non-allelic interactions. Significance was observed for scale C in crosses 1 and 3 whereas for scale D in crosses 2 and 3. None of the scales was significant in cross 4 indicating the absence of epistasis.

Among the genetic components, m was significant and greater than all other effects in all the four crosses. Positively significant additive effect (d) was observed in cross 4 whereas it was negative and non-significant in the other crosses. Dominance effect (h) was negatively significant in cross 3 but non-significant in all others.

Of the interaction effects, additive x additive (i) was significant and negative in crosses 2 and 3. Additive x dominance effect (j) was present in cross 1 only whereas dominance x dominance effect (l) was observed in crosses 1 and 3 and it was higher in magnitude than other effects in the respective crosses. Opposite signs of h and l in the crosses 1 and 3 indicated the duplicate nature of epistatis.

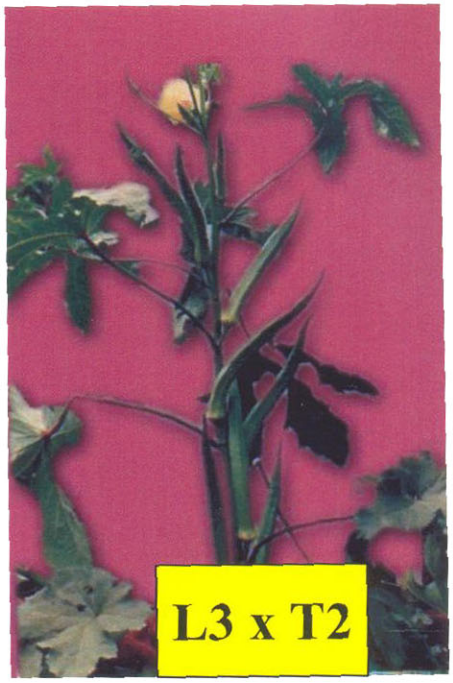


Plate 10. Selected hybrids

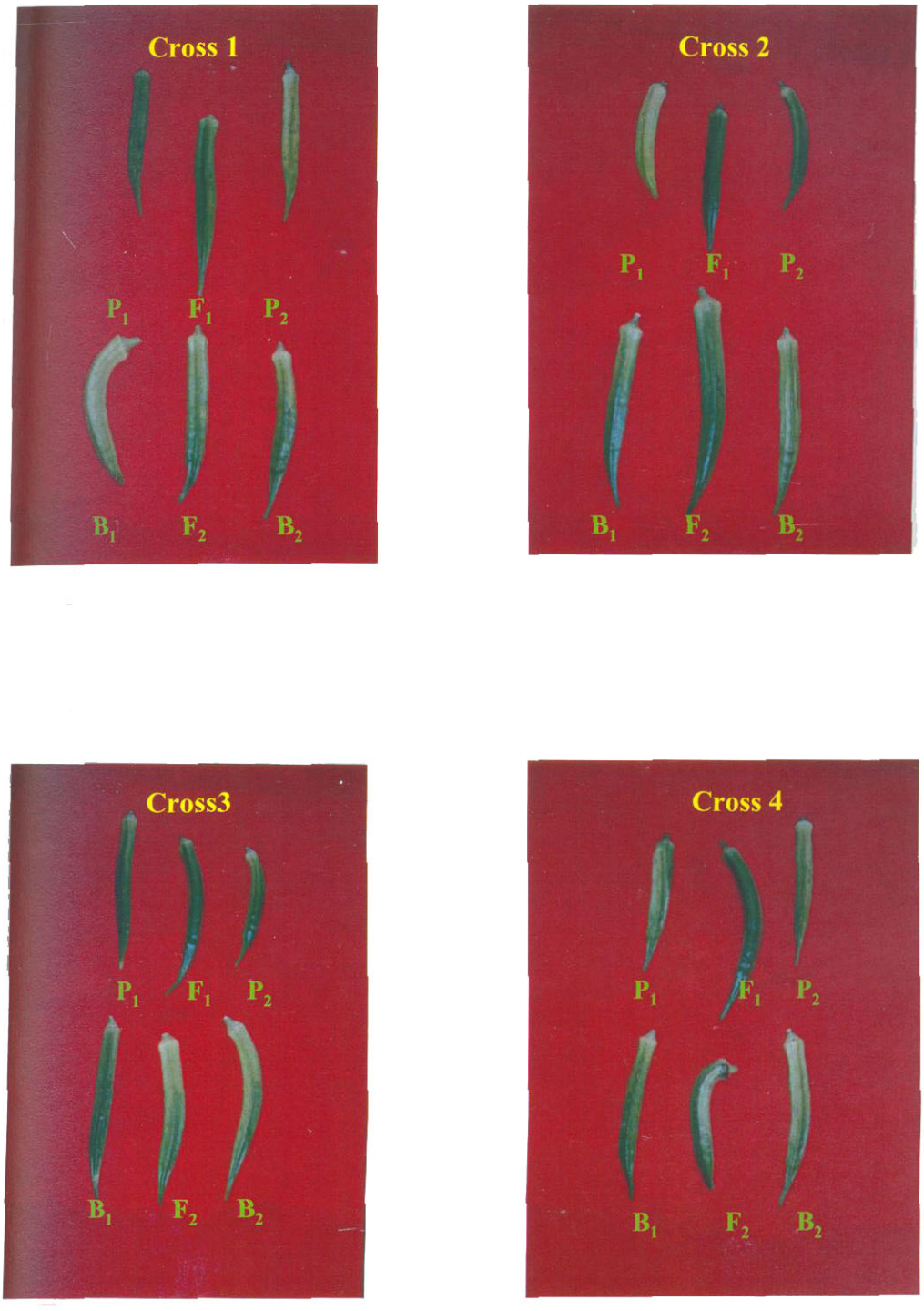


Plate 11 . Fruits of six generations in four selected crosses

Table 41. Generation means (±SE), scale values (± SE) and estimates of genetic components (± SE) in four selected crosses of okra

	Days to first flower				Leaf axil bearing first flower				Leaf area				Pollen sterility			
	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4
Generation means																
P_1	43.07 ±0.66	45.93 ±1.27	46.93 ±0.35	44.40 ±1.22	5.00 ±0.12	5.47 ±0.07	5.67 ±0.07	5.60 ±0.31	576.63 ±25.22	406.99 ±29.73	506.87 ±10.63	517.87 ±28.15	5.66 ±0.28	20.01 ±0.59	15.19 ±1.09	15.19 ±1.09
P_2	43.00 ±0.72	45.40 ±0.50	44.00 ±1.83	45.40 ±0.35	5.40 ±0.12	5.60 ±0.12	5.40 ±0.01	5.60 ±0.12	261.03 ±30.66	327.58 ±18.29	309.45 ±29.02	325.07 ±47.23	14.66 ±1.29	15.51 ±0.59	14.66 ±1.29	15.51 ±0.59
F_1	43.87 ±0.88	46.33 ±2.01	46.13 ±0.55	45.47 ±1.31	4.93 ±0.18	5.27 ±0.24	5.27 ±0.24	5.40 ±0.12	374.57 ±43.64	494.47 ±25.37	350.19 ±8.32	446.74 ±17.53	8.49 ±0.81	12.38 ±0.67	9.12 ±0.91	9.46 ±0.68
F_2	45.44 ±0.76	46.76 ±0.76	47.67 ±0.65	45.49 ±0.81	5.20 ±0.08	5.27 ±0.14	5.33 ±0.15	5.27 ±0.08	534.06 ±52.10	616.75 ±27.99	376.79 ±19.20	434.67 ±10.35	12.79 ±1.30	13.20 ±1.39	12.33 ±0.86	10.66 ±0.61
B_1	44.73 ±1.22	44.67 ±0.52	43.87 ±1.38	46.87 ±0.84	5.27 ±0.13	5.40 ±0.20	5.00 ±0.12	5.47 ±0.07	366.70 ±31.59	416.49 ±34.95	503.89 ±32.09	507.24 ±8.06	10.74 ±0.39	20.79 ±1.09	13.51 ±0.69	14.43 ±0.31
B_2	46.93 ±0.68	45.00 ±1.03	46.47 ±0.71	45.53 ±0.53	5.53 ±0.07	5.60 ±0.12	5.60 ±0.12	5.60 ±0.00	307.14 ±22.12	381.33 ±32.56	246.62 ±22.93	409.53 ±7.78	14.51 ±0.48	13.96 ±1.36	14.63 ±1.06	16.25 ±1.22
Scales																
A	2.53 ±2.68	-2.93 ±2.59	-5.33 ±2.83	3.87 ±2.45	0.60 ±0.34	0.07 ±0.47	-0.93** ±0.34	-0.07 ±0.35	-217.80** ±80.83	68.49 ±80.09	150.73* ±65.59	49.86 ±36.87	7.33** ±1.16	9.20** ±2.49	2.71 ±1.98	4.12** ±1.43
B	7.00** ±1.77	-1.73 ±2.92	2.80 ±2.38	-1.80 ±1.73	0.73** ±0.25	0.33 ±0.35	0.53 ±0.33	0.20 ±0.16	-21.32 ±69.29	-59.39 ±72.24	-166.39** ±54.91	47.24 ±52.73	5.88** ±1.81	0.03 ±2.87	5.47* ±2.65	7.43** ±2.59
C	7.97* ±3.63	3.03 ±5.21	7.47* ±2.37	1.23 ±4.37	-0.53 ±0.49	-0.53 ±0.75	-0.27 ±0.78	-0.93 ±0.51	549.44* ±229.42	743.47** ±127.78	-9.55 ±84.43	2.26 ±77.24	13.87* ±5.61	-7.48 ±5.84	1.21 ±4.25	-7.15* ±3.06
D	-0.78 ±2.06	3.85* ±1.90	5.00* ±2.02	-0.42 ±1.91	-0.40 ±0.21	-0.47 ±0.36	0.07 ±0.35	-0.53** ±0.17	394.28** ±111.11	435.67** ±73.59	3.06 ±55.05	-47.42* ±23.53	0.33 ±2.68	-8.35* ±3.28	-3.49 ±2.14	-9.35** ±1.75
Genetic components																
m	45.44** ±0.76	46.76** ±0.76	47.67** ±0.65	45.49** ±0.81	5.20** ±0.08	5.27** ±0.14	5.33** ±0.15	5.27** ±0.08	534.06** ±52.10	616.75** ±27.99	376.79** ±19.20	434.67** ±10.35	12.79** ±1.30	13.20** ±1.39	12.33** ±0.86	10.66** ±0.61
d	-2.20 ±1.40	-0.33 ±1.15	-2.60 ±1.55	2.33* ±0.99	-0.27 ±0.15	-0.20 ±0.23	-0.60** ±0.16	-0.13* ±0.07	59.56 ±38.56	35.16 ±47.77	257.27** ±39.44	97.71** ±11.20	-3.77** ±0.62	6.83** ±1.74	-1.11 ±1.27	-1.82 ±1.82
h	2.39 ±4.24	-7.03 ±4.36	-9.33* ±4.18	1.41 ±4.08	0.53 ±0.47	0.67 ±0.77	-0.40 ±0.73	0.87* ±0.39	-832.82** ±227.34	-744.15** ±150.36	-64.08 ±111.48	120.11* ±57.25	-2.34 ±5.45	11.33 ±6.63	1.17 ±4.46	12.89** ±3.62
i	1.56 ±4.12	-7.69* ±3.81	-10.00* ±4.04	- -	0.80 ±0.42	- -	-0.13 ±0.69	1.07** ±0.34	-788.56** ±222.23	-871.34** ±147.18	-6.11 ±110.09	94.84* ±47.06	-0.67 ±5.35	16.71* ±6.57	6.97 ±4.28	18.70** ±3.50
j	-2.23 ±1.48	- -	- -	- -	0.07 ±0.17	- -	-0.73** ±0.17	- -	-98.24* ±43.37	- -	158.56** ±42.36	- -	0.73 ±0.91	4.59* ±1.84	-1.38 ±1.53	-1.66 ±1.40
l	-11.09 ±6.67	- -	12.53 ±7.05	- -	-2.13** ±0.77	- -	0.53 ±1.02	- -	1027.68** ±276.45	999.21** ±229.86	21.78 ±178.95	- -	-12.54* ±6.13	-25.93** ±9.10	-15.16* ±6.62	-30.25** ±5.88
Epi	D	-	D	-	D	-	D	-	D	D	D	-	C	D	D	D

b. Leaf axil bearing first flower

The minimum and maximum means were noticed for F_1 and B_2 in cross 1 and for B_1 and P_1 in cross 3. In the case of cross 2, the lowest (F_1 and F_2), and the highest values (P_2 and B_2) were shown by two generations each while in cross 4, minimum mean was for F_2 and maximum was for three generations *viz.*, both parents and B_2. Significance was observed for scale A only in cross 3 (negative), for scale B only in cross 1 (positive) and for scale D only in cross 4 (negative). Epistasis was absent in cross 2 as indicated by the non-significant scales.

The effect m was significant and higher than all other effects in all the crosses. Negatively significant additive effect (d) could be observed in the crosses 3 and 4 while dominance effect (h) was positively significant in cross 4. Additive x additive (i) and additive x dominance (j) interactions were significant in cross 4 (positive) and cross 3 (negative) respectively while dominance x dominance (l) effect was negatively significant in cross 1. In cross 1, value of l was higher than other interactions and also d and h. The type of epistasis was duplicate as indicated by the opposite signs of h and l in crosses 1 and 3.

c. Leaf area

P_1 exhibited the highest leaf area in all the crosses except 2. Similarly, the lowest leaf area was observed for P_2 in crosses other than 3.

Significance could be noticed for scale A in cross 1 and 3 and for scale B in cross 3, denoting the presence of non-allelic interactions. The scales C and D were significant in both the crosses 1 and 3 while scale D was significant in cross 4 also.

In all the crosses, m was significant. Positively significant additive effect was observed in two crosses *viz.*, 3 and 4 whereas dominance effect was significant and positive for cross 4 but negative for the crosses 1 and 2. Significant values were displayed for additive x additive effect by the crosses 1, 2 (both negative) and 4 (positive), for additive x dominance(j)

effect by the crosses 1 (negative) and 3 (positive) and for dominance x dominance effect(l) by the crosses, 1 and 2 (both positive). Magnitude of l was higher than all other effects in the crosses 1 and 2 while in 3 and 4 crosses, m was the highest. The epistasis was duplicate in nature in all the crosses.

d. Pollen sterility

Among the generations, minimum pollen sterility (%) was displayed by P_1 in cross 1 and by F_1 in all other crosses while the maximum value was exhibited by P_2, B_1, P_1 and B_2 in the crosses 1,2,3 and 4 respectively.

Significance was noticed for scale A in cross 2 and for scale B in cross 3 while both these scales along with scale C were significant in crosses 1 and 4 also. Scale D exhibited significance in crosses 2 and 4.

The effect m was significant in all the crosses. Additive effect was significant and negative in cross 1 but positive in cross 2 whereas dominance effect was positively significant in cross 4.

Out of the interaction effects, positive significance was observed for additive x additive in crosses 2 and 4 and for additive x dominance in cross 2. Negative significance was noticed for dominance x dominance effect which was also greater than other effects in all the crosses.

Duplicate epistasis was prevalent in all the crosses except 1 in which h and l had similar signs.

e. Fruits plant^{-1}

In all the crosses, fruit number was the highest for F_1 hybrids while it was the lowest for B_2, B_1, P_1 and P_2 in the crosses 1,2,3 and 4 respectively.

The scales A and B were significant in crosses 2 and 4 and scale B was significant in cross 1 also. Though scale C exhibited significance in cross 4, scale D was non-significant in all the crosses. Since all the scales were non-significant, epistasis was absent in cross 3.

	Fruits plant^{-1}				Average fruit weight				Fruit weight plant^{-1}				Fruit length			
	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4
Generation means																
P_1	9.13 ±0.35	9.53 ±0.58	7.73 ±0.37	9.47 ±0.77	24.18 ±1.17	22.51 ±1.14	31.26 ±0.84	27.88 ±0.77	221.65 ±19.45	213.37 ±4.62	241.66 ±12.82	264.93 ±28.40	16.45 ±0.21	13.89 ±0.44	18.48 ±0.15	19.28 ±0.51
P_2	10.40 ±0.64	11.07 ±0.47	10.53 ±0.48	11.33 ±0.87	21.21 ±0.50	24.85 ±2.01	20.35 ±0.15	24.36 ±1.25	230.57 ±14.54	276.70 ±33.31	244.18 ±8.32	277.27 ±32.28	18.85 ±0.15	17.79 ±0.29	18.81 ±0.26	18.44 ±0.47
F_1	12.07 ±0.67	13.20 ±1.10	11.33 ±0.44	15.93 ±0.66	30.16 ±2.77	30.11 ±0.91	32.91 ±1.60	36.22 ±1.10	362.57 ±30.21	395.52 ±21.72	374.03 ±30.80	577.89 ±36.58	21.33 ±0.41	18.09 ±0.85	21.64 ±0.13	22.07 ±0.23
F_2	10.80 ±0.42	10.51 ±0.67	11.04 ±0.75	11.43 ±0.70	33.10 ±0.90	39.17 ±1.95	35.73 ±1.31	29.38 ±0.46	356.91 ±9.93	414.33 ±47.58	394.57 ±31.01	336.38 ±24.57	19.14 ±0.13	17.99 ±0.24	19.61 ±0.53	20.40 ±0.70
B_1	10.80 ±0.69	9.47 ±0.57	9.93 ±0.81	10.80 ±0.50	35.54 ±0.91	33.29 ±1.02	33.21 ±1.82	32.22 ±0.88	384.83 ±33.39	316.26 ±28.76	328.39 ±23.56	347.14 ±7.50	18.65 ±0.40	18.52 ±0.20	19.71 ±0.09	18.33 ±0.49
B_2	8.93 ±0.47	10.53 ±0.48	10.73 ±0.52	11.60 ±0.76	29.29 ±0.57	32.91 ±1.10	35.32 ±1.45	32.31 ±1.12	262.19 ±18.59	347.49 25.72	378.05 ±13.71	373.78 ±20.63	19.13 ±0.28	18.39 ±0.63	19.43 ±0.28	19.99 ±0.50
A	0.40 ±1.58	-3.80* ±1.69	0.80 ±1.72	-3.80** ±1.43	16.74** ±3.51	13.96** ±3.12	2.26 ±4.07	0.34 ±2.21	185.43* ±75.83	23.63 ±61.65	41.09 ±57.73	-148.53** ±48.67	-0.49 ±0.92	5.05** ±1.04	-0.71** ±0.28	-4.69** ±1.13
B	-4.60** ±1.31	-3.20* ±1.53	-0.40 ±1.23	-4.07* ±1.86	7.21* ±3.03	10.85** ±3.12	17.39** ±3.32	4.03 ±2.80	-58.76 ±50.06	22.77 ±65.01	167.88** ±42.07	-107.60 ±63.90	-0.93 ±0.71	0.91 ±1.55	-0.58 ±0.63	-0.52 ±1.13
C	-0.47 ±2.27	-4.96 ±3.56	3.24 ±3.19	-6.93* ±3.30	26.67** ±6.72	49.10** ±8.33	25.51** ±6.21	-7.18* ±3.22	260.29** ±76.26	376.22 ±198.10	374.39** ±139.34	-352.48** ±129.84	-0.41 ±1.01	4.10* ±2.04	-1.11 ±2.15	-0.27 ±2.94
D	1.87 ±1.19	1.02 ±1.54	1.42 ±1.79	0.47 ±1.67	1.36 ±2.09	12.15** ±4.18	2.93 ±3.51	-5.77** ±1.69	66.81 ±43.06	164.91 ±102.69	82.71 ±67.75	-48.17 ±53.82	0.51 ±0.55	-0.93 ±0.82	0.09 ±1.10	2.47 ±1.58
m	10.80** ±0.42	10.51** ±0.67	11.04** ±0.75	11.43** ±0.70	33.10** ±0.90	39.17** ±1.95	35.73** ±1.31	29.38** ±0.46	356.91** ±9.93	414.33** ±47.58	394.57** ±31.01	336.38** ±24.57	19.14** ±0.13	17.99** ±0.24	19.61** ±0.53	20.40** ±0.70
d	1.87* ±0.84	-1.07 ±0.75	-0.80 ±0.96	-0.80 ±0.91	6.25** ±1.07	0.39 ±1.50	-2.11 ±2.33	-0.09 ±1.43	122.63** ±38.21	-31.23 ±38.58	-49.66 ±27.26	-26.64 ±21.95	-0.48 ±0.48	0.12 ±0.66	0.27 ±0.29	-1.67* ±0.70
h	-1.43 ±2.49	0.86 ±3.29	-0.64 ±3.61	4.60 ±3.45	4.74 ±5.06	-17.86* ±8.48	1.24 ±7.21	21.65** ±3.64	7.85 ±92.07	-179.33 ±207.20	-19.31 ±139.16	403.13** ±115.70	3.17** ±1.19	4.12* ±1.87	3.32 ±2.20	-1.74 ±3.18
i	-3.73 ±2.37	-2.04 ±3.08	- -	-0.93 ±3.34	-2.72 ±4.18	-24.29** ±8.35	-5.87 ±7.02	11.55** ±3.39	-133.61 ±86.13	- -	-165.42 ±135.50	96.34 ±107.64	- -	1.86 ±1.65	-0.17 ±2.19	-4.95 ±3.15
j	2.50** ±0.91	-0.30 ±0.83	- -	0.13 ±1.08	4.76** ±1.25	1.56 ±1.90	-7.56** ±2.37	- -	122.10** ±40.10	- -	-63.40* ±28.31	-20.47 ±30.73	- -	2.07** ±0.71	-0.06 ±0.33	-2.09** ±0.78
l	7.93* ±4.04	9.04 ±4.64	- -	8.80 ±4.91	-21.23** ±7.97	-0.51 ±10.27	-13.78 ±11.20	-15.91* ±6.55	6.94 ±170.83	- -	-43.55 ±176.92	159.80 ±156.74	- -	-7.82* ±3.34	1.46 ±2.45	10.16* ±4.07
Epi	D	C	-	C	D	C	D	D	C	-	C	C	-	D	C	D

All the crosses exhibited significance for m. Cross 1 displayed positively significant d, j and l effects whereas the other three crosses showed significance for none of the genetic effects. In all the crosses, m was the highest in magnitude followed by l. The cross 1 displayed duplicate epistasis while 2 and 4 were with complementary epistasis.

f. Average fruit weight

Maximum value of average fruit weight was observed for B_1 in cross 1, F_2 in both the crosses 2 and 3 and for F_1 in cross 4. Average fruit weight was minimum for P_2 in all the crosses except 2 in which P_1 had the minimum value.

Significance was noticed for both the scales A and B in crosses 1 and 2 while scale B was significant also in cross 3. Scale C exhibited significance in all the crosses whereas scale D was significant in crosses 2 and 4.

Significance was observed for m in all the crosses and it was also the highest in magnitude. Additive effect was positively significant in cross 1 only while dominance effect was positively significant in cross 4 and negatively significant in cross 2.

In all the four crosses, m was significant. For additive effect, significance was noticed in cross 1 only while dominance effect was significant and positive in cross 4 but negative in cross 2.

Additive x additive interaction was significant and positive in cross 4 and negative in cross 2. Positively significant additive x dominance effect was noticed in cross 1 while it was negative in cross 3 and absent in cross 4. Dominance x dominance effect was negatively significant in crosses 1 and 4. The l effect was higher in the crosses 1 and 3 while i and h were greater in crosses 2 and 4 respectively.

Epistasis was duplicate in all the crosses except 2 in which complementary epistatis existed.

g. Fruit weight plant^{-1}

The highest fruit weight plant^{-1} was exhibited by B_1 in cross 1, F_2 in crosses 2 and 4 and F_1 in cross 4 whereas P_1 exhibited the lowest value in all the crosses.

Scale A was significant in crosses 1 and 4 and scale B showed significance only in cross 3. Significance was observed for scale C in all the crosses except 2 and scale D in none of the crosses. Cross 2 had no epistatic effect as denoted by the non-significance of all the scales.

In all the crosses (except in cross 4) m exhibited significance and higher magnitude. Significance was observed for additive effect (positive) in cross 1, dominance effect (positive) in cross 4 and for additive x dominance interaction in crosses 1 (positive) and 3 (negative). The highest values of i were observed in all the crosses other than 4 in which h was the highest. Similar signs of h and l revealed complementary epistasis in all the crosses except 2 which had duplicate epistasis.

h. Fruit length

In three crosses *viz*., 1, 3 and 4 the longest fruits were observed in F_1 while in cross 2, B_1 had the longest fruits. Minimum fruit length was exhibited by P_1 in crosses 1, 2 and 3 and by B_1 in cross 4.

Significance was observed for scale A in all the crosses except 1 and for scale C in cross 2. No epistasis was noticed in cross 1.

In all the crosses, m was significant and higher in magnitude. Significance was noticed for additive effect in cross 4 (negative), dominance effect in crosses 1 and 2 (both positive), additive x dominance effect in crosses 2 (positive) and 4 (negative) and for dominance x dominance effect in crosses 2 (negative) and 4 (positive). Values were higher for h in cross 3 and for l in crosses 2 and 4. Complementary epistasis was observed in cross 3 while duplicate epistasis was displayed by the crosses 2 and 4.

i.Fruit girth

Maximum and minimum values of fruit girth were observed respectively for P_1 and F_2 in cross 1, F_2 and P_2 in cross 2, F_1 and P_2 in cross 3 and F_1 and B_1 in cross 4.

Significance was noticed for scale A in crosses 1 and 4, scale B in cross 4, scale C in 1 and 2 and for scale D in cross 4. Epistasis was totally absent in cross 3 while only dominance x dominance effect was observed in cross 2.

In all the crosses, m was significant and greater in magnitude. Additive and dominance effects were not significant in any of the crosses. Among the interactions, both additive x additive (negative) and dominance x dominance (positive) registered significance in cross 4 while additive x dominance effect was significant only in cross 1 (negative). Higher magnitude was observed for h in cross 1 and for l in crosses 2 and 4. Epistasis was revealed to be complementary in crosses 1 and 2 while duplicate in 4.

j.Ridges $fruit^{-1}$

The highest number of ridges was noticed for B_1 in cross 1 and for B_2 in the other crosses while the lowest value was noticed for P_1 in crosses 1 and 2, B_1 in cross 3 and for P_1 and F_1 in cross 4.

Scales A and D were significant in crosses 1 and 3 and scale B was significant in crosses 3 and 4. In all the crosses, m showed significance and higher magnitude. Cross 1 exhibited significance for h, i and l effects while cross 3 displayed significance for all the genetic effects except j. None of the effects registered significance in cross 4. Generally, l values were higher than the others. In all the crosses, epistatsis was duplicate in nature while it was absent in cross 2.

	Fruit girth				Ridges fruit^{-1}				Seeds fruit^{-1}				Plant duration			
	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4
Generation means																
P_1	6.46 ±0.17	6.23 ±0.27	6.37 ±0.23	6.61 ±0.08	5.00 ±0.00	5.07 ±0.07	5.07 ±0.07	5.00 ±0.00	56.07 ±0.37	48.67 ±0.74	59.93 ±1.27	50.33 ±4.26	115.80 ±0.87	109.47 ±0.48	106.87 ±0.59	106.27 ±0.52
P_2	5.73 ±0.10	5.74 ±0.21	5.79 ±0.06	6.25 ±0.10	5.33 ±0.13	5.27 ±0.13	5.33 ±0.07	5.13 ±0.13	56.40 ±2.08	50.40 ±1.45	54.27 ±0.44	51.27 ±1.39	120.73 ±0.68	107.33 ±0.37	113.20 ±2.62	107.67 ±0.59
F_1	6.37 ±0.08	6.06 ±0.11	7.00 ±0.14	6.94 ±0.05	5.19 ±0.12	5.27 ±0.13	5.27 ±0.07	5.00 ±0.00	53.61 ±4.07	52.20 ±2.91	51.00 ±0.24	53.00 ±2.14	125.60 ±1.21	113.87 ±0.52	121.33 ±0.24	114.87 ±0.74
F_2	5.56 ±0.16	6.51 ±0.17	6.82 ±0.12	6.37 ±0.22	5.20 ±0.07	5.11 ±0.06	5.21 ±0.03	5.30 ±0.16	52.75 ±2.62	49.82 ±1.13	48.99 ±1.24	54.14 ±1.17	121.87 ±2.07	123.16 ±0.22	123.55 ±1.72	119.07 ±2.25
B_1	5.67 ±0.13	6.43 ±0.18	6.60 ±0.14	5.77 ±0.14	5.60 ±0.12	5.13 ±0.07	5.00 ±0.00	5.34 ±0.25	51.07 ±1.65	58.24 ±3.39	47.00 ±1.33	46.40 ±1.40	113.80 ±2.08	111.40 ±1.33	106.73 ±0.55	107.13 ±1.65
B_2	5.95 ±0.20	6.27 ±0.23	6.55 ±0.10	5.96 ±0.19	5.40 ±0.20	5.33 ±0.18	5.67 ±0.07	5.60 ±0.12	50.40 ±1.29	54.27 ±0.55	52.53 ±0.33	51.60 ±2.09	122.60 ±0.92	114.87 ±3.27	109.07 ±0.37	106.93 ±1.05
A	-1.48** ±0.32	0.57 ±0.46	-0.17 ±0.39	-2.01** ±0.29	1.01** ±0.26	-0.07 ±0.20	-0.33** ±0.09	0.69 ±0.59	-7.54 ±5.26	15.62* ±7.42	16.93** ±3.81	-10.53 ±5.53	-13.80** ±4.41	-0.53 ±2.76	-14.73** ±1.26	-6.87* ±3.42
B	-0.20 ±0.42	0.75 ±0.52	0.32 ±0.25	-1.27** ±0.39	0.28 ±0.44	0.13 ±0.40	0.73** ±0.16	1.07** ±0.27	-9.21 ±5.25	5.93 ±3.43	-0.20 ±2.54	-1.07 ±4.89	-1.13 ±2.30	8.53 ±6.56	-16.40** ±2.74	-8.67** ±2.30
C	-2.68** ±0.71	1.95* ±0.79	1.11 ±0.61	-1.28 ±0.89	0.10 ±0.38	-0.44 ±0.38	-0.09 ±0.21	1.05 ±0.64	-8.67 ±13.43	-4.17 ±7.56	-20.23** ±7.04	8.95 ±7.75	-0.27 ±8.68	48.12** ±1.48	31.48** ±7.39	32.63** ±9.15
D	-0.50 ±0.41	0.32 ±0.45	0.48 ±0.30	1.00* ±0.50	-0.59* ±0.27	-0.25 ±0.22	-0.25** ±0.09	-0.35 ±0.42	4.04 ±4.63	-12.86** ±4.11	-1.55 ±2.83	10.27** ±3.43	7.33 ±4.71	20.06** ±3.55	31.31** ±3.50	24.08** ±4.90
m	5.56** ±0.16	6.51** ±0.17	6.82** ±0.12	6.37** ±0.22	5.20** ±0.07	5.11** ±0.06	5.21** ±0.03	5.30** ±0.16	52.75** ±2.62	49.82** ±1.13	48.99** ±1.24	54.14** ±1.17	121.87** ±2.07	123.16** ±0.22	123.55** ±1.72	119.07** ±2.25
d	-0.27 ±0.24	0.15 ±0.29	0.05 ±0.17	-0.19 ±0.24	0.20 ±0.23	-0.20 ±0.19	-0.67** ±0.07	-0.26 ±0.28	0.67 ±2.09	3.98 ±3.43	-5.53** ±1.37	-5.20* ±2.52	-8.80** ±2.27	-3.47 ±3.53	-2.33** ±0.66	0.20 ±1.96
h	1.27 ±0.82	-0.56 ±0.92	-0.04 ±0.62	-1.49 ±1.00	1.21* ±0.55	0.61 ±0.46	0.56** ±0.20	0.63 ±0.84	-10.70 ±12.03	28.39** ±8.76	-3.01 ±6.19	-18.35* ±7.53	-7.33 ±9.52	-34.65** ±7.13	-51.31** ±7.13	-40.26** ±9.84
i	1.00 ±0.81	- -	- -	-2.00* ±0.99	1.19* ±0.53	- -	0.49** ±0.19	0.70 ±0.84	- -	25.73** ±8.23	3.09 ±5.66	-20.55** ±6.86	-14.67 ±9.43	-40.12** ±7.11	-62.61** ±7.00	-48.16** ±9.81
j	-0.64* ±0.26	- -	- -	-0.37 ±0.24	0.37 ±0.24	- -	-0.53 ±0.08	-0.19 ±0.28	- -	4.84 ±3.53	-8.37** ±1.53	- -	-6.33** ±2.34	- -	0.83 ±1.50	0.90 ±1.99
l	0.68 ±0.19	-0.67 ±1.41	- -	5.28** ±1.29	-2.47* ±1.00	- -	0.89** ±0.34	-2.45 ±1.28	- -	-47.28** ±15.67	14.04 ±8.93	- -	29.60* ±12.56	32.12* ±14.19	93.75** ±7.85	63.69** ±12.04
Epi	C	C	-	D	D	-	D	D	-	D	D	-	D	D	D	D

k.Seeds fruit^{-1}

Maximum and minimum values of seed number were observed respectively for P_2 and B_2 in cross 1, B_1 and P_1 in cross 2, P_1 and B_1 in cross 3 and F_2 and B_1 in cross 4.

Among the scales, significance was recorded for A in crosses 2 and 3, B in none of the crosses, C in cross 3 and for D in crosses 2 and 4. All the scales were non-significant in cross 1 revealing the absence of epistasis. In cross 4, significance of only scale D indicated that additive x additive interaction alone was present.

The effect m was significant in all the crosses. Additive effect was negatively significant in crosses 3 and 4 whereas dominance effect was significant and positive in cross 2 but negative in cross 4. Additive x additive effect exhibited significance in cross 2 (positive) and 4 (negative). Negative significance was noticed for additive x dominance effect in cross 3 and for dominance x dominance effect in cross 2. In crosses 2 and 3, l effects were higher in magnitude and the epistasis was duplicate in nature.

l. Plant duration

Plant duration was minimum for B_1 in crosses 1 and 3, P_2 in cross 2 and P_1 in cross 4 whereas maximum value was observed for F_1 in cross 1 and for F_2 in all other crosses.

All the four scales were significant in crosses 3 and 4. In addition, scale A was significant in cross 1 and the scales C and D were significant in cross 2.

Significance was observed for m and l in all the crosses, d in crosses 1 and 3, h and l in crosses 2,3 and 4 and for j in cross 1. In all the crosses m was the highest in magnitude, followed by l in crosses other than 2 in which i was the highest. All the crosses exhibited duplicate epistasis.

m.Crude fibre content

Minimum and maximum values for this trait were noticed respectively in P_1 and P_2 in cross 1, F_1 and B_1 in cross 2 and B_1 and P_2 in cross 3 while in cross 4 minimum value was in B_1 and maximum in both P_2 and B_2 generations

The only scale which exhibited significance was scale A in crosses 2 and 3 indicating the presence of non-allelic interactions in these crosses. No epistatic effect was observed in crosses 1 and 4.

The effect m was significant and higher in all the crosses. Negatively significant values were observed for additive effect in all crosses except 2 and for additive x dominance effect in cross 3 whereas other effects were not significant in any of the crosses. However, in cross 2, dominance x dominance effect was maximum in magnitude while in cross 3, dominance effect was the highest. Duplicate epistasis was observed in crosses 2 and 3.

n. Protein content

The highest value for protein content was observed for B_1 in crosses 1 and 2, for P_2 in cross 3 and for F_1 in cross 4 and the lowest value was for F_2 in crosses 1 and 4 and for B_2 in crosses 2 and 3.

Scale A exhibited significance in crosses 3 and 4, scale B in cross 3, scale C in all crosses and scale D in crosses other than 2.

Significance could be noticed in all the crosses for m which was also higher in magnitude in crosses 1 and 2. All the genetic effects were significant in crosses 3 and 4 while significant positive values were observed for d in cross 2 and for i in cross 1 apart from m. Higher magnitude was noticed for the effect l except in crosses 1 and 2. The crosses under evaluation had duplicate type of epistatsis.

Table 41 (Continued..)

	Crude fibre content				Protein content				Mucilage content				Fruit and shoot borer			
	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4
Generation means																
P_1	1.47 ±0.09	2.27 ±0.18	1.40 ±0.12	1.43 ±0.09	1.35 ±0.04	1.25 ±0.11	1.69 ±0.03	1.65 ±0.08	1.53 ±0.29	1.07 ±0.07	1.60 ±0.31	1.53 ±0.29	16.12 ±1.01	17.02 ±0.67	13.00 ±0.65	11.56 ±1.40
P_2	2.80 ±0.12	2.17 ±0.12	2.63 ±0.09	2.17 ±0.09	1.21 ±0.02	1.23 ±0.06	2.01 ±0.06	1.86 ±0.04	1.67 ±0.18	1.93 ±0.07	1.33 ±0.18	2.00 ±0.12	12.08 ±0.99	9.05 ±0.96	12.28 ±0.85	9.67 ±0.62
F_1	2.03 ±0.09	1.90 ±0.10	2.00 ±0.12	2.03 ±0.12	1.10 ±0.05	1.31 ±0.04	1.36 ±0.06	2.19 ±0.08	1.60 ±0.23	1.93 ±0.07	1.33 ±0.18	1.27 ±0.27	8.07 ±1.53	8.33 ±0.64	6.45 ±0.49	9.53 ±1.09
F_2	2.10 ±0.15	2.17 ±0.09	1.93 ±0.18	1.97 ±0.09	1.09 ±0.04	1.38 ±0.04	1.84 ±0.07	0.72 ±0.03	2.00 ±0.12	2.80 ±0.12	1.20 ±0.12	1.93 ±0.07	7.68 ±0.81	8.34 ±0.78	6.46 ±1.06	9.07 ±0.68
B_1	1.53 ±0.18	2.37 ±0.09	0.33 ±0.09	1.40 ±0.17	1.37 ±0.11	1.42 ±0.05	1.02 ±0.06	2.18 ±0.03	2.07 ±0.07	1.07 ±0.07	1.67 ±0.24	1.53 ±0.29	10.54 ±1.47	9.85 ±0.76	6.15 ±1.92	6.43 ±0.72
B_2	2.47 ±0.18	2.13 ±0.09	2.47 ±0.09	2.17 ±0.12	1.15 ±0.05	1.19 ±0.03	0.69 ±0.05	1.93 ±0.05	1.20 ±0.31	1.13 ±0.07	1.33 ±0.24	1.27 ±0.18	12.07 ±0.15	3.97 ±0.34	9.92 ±1.61	9.63 ±0.40
A	-0.43 ±0.37	0.57* ±0.27	-0.73** ±0.24	-0.67 ±0.38	0.29 ±0.23	0.28 ±0.15	-1.00** ±0.13	1.22** ±0.13	1.00* ±0.39	-0.87** ±0.16	0.40 ±0.60	0.27 ±0.70	-3.11 ±3.46	-5.65** ±1.79	-7.15 ±3.92	0.24 ±2.28
B	0.10 ±0.38	0.20 ±0.24	0.30 ±0.23	0.13 ±0.28	-0.01 ±0.12	0.15 ±0.10	-1.99** ±0.13	-0.19 ±0.13	-0.87 ±0.68	-1.60** ±0.16	0.00 ±0.54	-0.73 ±0.46	3.98* ±1.85	-9.43** ±1.34	1.11 ±3.36	0.05 ±1.49
C	0.07 ±0.65	0.43 ±0.46	-0.30 ±0.76	0.20 ±0.44	-0.40* ±0.18	0.42* ±0.21	0.96** ±0.32	-4.33** ±0.22	1.60* ±0.74	4.33** ±0.49	-0.80 ±0.68	1.67* ±0.67	-13.63** ±4.67	-9.36** ±3.57	-12.33** ±4.48	-4.03 ±3.79
D	0.20 ±0.39	-0.17 ±0.22	0.07 ±0.37	0.37 ±0.27	0.34* ±0.14	0.14 ±0.09	1.97** ±0.16	-2.68** ±0.08	0.73 ±0.39	3.40** ±0.25	-0.60 ±0.41	1.07** ±0.37	-7.25** ±2.19	2.86 ±1.77	-3.14 ±3.28	-1.92 ±1.58
m	2.10** ±0.15	2.17** ±0.09	1.93** ±0.18	1.97** ±0.09	1.09** ±0.04	1.38** ±0.04	1.84** ±0.07	0.72** ±0.03	2.00** ±0.12	2.80** ±0.12	1.20** ±0.12	1.93** ±0.07	7.68** ±0.81	8.34** ±0.78	6.46** ±1.06	9.07** ±0.68
d	-0.93** ±0.25	0.23 ±0.12	-1.13** ±0.12	-0.77** ±0.21	0.22 ±0.12	0.23** ±0.06	0.33** ±0.07	0.25** ±0.06	0.87** ±0.31	-0.07 ±0.09	0.33 ±0.34	0.27 ±0.34	-1.53 ±1.48	5.88** ±0.84	-3.78 ±2.50	0.80 ±0.82
h	-0.50 ±0.80	0.02 ±0.46	-0.15 ±0.76	0.50 ±0.57	0.50 ±0.29	-0.21 ±0.20	-4.44** ±0.33	6.14** ±0.18	-1.47 ±0.83	-6.37** ±0.51	1.07 ±0.86	-2.63** ±0.79	-8.48** ±4.69	-10.42** ±3.65	0.10 ±6.59	2.77 ±3.44
i	- -	0.33 ±0.43	-0.13 ±0.75	- -	0.68* ±0.29	- -	-3.95** ±0.33	5.35** ±0.16	-1.47 ±0.78	-6.80** ±0.50	- -	-2.13** ±0.73	14.51** ±4.37	-5.71 ±3.54	- -	- -
j	- -	0.18 ±0.16	-0.52** ±0.14	- -	- -	- -	0.49** ±0.08	0.70** ±0.07	0.93** ±0.36	0.37** ±0.11	- -	- -	-3.55** ±1.64	1.89 ±1.02	- -	- -
l	- -	-1.10 ±0.68	0.57 ±0.91	- -	0.96 ±0.52	0.16 ±0.31	6.94** ±0.44	-6.38** ±0.31	1.33 ±1.45	9.27** ±0.62	- -	2.60 ±1.52	-15.38* ±7.53	20.79** ±4.89	-0.25 ±10.96	- -
Epi	-	D	D	-	D	D	D	D	D	D	-	D	D	D	D	-

o. Mucilage content

Maximum content of mucilage was observed for B_1 in crosses 1 and 3, F_2 in cross 2 and P_2 in cross 4 whereas minimum value was for B_2 in cross 1, P_1 and B_1 in cross 2, F_2 in cross 3 and F_1 in cross 4.

Significance could be observed for scale A in crosses 1 and 2,for scale B in cross 2, for scale C in all crosses except 3 and for scale D in crosses 2 and 4.

In all the crosses, m was significant. Positively significant d was noticed in cross 1 while h and i were negatively significant in crosses 2 and 4. Significant positive values were observed for j in crosses 1 and 2 and l in cross 2. Epistasis was absent in cross 3 and of duplicate type in all the crosses. In magnitude, h and i exceeded the other effects in cross 1, l in cross 2 and h in cross 4.

p.Fruit and shoot borer incidence

Minimum borer incidence was noticed for F_2 in crosses 1 and 4, F_1 in cross 2 and B_1 in crosses 3 and 4 whereas maximum incidence was for P_1 in all the crosses.

Significance was exhibited by scale A in cross 2, scale B in crosses 1 and 2, scale C in crosses 1, 2 and 3 and for scale D in cross 1.

The effect m was noticed to be significant in all the crosses. All the interaction effects were significant in cross 1 while l was significant in cross 2 also. Epistasis was absent in cross 4.

Higher magnitude was observed for l in crosses 1 and 2 and for m in the other two crosses. Duplicate epistasis could be noticed in all the crosses in which it existed.

q.YVM incidence at 30 DAS

Minimum value for disease incidence was observed for all the generations in all crosses except for P_1 in cross 1 and F_2 in crosses 3 and 4.

Table 41 (Continued..)

	YVM-30 DAS				YVM 50 DAS				YVM-70 DAS				YVM final harvest			
	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4
Generation means																
P_1	1.20 ±0.12	1.00 -	1.00 -	1.00 -	1.40 ±0.23	1.00 -	1.00 -	1.00 -	1.87 ±0.41	1.27 ±0.18	1.00 -	1.20 ±0.12	2.67 ±0.41	2.00 ±0.42	1.40 ±0.31	1.80 ±0.42
P_2	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -
F_1	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -
F_2	1.00 -	1.00 -	1.02 -	1.02 ±0.02	1.02 ±0.02	1.02 ±0.02	1.07 ±0.04	1.07 -	1.18 ±0.08	1.11 ±0.06	1.36 ±0.11	1.27 ±0.07	1.53 ±0.21	1.45 ±0.22	1.98 ±0.24	1.69 ±0.16
B_1	1.00 -	1.00 -	1.00 -	1.00 -	1.07 ±0.07	1.00 -	1.00 -	1.00 -	1.47 ±0.18	1.13 ±0.07	1.13 ±0.07	1.13 ±0.07	2.07 ±0.37	1.40 ±0.20	1.20 ±0.20	1.20 ±0.20
B_2	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -	1.00 -
A	-0.20 ±0.12	- -	- -	- -	-0.27 ±0.27	- -	- -	- -	0.07 ±0.54	0.00 ±0.22	0.27* ±0.13	0.07 ±0.18	0.47 ±0.85	0.20 ±0.58	0.00 ±0.50	-0.40 ±0.58
B	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -
C	-0.20 ±0.12	- -	0.09 ±0.09	0.09 ±0.09	-0.31 ±0.25	0.09 ±0.09	0.27 ±0.15	0.27 ±0.15	-0.16 ±0.51	0.17 ±0.29	1.43** ±0.45	0.87** ±0.29	0.47 ±0.94	0.79 ±0.99	3.51** ±0.99	1.95** ±0.75
D	- -	- -	0.05 ±0.05	0.05 ±0.05	-0.02 ±0.08	0.05 ±0.05	0.13 ±0.08	0.13 ±0.08	-0.11 ±0.24	0.09 ±0.13	0.58* ±0.24	0.40** ±0.15	0.00 ±0.57	0.49 ±0.49	1.75** ±0.51	1.17** ±0.37
m	1.00 -	1.00 -	1.02** ±0.02	1.02** ±0.02	1.02** ±0.02	1.02** ±0.02	1.07** ±0.04	1.07** ±0.04	1.18** ±0.08	1.11** ±0.06	1.36** ±0.11	1.27** ±0.07	1.53** ±0.21	1.45** ±0.22	1.98** ±0.24	1.69** ±0.16
d	- -	- -	- -	- -	0.07 ±0.07	- -	- -	- -	0.47** ±0.18	0.13* ±0.07	0.13* ±0.07	0.13* ±0.07	1.07** ±0.37	0.40* ±0.20	0.20 ±0.20	0.20 ±0.20
h	-0.10 ±0.06	- -	-0.09 ±0.09	-0.09 ±0.09	-0.16 ±0.20	-0.09 ±0.09	-0.27 ±0.15	-0.27 ±0.15	-0.21 ±0.51	-0.31 ±0.28	-1.16* ±0.47	-0.90** ±0.30	-0.83 ±1.15	-1.49 ±1.00	-3.71** ±1.04	-2.75** ±0.77
i	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	-1.16 ±0.47	-0.80** ±0.30	- -	- -	-3.51** ±1.02	-2.35** ±0.74
j	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.13* ±0.07	- -	- -	- -	- -	- -
l	- -	- -	- -	- -	- -	- -	- -	- -	- -	- -	0.89 ±0.53	0.73 ±0.39	- -	- -	3.51** ±1.27	2.75* ±1.10
Epi	-	-	-	-	-	-	-	-	-	-	D	D	-	-	D	D

None of the scales and genetic effects was significant in any of the crosses revealing the absence of epistasis.

r. YVM incidence at 50 DAS

All the generations in all the crosses had minimum score for YVM incidence at this stage except for P_1 and B_1 in cross 1 and for F_2 in all the crosses. Scales were either absent or non-significant in all the crosses. Only m exhibited significance in all the crosses. Epistasis was found to be duplicate in all the crosses.

s. YVM incidence at 70 DAS

The generations P_2, F_1 and B_2 in all the crosses exhibited minimum score for disease incidence. Scale A was significant only in cross 3 while the scales C and D were significant in crosses 3 and 4. No epistasis could be observed in crosses 1 and 2.

Among the genetic components, m and d were significant and positive in all the crosses. Negatively significant values were noticed for h and i in crosses 3 and 4 while j was positively significant in cross 3. In all the crosses, m was greater in magnitude followed by d in cross 1 and h in other crosses. In cross 3, i was equal to h in magnitude.

Epistasis was duplicate in crosses 3 and 4.

t.YVM incidence during final harvest

P_2, F_1 and B_2 generations exhibited minimum score for YVM incidence in all the crosses. Maximum score was noticed for P_1 in crosses 1,2 and 4 and for F_2 in cross 3.

Scale A was non-significant while scale B was absent in all the crosses. Scales C and D were significant in crosses 3 and 4.

In all the crosses, m exhibited significance. The effect d was positively significant in crosses 1 and 2 while h and i were negatively significant in crosses 3 and 4. Positively significant l effect was observed in crosses 3 and 4.

Table 41 (Continued..)

	Leaf roller				Leaf spot			
	Cross 1	Cross 2	Cross 3	Cross 4	Cross 1	Cross 2	Cross 3	Cross 4
Generation means								
P_1	21.81 ±3.34	13.78 ±1.01	19.49 ±2.44	18.13 ±1.23	2.31 ±0.16	2.04 ±0.09	2.24 ±0.06	2.24 ±0.08
P_2	18.31 ±3.09	12.48 ±1.04	25.24 ±2.46	6.97 ±0.41	2.82 ±0.18	2.31 ±0.35	2.62 ±0.29	2.47 ±0.04
F_1	11.64 ±1.70	25.76 ±2.95	25.01 ±0.90	8.48 ±0.60	2.44 ±0.15	1.67 ±0.04	2.38 ±0.10	2.47 ±0.17
F_2	12.77 ±1.10	13.44 ±0.83	7.98 ±1.61	12.89 ±1.15	2.45 ±0.37	2.07 ±0.04	2.30 ±0.06	2.33 ±0.05
B_1	11.49 ±1.15	8.83 ±1.08	16.68 ±1.57	4.98 ±0.49	2.02 ±0.14	2.09 ±0.10	2.42 ±0.12	2.67 ±0.04
B_2	1.16 ±0.58	11.70 ±1.14	23.36 ±3.76	8.20 ±1.19	2.49 ±0.18	2.31 ±0.28	3.04 ±0.06	2.69 ±0.13
A	-10.47* ±4.39	-21.89** ±3.79	-11.14** ±4.08	-16.65** ±1.68	-0.71* ±0.35	0.47* ±0.22	0.23 ±0.26	0.62** ±0.20
B	-27.62** ±3.72	-14.84** ±3.86	-3.53 ±7.96	0.96 ±2.48	-0.29 ±0.44	0.65 ±0.66	1.09** ±0.33	0.45 ±0.31
C	-12.30 ±7.18	-24.04** ±6.92	-62.82** ±7.54	9.49 ±4.92	-0.21 ±1.51	0.58 ±0.41	-0.43 ±0.44	-0.34 ±0.39
D	12.90** ±2.54	6.35** ±2.28	-24.08** ±5.20	12.59** ±2.63	0.40 ±0.77	-0.27 ±0.31	-0.87** ±0.18	-0.70** ±0.17
m	12.77** ±1.10	13.44** ±0.83	7.98** ±1.61	12.89** ±1.15	2.45** ±0.37	2.07** ±0.04	2.30** ±0.06	2.33** ±0.05
d	10.32** ±1.29	-2.87 ±1.57	-6.68 ±4.07	-3.22* ±1.29	-0.46* ±0.23	-0.22 ±0.30	-0.62** ±0.13	-0.02 ±0.14
h	-34.22** ±5.83	-0.06 ±5.48	50.80** ±10.58	-29.25** ±5.34	-0.92 ±1.54	0.03 ±0.65	1.69** ±0.41	1.52** ±0.38
i	-25.79** ±5.09	-12.69** ±4.56	48.15** ±10.40	-25.19** ±5.26	-0.79 ±1.53	0.54 ±0.62	1.75** ±0.37	1.41** ±0.33
j	8.57** ±2.61	3.53* ±1.73	3.81 ±4.43	-8.80** ±1.44	-0.21 ±0.26	-0.09 ±0.35	-0.43* ±0.20	0.09 ±0.15
l	63.89** ±8.83	49.43** ±9.33	-33.49 ±17.95	40.88** ±7.12	1.80 ±1.77	-1.66 ±1.25	-3.06** ±0.69	-2.48** ±0.68
Epi	D	D	D	D	D	D	D	D

Considering the magnitude, m was the highest in cross 1, followed by d whereas h was the highest in crosses 2 and 3. In cross 4, both h and l were the highest and equal in magnitude. Duplicate epistasis was seen in all the crosses except 1 which had complementary epistasis.

u. Leaf roller

Incidence of leaf roller (Plate 12) was the lowest for B_2 in cross 1, for B_1 in crosses 2 and 4 and for F_2 in cross 3 while the highest incidence was observed for P_1 in crosses 1 and 4, F_1 in cross 2 and P_2 in cross 3.

Significance was noticed for scale A and D in all the crosses, scale B in crosses 1 and 2 and for scale C in crosses 2 and 3.

All the crosses exhibited significance for m effect. In cross 1, d was positively significant while in cross 4, it was negatively significant. Significance was noticed for h in crosses 1 (negative), 3 (positive) and 4 (negative). In all the crosses, i was significant and the value was negative in all except cross 3. The effect j was significant in all crosses except cross 3 and the values were negative except in cross 1. Positively significant l values were seen in crosses 1, 2 and 4. Magnitude of the effects were the highest for l in all the crosses others than 3 in which h was predominant. All the crosses displayed duplicate epistasis.

v. Leaf spot

Among the generations, the lowest values for the incidence of leaf spot (Plate 13) was observed for B_1 in cross 1, F_1 in cross 2 and P_1 in both 3 and 4 crosses. The highest incidence of leaf spot was observed for P_2 in cross 1, P_2 and B_2 in cross 2 and for B_2 in crosses 3 and 4.

Among the scales, significance was displayed by A in all the crosses except 3, B in cross 3, C in none and D in crosses 3 and 4.

Significant value of m was observed in all the crosses. Negatively significant d effect was present in crosses 1 and 3 while h and i were positively significant in crosses 3 and 4. Negatively significant values were noticed for j in cross 3 and l in crosses 3 and 4. In magnitude, the

Plate 12. Symptom of okra leaf roller

Plate 13. Rating scale for okra leaf spot disease

Table 42. Transgressive segregants in four crosses of okra

Sl. No.	Characters	Transgressive segregants (%)			
		Cross 1	Cross 2	Cross 3	Cross 4
1	Days to first flower	15.56	40.00	22.22	35.56
2	Leaf axil bearing first flower	13.33	64.44	71.11	71.11
3	Leaf area	37.78	31.11	37.78	28.89
4	Pollen sterility	44.44	26.67	35.56	15.56
5	Fruits plant^{-1}	34.00	33.33	37.78	26.67
6	Average fruit weight	88.89	97.78	71.11	62.22
7	Fruit weight plant^{-1}	88.89	75.56	93.33	62.22
8	Fruit length	60.00	60.00	73.33	66.67
9	Fruit girth	11.11	17.78	68.89	31.31
10	Ridges fruit^{-1}	17.78	11.11	22.22	15.56
11	Seeds fruit^{-1}	31.11	53.33	8.89	51.11
12	Plant duration	15.56	4.44	2.22	8.89
13	Crude fibre content	17.78	26.67	22.22	13.33
14	Protein content	8.89	20.00	31.11	15.56
15	Mucilage content	22.22	35.56	13.33	31.11
16	Fruit and shoot borer incidence	60.00	37.78	84.78	40.00
17	YVM incidence –Final harvest	15.56	11.11	31.11	26.67
18	Leaf roller incidence	62.22	55.56	75.56	51.11
19	Leaf spot incidence	57.78	31.85	58.52	60.00

highest was m in crosses 1 and 2 and l in the other two crosses. Epistasis was duplicate in nature in all the crosses.

4.3.1 Transgressive Segregants

Transgressive segregants were observed in the four crosses for all the characters evaluated except for YVM incidence at 30 DAS in crosses 1 and 2 (Table 42). The highest values were observed in cross 1 for fruit weight plant^{-1} and average fruit weight (88.89 %), in cross 2 for average fruit weight (97.78 %) and fruit weight plant^{-1} (75.56 %), in cross 3 for fruit weight plant^{-1} (93.33 %) and fruit and shoot borer incidence (84.78 %) and in cross 4 for leaf axil bearing first flower (71.11 %) and fruit length (66.67 %).

Minimum values of transgressive segregants were observed in cross 1 for protein content (8.89 %) and in the other crosses for plant duration (4.44, 2.22 and 8.89 % respectively).

Discussion

5. DISCUSSION

The salient results gathered in the light of the present investigation are discussed here under:

5.1 GERMPLASM EVALUATION

Selection, the cardinal principle of plant breeding, entails the practice of sorting out the desirable representatives from amongst a group of genotypes thereby allowing only their progenies to perpetuate. Obviously, selection operates in all kinds of variability – existing or created – and under all types of plant breeding procedures / strategies and hence it is the corner stone of all plant breeding practices (Sharma, 1994). The breeding procedure, efficiency of selection and final success are dependent on the germplasm chosen (Zelleke, 2000). Improvement in any crop is proportional to the magnitude of genetic variability in the germplasm, which needs to be examined thoroughly by assembling and evaluating as much genotypes as possible, pooled from diverse ecographical situations.

Keeping this objective in focus, 101 genotypes of *Abelmoschus esculentus* of diverse origin were pooled and evaluated for resistance to YVM as well as for their yield potential.

5.1.1 Screening for YVM Resistance

5.1.1.1 YVM incidence

For developing new varieties resistant to YVM disease, identification of source of resistance in the available germplasm forms the first stepping stone. Hence, the 101 okra genotypes collected from various regions of the country were screened for YVM resistance in the field under natural epiphytotic situations during the four stages of the crop *viz.*, 30 DAS, 50 DAS, 70 DAS and final harvest. Similar large scale screening of okra germplasm for YVM resistance was attempted earlier by Salehuzzman (1985) and Arora *et al.* (1992). In the present study, the disease intensity was observed to be gradually increasing from 30 DAS to final harvest.

Most of the genotypes were free from the disease during 30 DAS. Subsequently many of them became susceptible to it.

At 30 DAS, high resistance to YVM was exhibited by all the genotypes except eleven, which belonged to the resistant category. However, none of the genotypes could be categorised as moderately resistant, susceptible or highly susceptible types.

A sharp decline in the number of highly resistant genotypes could be noticed at 50 DAS. It was evident that only fifteen okra types could retain the high resistance exhibited by them in the previous stage. Resistant and moderately resistant categories comprised of 32 and 38 genotypes respectively whereas fifteen genotypes belonged to the susceptible class. The only one treatment which fell under the highly susceptible section was T62, being the most vulnerable genotype to the disease.

The 70 DAS stage of the crop witnessed a notable reduction in the number of genotypes belonging to highly resistant and resistant groups which retained eight and thirteen accessions respectively. Moderately resistant group consisted of 29 genotypes, while the membership of susceptible and highly susceptible groups was enhanced to 38 and thirteen in the respective order.

The number of genotypes in the highly resistant category during final harvest was reduced to four. Resistant and moderately resistant categories could claim only eight and seven genotypes respectively. Following the same trend, susceptible category retained only twelve genotypes. A remarkable rise was evident in the number of members in highly susceptible group, which accounted majority (70 nos.) of the genotypes to its credit.

In the present investigation, disease incidence was absent in majority of the cultivars at 30 DAS and disease symptoms started to appear during 30 to 50 DAS period. Bhagat *et al.* (2001) also have arrived at similar conclusion wherein maximum rate of YVM disease development in okra was between 35 and 45 DAS of the crop.

The four okra genotypes which could express highly resistant property throughout the crop phase included NBPGR / TCR – 2060 (T34), Parbhani Kranti (T85), Varsha Uphar (T86) and Selection-46 (T91).

Reports are available regarding the identification of varietal resistance to YVM in okra (Nath, 1970; Rao and Bidari, 1976; Khan and Mukhopadhyay, 1986; Singh and Singh, 1986; Arora *et al.*, 1992). High resistance identified in Parbhani Kranti is in tune with the reports of Sharma *et al.* (1993) and Poopathi *et al.* (1996). However, it was described as moderately resistant by Sangar (1997) and tolerant by Rajamony *et al.* (1995, 2002). Srivastava *et al.* (1995) and Indurani (1999) shared the view of high resistance in Varsha Uphar.

Eventhough Arka Anamika, the highly popular variety was reported by earlier researchers as resistant (Bora *et al.*, 1992; Mathew *et al.*, 1993; Sangar, 1997; Sannigrahi and Choudhary, 1998; Indurani, 1999), moderately resistant (Srivastava *et al.*, 1995) and tolerant (Rajamony *et al.*, 1995, 2002) to YVM, it appeared to be highly susceptible during the present study. Similarly, Arka Abhay which expressed moderate resistance in this study was previously observed as resistant by Sangar (1997) and Sannigrahi and Choudhary (1998).

In contrary to the observations of Varma and Mukherjee (1955) who reported pink types as resistant, the two red coloured genotypes (Aruna and Local Red) included in the current study were susceptible to the disease.

5.1.2.2 Population of Vectors

White fly (*Bemisia tabaci*) acts as the major vector of YVM disease (Varma, 1952). However, role of okra leaf hopper (*Empoasca devastans*) in YVM transmission was suggested by Varma (1955). Hence populations of both these two vectors on various genotypes were observed during morning and evening hours of the same day at 30, 50 and 70 DAS stages of the crop. Interaction between genotypes and vectors was non-significant in all the stages.

5.1.2.3 Association of YVM incidence with population of vectors

It was clear from the association analysis that morning and evening populations of both white fly and leaf hopper at 30 DAS had significant influence on the development of YVM from 50 DAS to final harvest. This indicates the fact that feeding by the vectors during the initial stage of crop growth leads to the incidence and development of YVM disease throughout the crop phase. Moreover, white fly count (both morning and evening) during 50 DAS also influenced the disease expression during the final phase of the crop. Bhagat *et al.* (2001) also arrived at similar conclusion that YVM disease development occurred maximum during 35 – 45 DAS of the crop.

No information could be traced out from the available literature, regarding the magnitude and influence of vector population during various stages of crop growth on YVM disease development.

5.1.2 Evaluation for Yield Traits

An insight into the extent of variability available in the genetic stock is of prime importance as it acts as the key factor which provides the best picture of genetic gain achievable through selection. Critical assessment of nature and magnitude of variation is the first and the foremost step in formulating an effective breeding programme. In quantitative characters, phenotype is an unreliable indicator of genotype and hence it is desirable to test the genetic value of individuals prior to selection. Since the observed variability in a population is the sum total of variation arising due to genotypic and environmental effects, knowledge on the nature and magnitude of genetic variation contributing to gain under selection is essential (Allard, 1960). Analysis of variance helps in partitioning the total phenotypic variation into components such as genotypic and environmental (error) variances, thereby providing information regarding the breeding value of genotypes involved and also the nature and magnitude of variability in the expression of a particular trait.

5.1.2.1 Analysis of Variance

ANOVA revealed remarkable variation in all the traits under investigation. Several research findings are available dealing with the varietal variation in okra with respect to vivid characters (Ariyo, 1990a; Kumbhani *et al.*, 1993; Gondane and Lal, 1994; Bindu *et al.*, 1997). Some worthmentioning works among them include those of Murthy and Bavaji (1980) for number, length and yield of fruits, Vashistha *et al.* (1982) for yield, Jeyapandi and Balakrishnan (1992) for seeds fruit^{-1}, Rajani and Manju (1997) for days to first flower, leaf area, YVM incidence and number, length, girth, weight and yield of fruits, Hazra and Basu (2000) for days to flower, seeds fruit^{-1} and number, weight and yield of fruits, Philip *et al.* (2000) for number, weight, yield and crude fibre content of fruits and incidence of YVM and fruit and shoot borer and Gandhi *et al.* (2001) for number, length, girth and seeds of fruits.

Reports which are contradictory to the present findings also could be encountered with. Absence of varietal variation was pointed out for leaf axil bearing first flower by Bindu (1993) and for YVM incidence by Sheela (1994). However, the variation was non-significant for YVM incidence at 30 DAS during the present study also, though it attained significance during the subsequent stages. Only a narrow range of variability was noticed for crude fibre content of fruits by Elangovan *et al.* (1983). As pointed out by Hazra and Basu (2000), variation was low for ridges on fruits and leaf axil bearing first flower and moderate for fruit length.

Perusal of the *per se* performance of 101 genotypes had thrown light into the identification of some promising types which showed superiority with regard to various characters as presented below.

Treatment No.	Genotype	Characters
15	NBPGR/ TCR-2020	Days to first flower, leaf axil bearing first flower, pollen fertility, fruits plant^{-1}, fruit colour seeds fruit^{-1}, ridges fruit^{-1}, fruit and shoot borer resistance

16	NBPGR/ TCR-1498	Days to first flower, leaf axil bearing first flower, leaf area, pollen fertility, fruit and shoot borer resistance
37	NBPGR / TCR-2019	Days to first flower, leaf axil bearing first flower, pollen fertility, fruit and shoot borer resistance
82	MDU-1	Days to first flower, leaf axil bearing first flower, leaf area, pollen fertility, fruits plant^{-1}, fruit and shoot borer resistance
83	NBPGR/TCR-985	Days to first flower, leaf axil bearing first flower, leaf area, pollen fertility, average fruit weight, fruit weight plant^{-1}, protein content
34	NBPGR/TCR-2060	Days to first flower, leaf axil bearing first flower, leaf area, pollen fertility, plant duration, YVM resistance
85	Parbhani Kranti	Days to first flower, leaf axil bearing first flower, leaf area, pollen fertility, fruits plant^{-1}, average fruit weight, fruit weight plant^{-1}, protein content, YVM resistance
86	Varsha Uphar	Days to first flower, leaf axil bearing first flower, leaf area, pollen fertility, fruits plant^{-1}, average fruit weight, fruit weight plant^{-1}, fruit and shoot borer resistance, YVM resistance
90	Selection-13	Days to first flower, leaf area, average fruit weight
48	NBPGR/TCR-2137	Leaf axil bearing first flower, mucilage content

51	NBPGR/TCR-2228	Leaf axil bearing first flower, crude fibre content
95	Kannur Local Red	Leaf area, average fruit weight
84	NBPGR/TCR-893	Fruits plant^{-1}, ridges fruit^{-1}
92	Anakkomban-I	Average fruit weight, fruit length, ridges fruit^{-1}
91	Selection-46	Average fruit weight, crude fibre content, YVM resistance
93	Anakkomban-II	Average fruit weight, fruit length, ridges and seeds fruit^{-1}
101	Payyannur Local	Average fruit weight, fruit length, ridges fruit^{-1}

High yield observed for Parbhani Kranti in this study is in accordance with the opinions of Singh *et al.* (1993) and Lal *et al.* (2001). Singh (2000) reported that Parbhani Kranti displayed high yield and pod weight along with high resistance to YVM consistently for three years which corroborates with the present findings. In contradiction with the reports of Mathew *et al.* (1993), Arka Anamika could not perform well in this experiment.

5.1.2.2 Genetic parameters

The genetic parameters like variance, coefficient of variation, heritability and genetic advance provide a clear insight into the extent of variability and a relative measure of efficiency of selection based on phenotype.

5.1.2.2.1 Coefficient of variation

A unit free tool of evaluation is highly essential for comparing the characters measured in diverse units. Unlike variance, coefficient of variation provides an excellent means for such a need.

Phenotypic value being the aggregate of genotypic effect and environmental influence, selection solely based on external parameters may be misleading. Thus, in comparison with its phenotypic counterpart, genotypic coefficient of variation (GCV) is a more precise and true indicator of the extent of genetic variability in a population.

During the current study, high phenotypic and genotypic coefficients of variation were observed for most of the traits including yield and its major components. However, GCV was moderate for fruit girth, ridges and seeds fruit^{-1} and leaf axil bearing first flower but low for plant duration and YVM incidence at 30 DAS. Information regarding PCV and GCV values which were high for incidence of YVM and fruit and shoot borer, moderate for fruit girth and low for plant duration reported by Philip (1998) agrees with the above results. Meanwhile, the same author also expressed contradictory view by projecting low PCV and GCV for leaf area and days to first flower.

High values of PCV with corresponding high values of GCV in most of the traits indicate the presence of great extent of genetic variability in these characters suggesting better scope for improvement through phenotypic selection.

5.1.2.2.2 Heritability

Selection acts on genetic differences and the benefits from selection for a particular trait depends largely on its heritability (Allard, 1960). So it is evident that GCV alone is not sufficient for successful selection. In the view of Burton (1952), GCV along with heritability would provide a precise idea regarding the amount of genetic gain to be expected by selection.

The breeding value of a crop determines the extent to which it is capable of transmitting its potential to the succeeding generations. Obviously, if a breeder chooses certain individuals to be parents according to their phenotypic values, the success in manipulating the characteristics of population could be predicted solely from the degree of correspondence

between phenotype and breeding value, which could be measured by the statistical tool, heritability. Estimates of heritability acts as a predictive measurement in expressing the reliability of phenotype ie., the degree to which the phenotype reflects the respective genotype. Hence, heritability denotes the effectiveness with which selection of genotype could be practised based on their phenotypic performance.

Present investigation revealed high values of heritability in the characters studied including yield and its major components *viz*., days to first flower, leaf area, fruits plant^{-1}, average fruit weight, fruit length, fruit girth, fruit colour, fruit pubescence, ridges and seeds fruit^{-1} and content of crude fibre, protein and mucilage of fruits, indicating the predominance of genetic component and low environmental influence on these characters. Very high estimates of heritability (> 90 %) witnessed in the case of fruit yield as well as fruit number is a highly desirable phenomenon.

This result is in conformity with the reports of many earlier workers such as El-Macksoud *et al.* (1986) for days to first flower, number of fruits and fruit weight, Yadav (1986) for number, length and yield of fruits and seeds, Sadashiva (1988) for girth and weight of fruits and Yassin and Anbu (1997) for number, average weight and yield of fruits. But low heritability observed by Ngah and Graham (1973) for fruit weight, Singh *et al.* (1974) for fruit number and weight of fruits, Rao and Ramu (1975) for fruit girth, Lal *et al.* (1977) for yield, Thaker *et al.* (1981b) for leaf area, fruit weight and yield, Patel and Dalal (1992) and Rajani and Manju (1997) for fruits are in disagreement with the above results.

More or less equal influence of genetic and environmental factors in the case of pollen sterility, leaf axil bearing first flower, plant duration and incidence of fruit and shoot borer and YVM during 70 DAS as well as final harvest was evident from their moderate heritability. However, in the view of Philip (1998) all these traits possessed high heritability.

5.1.2.2.3 Genetic advance

High heritability (broad sense) does not always indicate better response to selection since it is inclusive of non-additive genetic variance also. Hence, for predicting the real resultant effects of selection, high heritability coupled with high genetic advance would be a more reliable criterion than simple heritability value alone (Johnson *et al.*, 1955).

Genetic advance is an useful indicator of the progress that could be expected as a result of exercising selection on the pertinent population. High value of genetic advance depicts better and surer progress on the mean value of population in the succeeding generations. Characters with high magnitude of heritability as well as genetic advance are controlled by additive gene action and therefore amenable to genetic improvement through selection.

In the current study, very high genetic advance was observed for fruit yield plant^{-1} which clearly indicates the additive gene action involved in this trait which makes the selection highly effective. This is in conformity with the opinion of Mishra and Chhonkar (1979).

All other traits, except plant duration, were bestowed with high genetic advance. Supporting evidences for this were previously presented by Murthy and Bavaji (1980) for number of fruits and days to flower, Thaker *et al.* (1981b) for leaf area and number, length, weight and yield of fruits and Yassin and Anbu (1997) for fruits and yield.

High heritability coupled with high genetic advance (as % of mean) was displayed by fourteen traits *viz.*, days to first flower, leaf area, fruits plant^{-1}, average fruit weight, fruit weight plant^{-1}, fruit length, fruit girth, ridges fruit^{-1}, seeds fruit^{-1}, crude fibre content, protein content and mucilage content. Predominant role of additive genetic effects for these characters is indicated thereby making the selection rewarding to a great extent. Views regarding high values of both heritability and genetic advance put forth by several researchers like Rao (1972) for days to first flower, Singh *et al.* (1974) for length and girth of fruits, Reddy *et al.* (1985) for yield, Vijay

and Manohar (1990) for ridges fruit^{-1}, Jeyapandi and Balakrishnan (1992) for number, length, weight and yield of fruits and Sheela (1994) for fruit yield, leaf area and seeds fruit^{-1} are in accordance with this finding.

At the same time, contradictory opinions like moderate values of both heritability and genetic advance for number, length and average weight of fruits (Balachandran, 1984), moderate heritability coupled with high genetic advance for pod number (Gondane and Lal, 1994), moderate heritability along with low genetic advance for fruit girth (Bindu *et al.*, 1997), high heritability along with moderate genetic advance for leaf area, fruit length, average fruit weight and yield (Bindu *et al.*, 1997) and low values for both heritability and genetic advance for yield (Balachandran, 1984) and seeds fruit^{-1} also could be encountered with.

Four traits *viz.*, pollen sterility, leaf axil bearing first flower and incidence of fruit and shoot borer and YVM during final harvest possessed moderate heritability along with high genetic advance (as % of mean) indicating additive gene effects operating for these characters. Opposite opinions expressing low values of both heritability and genetic advance were furnished by Bindu *et al.* (1997) for leaf axil bearing first flower and Sheela (1994) for YVM incidence. Estimates of both heritability and genetic advance were moderate for plant duration revealing more environmental influence which makes the selection less effective for this character.

5.1.2.4 Association analyses

5.1.2.4.1 Correlation

Correlation analysis provides reliable estimates on the nature, extent and direction of selection. Estimation of correlation coefficient is an important step in planning selection experiments as it forms a strong foundation for developing selection index.

Selection based on yield along with its components could be more efficient than that on the basis of yield alone (Evans, 1978). Knowledge

on the degree and nature of association among traits would prepare the breeder to pinpoint a character/characters whose selection would automatically result in an overall progress of those characters which are positively correlated with yield and also in the elimination of such characters exhibiting negative association.

Genotypic correlation provides a reliable measure of genetic association between traits and helps to differentiate the vital association useful in breeding from the non-vital ones (Falconer, 1981).

In the present study, most of the character combinations displayed an interesting trend that genotypic correlation coefficients (r_{Gxy}) were of the highest magnitude, followed by the respective phenotypic correlation coefficients (r_{Pxy}) though both were in the same direction. This corroborates with the findings of Murthy and Bavaji (1980) who observed higher magnitude of r_{Gxy} than r_{Pxy}. Environmental correlation coefficients (r_{Exy}) were the lowest and in many cases with opposite sign to that of genotypic. This justifies the lower magnitude of phenotypic correlation coefficients than genotypic, as phenotype ultimately reflects the interaction of genetic and environmental factors.

Deviation from this general pattern could be noticed for association of certain characters. Though both were in the same direction, phenotypic correlation coefficient exceeded genotypic correlation coefficient for days to first flower with YVM incidence during final harvest indicating the low genetic association between these traits. Here environmental correlation coefficient was negative while other two coefficients were in positive direction.

Greater magnitude of r_{Gxy} than r_{Pxy} observed for days to first flower with average fruit weight as well as fruit weight plant^{-1} indicates the major role of environmental effects in reducing the magnitude and reversing the direction of genetic association between these characters.

The characters *viz.*, pollen sterility with fibre content and fruit number with ridges fruit^{-1} displayed positive genotypic and environmental

correlations but negative phenotypic association. In the former pair, rp was higher than the other two but in the later all the coefficients were equal.

Considering the genetic correlation in detail, the most important trait fruit weight plant^{-1} (yield) exhibited significant and positive association with its components *viz.*, leaf area, fruit number, average fruit weight, fruit length, fruit girth, seeds fruit^{-1}, plant duration and protein content and desirable negatively significant association with days to first flower, leaf axil bearing first flower, pollen sterility and incidence of fruit and shoot borer and YVM. Hence intensive selection based on the foresaid traits would be a useful criterion to attain yield improvement.

Some of the reports supporting this finding are: positive association of yield with fruits and fruit length was observed by Mahajan and Sharma (1979), Yadav (1986) etc. High association of fruit number with yield in okra was stressed by Mathews (1986), Lakshmi *et al.* (1996) and Indurani (1999) suggesting it as a major and dependable criterion in selection programmes intended for yield improvement. According to Sheela (1986), yield had positive correlation with number, length, girth, weight and seed number of fruits. Sundhari *et al.* (1992) also mentioned about the positive association of these fruit attributes except seed number with yield. Number and girth of fruits were correlated positively with yield as observed by Veeraraghavathatham and Irulappan (1990). Furthermore, positive association of yield with number and average fruit weight was suggested by many researchers including Ariyo (1992), Gondane *et al.* (1995), Subhasini *et al.* (1996) and Philip and Manju (2002).

Positive association of earliness was reported for yield by Balachandran (1984). However, in contrary to this and also to the present results, Korla and Rastogi (1978) reported positive association for days to flower with yield. Some other supporting evidences were furnished earlier by Majumdar *et al.* (1974), John (1997) and Philip (1998) regarding the beneficial negative association between days to flower and yield.

Interrelationships of component characters also were analysed during the present investigation. Positive association of days to first flower with leaf axil bearing first flower, pollen sterility, ridges fruit^{-1} and plant duration and its negative association with fruit number, average fruit weight, fruit yield and fruit length are in agreement with the opinion of Philip (1998). John (1997) also had pointed out the negative correlation of this character with fruit length. On noticing the negative association of days to first flower with yield, Korla and Rastogi (1978) and Sheela (1994) suggested that selection of early types would lead to the development of high yielding types. However, the negative association of days to first flower with leaf area is in contrary to the reports of John (1997) and Philip (1998). Furthermore, late flowering was suggested to be associated with more and larger fruits by El-Macksoud *et al.* (1984).

Similar to the opinion of Philip (1998), pollen sterility was associated negatively with number, length and yield of fruits. John (1997) also described the inverse relationship of this trait with fruit number. Contradicting the present results, some of the earlier reports suggested the existence of positive association for pollen sterility with leaf area, fruit girth, seeds, plant duration (John, 1997) and with average fruit weight, fruit length, fruit girth and ridges fruit^{-1} (Philip, 1998).

Fruit number, the major yield component, was associated positively with yield as well as its other components including average fruit weight, fruit length, fruit girth, seed number, protein content and plant duration. Positive association of fruits plant^{-1} with yield and plant duration (Philip, 1998) and with average fruit weight (Alex, 1986) had already been reported. In fact, several researchers had identified fruit number as a trait having strong positive influence on yield (Mahajan and Sharma, 1979; Sheela, 1994). However, inverse relationship was observed between fruit length and average fruit weight by John (1997) and Philip (1998).

Positive association of average fruit weight with fruit length and fruit girth corroborates with the opinions of John (1997) and Philip (1998).

Similar positive association of this trait with seed number also was observed by Philip (1998). However, the above two authors noticed positive association between average fruit weight and ridges $fruit^{-1}$ in contrary to the present results.

The positive association observed among length, girth, seeds and ridges of fruit and plant duration is in conformity with the earlier observations of Alex (1986). But negative association was noticed by Philip (1998) for fruit length with the other traits in F_5M_5 generation plants.

Among the quantitative characters, association was positive between fruit pubescence and crude fibre content but negative for mucilage content with fibre as well as protein content. Crude fibre content exhibited significant association with fruit girth and ridges and non-significant association with number and length of fruits which is in accordance with the results of Philip (1998).

During final harvest, YVM incidence had significant negative association with number, average weight, yield, length, girth, ridges and fibre content of fruits, plant duration and leaf area. Sheela (1994) suggested that for developing YVM resistant varieties, stress must be given during selection for earliness and high fruit weight.

5.1.2.4.2 Path analysis

Correlation analysis may not give a true picture of the relative cause and effects of each character that attributes to final yield. This necessitates the assessment of merit of traits by analysing the direct and indirect effects of each of them towards yield which provides valuable information in selecting the character for crop improvement. Rate of improvement is expected to be rapid if differential emphasis is laid on the component character during selection. The basis of differential emphasis could be the degree of influence of component characters on the economic trait of interest.

Path coefficient analysis during the current investigation revealed the direct and indirect effects exerted on yield by the thirteen characters, which had high genetic correlation with it.

Exertion of positive direct effect on yield was maximum by plant duration followed by pollen sterility and average fruit weight. High direct effect in positive direction by average fruit weight had been pointed out by several earlier researchers including Partap *et al.* (1982), Reddy *et al* (1985), Balakrishnan and Balakrishnan (1990), Bindu (1993), Sheela (1994), Lakshmi *et al.* (1996) and Dhall *et al.* (2000). Positive direct effect was the lowest by protein content followed by seed number and leaf area. But description of high positive direct effect could be met with in the works of Kale *et al.* (1989) for leaf area and Lakshmi *et al.* (1996) for seed number.

Direct effect in negative direction was the highest by days to flower followed by leaf axil bearing first flower. The two major yield components *viz.*, fruit number and fruit length exhibited negative direct effects as against the reports of Kale *et al.* (1989), Mishra and Singh, (1992) and Dhall *et al.* (2000) which were in positive direction.

Among the indirect effects, maximum values in positive direction was observed for fruit number through days to first flower and plant duration. Another trait which exhibited high positive indirect effect was fruit length, influencing via average fruit weight. Low positive indirect effects through protein content were exerted by average fruit weight, fruit length, fruit girth, seeds, plant duration and leaf axil bearing first flower in positive direction and by days to first flower and leaf axil of first flower, incidence of fruit and shoot borer and YVM and pollen sterility in negative direction. The highest negative indirect effect on yield was observed for leaf axil bearing first flower through days to first flower, followed by fruit number through pollen sterility and YVM incidence through plant duration.

Days to first flower, though had the highest negative direct effect, its correlation coefficient was reduced considerably due to the positive indirect

effects through the other component traits mainly plant duration and pollen sterility. Leaf axil bearing first flower had exhibited both direct effect and correlation coefficient in negative direction. In contrary to the opinion of Kale *et al.* (1989), a very low positive direct effect was exerted by leaf area on yield. However, its correlation coefficient was highly modified by the positive indirect effects through other traits, especially average fruit weight, plant duration and days to first flower.

Though pollen sterility exerted a highly positive direct effect on yield, it was modified into desirable highly negative correlation due to the indirect effects in negative direction employed via plant duration, days to first flower and average fruit weight.

The present study witnessed a very low direct effect of fruit number, that too in negative direction, with yield which is contradictory to many of the earlier observations (Ramu, 1976; Singh and Singh, 1979a; Sheela, 1988a; Dhankhar and Dhankhar, 2002) in magnitude as well as direction. However, it experienced a desirable modification into highly positive genotypic correlation coefficient which was achieved by the influence of positive indirect effects via most of the other traits especially days to first flower and plant duration.

The high positive correlation coefficient of average fruit weight with yield could be attributed to its high direct effects. This finding corroborates with the views of Partap *et al.* (1982), Reddy *et al.* (1985), Balakrishnan and Balakrishnan (1990), Bindu (1993) and Sheela (1994).

Negative direct effect exhibited by fruit length is in disagreement with the results obtained by Kale *et al.* (1989), Mishra and Singh (1992) and Dhall *et al.* (2000). Meanwhile, its total correlation became positive due to the modification by the indirect effects manifested through average fruit weight, days to first flower and plant duration.

The direct effect and correlation coefficient of fruit girth on yield were positive and almost equal in magnitude indicating the absence of appreciable influence by the indirect effects. Though the direct effect

exerted by seed number on yield was very low, it was much enhanced by the positive indirect effects through plant duration, average fruit weight and fruit girth, resulting in a higher correlation coefficient. High and positive direct effect on yield had been indicated previously for this trait by Lakshmi *et al.* (1996).

Though plant duration exerted the highest positive direct effect on yield, it was counteracted by the reverse indirect effects as evident from the lower correlation coefficient. Negative indirect effects involved in this modification were through most other characters, maximum being through pollen sterility, followed by days to first flower and YVM incidence.

Regarding protein content, though it exerted the lowest direct effect on yield, the correlation coefficient was modified by the positive indirect effects through most of the other traits of which the maximum was via plant duration followed by average fruit weight. Incidence of fruit and shoot borer had positive direct effect on yield while its correlation coefficient was in the reverse direction. This desirable modification was effected due to the influence of negative indirect effects through majority of the other component characters especially days to first flower, plant duration, average fruit weight and leaf axil bearing first flower. Similar modification of undesirable positive direct effect into beneficial negative correlation was noticed for YVM incidence also, by the negative indirect effects via many other traits among which the highest was through plant duration followed by average fruit weight, days to first flower and fruit girth.

5.1.2.5 Selection index

A plant breeder's workshop might be endowed with an assembly of a large number of genetic stock. The superior genotypes can be selected from the germplasm by employing a suitable index with the help of discriminant function based on reliable and effective characters. Use of selection index also provides scope for greater efficiency in enhancing the yield through component selection rather than straight selection for yield alone.

Selection indices were employed for improving earliness, pod yield and seed yield in okra by Lal(1986). In the current study, selection indices were formulated for the 101 genotypes under evaluation, based on yield and thirteen yield attributes that displayed high association with yield. Among the genotypes with high selection indices, five high yielding but YVM susceptible ones *viz.*, NBPGR/TCR-985, NBPGR/TCR-2019, MDU-1, NBPGR/TCR-2020 and NBPGR/TCR-1498 were employed as lines while three highly resistant genotypes *viz.*, Varsha Uphar, Parbhani Kranti and NBPGR/TCR-2060 were utilised as testers (Plate 7) in the line x tester crossing programme.

5.1.2.6 Confirmation of disease resistance

For the confirmation of disease resistance, grafting trials were conducted using highly resistant and highly susceptible (Kiran) genotypes as scion and rootstock respectively. Absence of disease symptoms on subsequent growth of scion confirmed the resistance in the respective genotypes. Similar grafting trials for confirming the YVM resistance in okra were performed previously by Salehuzzman (1985) and Ali *et al.* (2000).

Disease resistance was confirmed further by carrying out artificial inoculation feeding on the plants of the highly resistant genotypes, using viruliferous white flies carrying YVM virus. In this trial also, the treated plants did not develop any disease symptom even after one month of inoculation, thereby confirming the presence of high resistance in the tested genotypes.

In order to clarify the morphological basis of YVM resistance, the leaves of highly resistant and susceptible genotypes were examined under digital microscope and the photographs obtained reflected light into the increase in the number and length of hairs in the highly resistant genotypes compared to the susceptible ones.

Physiological basis of disease resistance was analysed by assessing the phenol content in the leaves of selected parents. Generally the resistant testers possessed higher phenol content than the susceptible lines suggesting the role of phenols in imparting YVM resistance to okra plants. Previous reports of Arumugham and Muthukrishnan (1981b) and Ahmed *et al.* (1994) also are in tune with this finding.

5.2 LINE X TESTER ANALYSIS

The prime aim of any hybridisation programme is to bring together the desirable and beneficial genes available in the parents into a single variety. A variety of biometrical methods are routinely being employed to detect precisely the genetic make up of genotypes under consideration as well as to evaluate effectively their combining ability, for developing a suitable breeding methodology. Line x tester analysis, being unique among them, envisages the screening of a large number of genotypes at a time and is highly dependable in determining the relative ability of the males and females for synthesising desirable hybrid combinations. Futhermore, this mating design provides information regarding the utility of various lines and testers to generate segregating population from which promising genotypes could be sorted out.

During the current research programme, line x tester analysis was undertaken in order to sort out the top ranking parents as well as crosses by examining their mean performance, general combining ability of parents and specific combining ability along with heterosis estimates of crosses. Significant variation existed for most of the traits for lines, testers and their interaction, as revealed by the ANOVA, which justifies the adequacy of genotypes chosen for hybridisation programme and also indicates the involvement of both additive and non-additive genetic components for the corresponding characters. The salient results derived are discussed under two major sections *viz.*,(i)estimates of combining ability, genetic

components of variance and heterosis with regard to various traits (ii) evaluation and selection of parents and hybrids.

5.2.1 Heterosis

Exploitation of hybrid vigour is one of the most important tools in the hands of plant breeders in order to break the yield ceiling. Commercial utilisation of hybrid vigour is further facilitated in okra as its floral biology enables easy emasculation and pollination besides being able to produce large number of seeds in a single pollination. Heterosis breeding is an alternative method for obtaining quantum jumps in the production and productivity in okra. Magnitude of heterosis particularly for yield is of paramount importance. However, expression of even to a small magnitude for individual component character also is a desirable factor (Hatchcock and Mc Daniel, 1973). Heterosis is the result of certain types of gene effects *viz*., additive, dominance and epistasis (additive x additive, additive x dominance and dominance x dominance interactions). Of these, higher the contribution of additive gene effects, greater would be the retention of hybrid vigour in subsequent segregating generations.

Heterosis expression for various characters with regard to the respective mid, standard, better and best parents of fifteen hybrids were analysed. Estimates of relative heterosis exhibited by the hybrids was high for YVM incidence, fruit weight plant^{-1}, fruit and shoot borer incidence and pollen sterility.

Standard heterosis recorded high values for fruit and shoot borer incidence, fruit yield, leaf area and YVM incidence. High estimates of standard heterosis could be traced out in the previous studies conducted by Agarrado and Rasco (1986) and Saha and Kabir (2001) for yield and by Rajani (1995) for yield and fruit and shoot borer incidence.

Pollen sterility possessed the highest value for heterobeltiosis while heterosis over both better and best parents were high for borer incidence, fruit yield and average fruit weight.

5.2.2 Combining Ability

The credit for introducing the concept of combining ability must be conferred upon Sprague and Tatum (1942) who defined it as the relative ability to transmit the desirable performance of a genotype to its crosses. General combining ability, the average performance of a strain in a series of crosses, reflects the additive gene effects of parents. On the other hand, specific combining ability indicates those situations in which certain crosses do relatively better or worse than would be expected on the basis of average performance of their respective parents and it is a measure of non-additive gene action (Rojas and Sprague, 1942).

On a relative assessment of the magnitude of general combining ability effects of both lines and testers, fruit yield displayed highly significant values followed by leaf area. High *gca* effects were estimated for yield in okra by Vijay and Manohar (1986a) also.

Highly significant *sca* effects also could be observed for fruit yield followed by leaf area which are in consonance with the observations of Poshiya and Shukla (1986a) and Sadashiva (1988).

5.2.3 Evaluation and Selection of Parents and Hybrids

5.2.3.1 Parents

The performance of crosses developed in a hybridisation programme depends largely on the parental attributes. This emphasises that choice of parents should be based on their *per se* performance along with general combining ability estimates (Yadav and Murthy, 1966) which indicate the genetic potentiality of a genotype. Selection practised on phenotypic performance alone may not always lead to the desired success in crossing programmes. On the other hand, *gca* effects and mean performance if evaluated separately may result in the identification of different individuals. This pinpoints the relevance of the combined assessment of parents using both these criteria at a time.

5.2.3.1.1 Per se performance of parents

Far excellence could be noticed for L_5 compared to the other lines, owing to its noteworthy performance with respect to fruit yield and its major contributors *viz.*, number, average weight, length and girth of fruits. Besides these, L_5 was also bestowed with the lowest YVM incidence as well as leaf axil of first flower production. Being next to L_5, L_2 displayed superiority for days to first flower, pollen sterility, fruit girth and fruit and shoot borer incidence. The best performance for ridges and seeds fruit^{-1} and plant duration was recorded by L_1, for fruit girth and YVM incidence by L_4 and L_3 and for leaf area by L_3.

The best performing tester T_2, which excelled for eight traits, was closely followed by T_3 with superior performance for seven traits. T_2 outperformed its co-testers with respect to fruit yield and all the fruit attributes *viz.*, number, average weight, length, girth, ridges and seeds of fruits while T_3 was superior for days and leaf axil of first flower, leaf area, pollen sterility and plant duration. T_1 was the least preferred tester by fruit and shoot borer. It is worth mentioning that all the testers were equally well when ridges fruit^{-1} and YVM incidence during final harvest were taken into consideration.

5.2.3.1.2 General combining ability effects of parents

Within the group of lines, L_5 was a good general combiner for pollen sterility, average fruit weight, fruit yield and fruit length besides being an average combiner for leaf axil bearing first flower and YVM incidence. Previously, Thaker *et al.* (1981a) observed high *gca* effects for length and average weight of fruits. Also, Vijay and Manohar (1986a) recorded highly significant *gca* effects for many economic characters in okra including average fruit weight, fruit length and fruit yield. As far as fruit yield and its major component fruit number were concerned, L_4 exhibited good general combining ability along with average *gca* effect (best among the hybrids but non-significant) for fruit girth. The line L_2 possessed good *gca*

effects for three traits *viz.*, days to first flower, leaf axil of first flower and seed number together with average combining power for fruit yield, pollen sterility and fruit and shoot borer incidence. Expression of good *gca* values for leaf area, plant duration and fruit and shoot borer incidence was evident in L_3 while L_1 had good *gca* effect for ridges fruit^{-1}. Though non-significant, desirable and equal *gca* effects were exhibited by L_3, L_4 and L_5 for YVM incidence during final harvest.

The status of T_2 among the testers was noteworthy owing to its best general combining ability for major share of the traits under consideration including fruit yield, fruit number, average fruit weight, days to first flower, leaf axil of first flower, leaf area, pollen sterility and fruit and shoot borer incidence and average combining ability for ridges fruit^{-1} and fruit girth (both non-significant). Good *gca* effects were recorded by T_1 for fruit length, ridges fruit^{-1} (both non-significant) and seeds fruit^{-1} and by T_3 (Varsha Uphar) for plant duration. However, in the opinion of Indurani (1999) Varsha Uphar was the best general combiner for average fruit weight and fruit yield plant^{-1}. Regarding YVM incidence during final harvest, all the testers were with non-significant *gca* effects among which only T_1 was in the desirable negative direction.

5.2.3.1.3 Choice of superior parents

Combined appraisal of the *per se* performance and *gca* effects of both lines and testers highlighted the general trend that the mean values of parents totally reflected the *gca* effects in respect of majority of the traits. This is in consonance with the opinion projected by Rao (1977) stating that parents having high mean performance also displayed good *gca* effects.

Considering the overall performance, L_5 deserves the position of the most superior line for the excellent performance coupled with remarkable combining power with regard to fruit yield and number, length and average weight of fruits and also for leaf axil bearing first flower and YVM incidence. The second best position was occupied by L_4 which excelled in

both ways with respect to fruit yield, fruit number, fruit length, average fruit weight and YVM incidence.

T_2 could be designated as the best tester owing to its grand display of the highest mean values as well as *gca* effects regarding fruit yield, fruit attributes *viz.*, number, average weight and girth and also leaf axil bearing first flower.

5.2.3.2 Hybrids

The factors that must be considered for hybrid vigour exploitation are the *per se* performance, heterosis values and *sca* effects of the crosses. As mean values for various traits reflect the field performance as such, they should be considered with utmost importance. The *sca* effect solely may not be the criterion for assessing hybrid vigour because hybrids with high *sca* effects may sometimes possess low heterosis estimates and vice-versa. Hence mean performance, standard heterosis and *sca* effects should be utilised together for choosing the topmost and beneficial cross combinations.

a. Days to first flower

The hybrids L_3 x T_2 and L_2 x T_1 exhibited superiority, for this trait with respects to all the three selection criteria. L_3 x T_2 was a poor x good combination whereas L_2 x T_1 was a combination of good x poor. High *sca* effect resulted from the interaction between positive and negative alleles from the parents (Dubey, 1975) and they depict the interaction effect of additive and dominance components.

b. Leaf axil bearing first flower

Though mean performance was superior for L_2 x T_1, L_2 x T_2 and L_5 x T_2, they showed non-significant values of standard heterosis as well as *sca* effects. Sadashiva (1988) observed high *sca* effects for this trait. L_2 x T_1 had the highest values for both in the desirable negative direction. Hence

L_2 x T_1 (a good and poor combination) could be regarded as a good hybrid for this trait.

c. Leaf area

L_2 x T_1 expressed the highest leaf area followed by L_3 x T_2, L_3 x T_3, L_5 x T_2 and L_2 x T_2 which also had highly significant estimates of standard heterosis. Among these, L_2 x T_1 was the hybrid of average x poor general combiners indicating the involvement of both additive and non-additive factors and this was applicable to L_3 x T_3 (good x poor) also. Meanwhile, L_4 x T_3 was produced by crossing parents both with poor general combining ability. This implies the major influence of non-additive genetic factors but this was not realised in the mean performance or heterosis. Hence only L_2 x T_1 and L_3 x T_3 may be selected as top ranking crosses for leaf area.

d. Pollen sterility

Three hybrids *viz.*, L_5 x T_1, L_5 x T_2 and L_2 x T_1 were superior with respect to mean performance and standard heterosis. Though L_3 x T_1 (poor x poor) had the highest *sca* effects, it did not possess correspondingly high mean values or heterosis. Hybrids with high *sca* effect need not exhibit high mean values and hence *sca* effects may not be the appropriate criterion for selecting superior crosses (Grakh and Choudhary, 1985). Other two crosses with high *sca* effects were L_5 x T_1 and L_2 x T_1 and both had good x poor parentage indicating the interaction between additive and non-additive genetic factors. In L_5 x T_2, both parents were with good general combining ability and the interaction of additive factors lead to hybrid vigour fixable by selection and this also justifies the low *sca* effects in the hybrid. Thus the list of best hybrids for pollen sterility includes L_2 x T_1, L_5 x T_1 and L_5 x T_2.

e. Fruits plant^{-1}

High number and standard heterosis for fruits plant^{-1} were observed for L_5 x T_2, L_2 x T_1, L_3 x T_2 and L_4 x T_2. As far as *sca* effects were

concerned, L_2 x T_1, L_3 x T_3, L_1 x T_3 and L_3 x T_2 exhibited high values. This is in conformity with the reports of Sadashiva (1988), Wankhade *et al.* (1995) and Indurani (1999) But L_3 x T_3 and L_1 x T_3 which involved poor parents did not have perform well with respect to mean values and standard heterosis. L_2 x T_1 and L_3 x T_2 were the products of average x poor and poor x good general combiners denoting the favourable interaction between desirable and undesirable alleles of the parents.

The topmost hybrids for fruit number were L_2 x T_1 and L_3 x T_2 considering the overall performance. However, L_5 x T_2 also was good owing to its best mean performance as well as standard heterosis.

f. Average fruit weight

Mean performance and standard heterosis were high for L_2 x T_1, L_4 x T_3, L_5 x T_1, L_5 x T_2 and L_4 x T_2. Though *sca* effect was the highest for L_1 x T_1 (poor x good), correspondingly high values were not evident for mean values and standard heterosis similar to the view of Grakh and Choudhary (1985). Other best specific combinations were L_2 x T_1, L_4 x T_3, L_3 x T_2 and L_3 x T_3. Sadashiva (1988) and Indurani (1999) observed high *sca* effects for average fruit weight. The first two were the combinations of average x good and good x poor parents indicating the promising interaction between desirable and undesirable alleles. The remaining two hybrids involved poor x good and poor x poor combining parents, which could not perform well for both mean values and standard heterosis. Thus L_2 x T_1 and L_4 x T_3 had superior overall performance. In spite of the lack of desirable *sca* effects, L_4 x T_2, L_5 x T_1 and L_5 x T_2 also could be added to this series owing to their superior mean values as well as standard heterosis.

g. Fruit weight plant^{-1}

The hybrid L_2 x T_1 occupied a remarkable position being the topmost cross for fruit yield with respect to all the three selection criteria. It was the product of two average general combiners pointing out the favourable interplay of desirable and undesirable alleles present in both the parents

thereby revealing the combined involvement of additive and dominance factors. Overall performance of L_5 x T_2 (good x good), L_5 x T_1 (good x average), L_4 x T_3 (good x poor) and L_3 x T_2 (poor x good) also were outstanding. The presence of at least one good general combiner in the case of all these excellent hybrids is noteworthy. Sadashiva (1988), Lakshmi *et al.* (1995) and Wankhade *et al.* (1995) had previously reported high *sca* effects for fruit yield in okra.

L_5 x T_2 was produced from two good general combiners indicating additive interaction behind its superiority, which may be responsible for its lower *sca* effects than that of the other best hybrids mentioned above. This implies that L_5 x T_2 is a good combination for heterosis breeding as well as for yield improvement by selection in advanced generations.

L_5 x T_1, a hybrid of good x average parentage, involved the interaction of additive and non-additive components of gene action which implies that this is suited for heterosis breeding. The other two crosses, L_4 x T_3 and L_3 x T_2 were the combinations of good and poor general combiners and these were also suited to heterosis breeding. Some other hybrids worth mentioning for fruit yield were L_4 x T_2 with high heterosis and L_3 x T_3 and L_1 x T_1 with high *sca* effects, which failed to exhibit consistency for the other criteria of selection.

h. Fruit length

High fruit length was observed for L_2 x T_1, L_5 x T_2 of which the first two possessed high standard heterosis also. Highly significant *sca* effects were noticed for all the three crosses along with L_3 x T_3 and L_4 x T_3. This agrees with the opinions of Lakshmiprasanna (1996) and Rajani *et al.* (2001). L_2 x T_1 and L_5 x T_2 were the topmost hybrids considering the overall performance. Both these had good general combiners as parents denoting additive x additive interaction.

i. Fruit girth

Both mean values and standard heterosis were high for L_2 x T_1, L_4 x T_3, L_3 x T_2 and L_4 x T_1 among which the first one had the highest mean values while the second one exhibited the highest heterosis. However, high *sca* effects were noticed for L_2 x T_1 and L_3 x T_2 only thereby making them the best hybrids for fruit girth. Both these were the combinations of average and poor combiners which involved the interaction of additive and dominant factors. High *sca* effects for this trait was observed by Lakshmiprasanna (1996) also.

j. Ridges fruit^{-1}

For this trait, none of the hybrids was superior with respect to all the three selection criteria. The three hybrids of L_1 with T_1, T_2 and T_3 had the high mean values as well as standard heterosis, but were with inferior *sca* effects. These crosses were the combinations of a common good general comber with average (T_1, T_2) and poor (T_3) combiners which indicate the predominance of additive genetic factors present in the common line parent. Hence the high mean performance and standard heterosis which resulted from additive effects are fixable through selection and also could be exploited through heterosis breeding. On the other side, L_5 x T_2 though had the highest *sca* effect, it was not evident in its mean performance or heterosis expression. Hence L_1 x T_1, L_1 x T_2 and L_1 x T_3 could be regarded as superior for this trait.

k. Seeds fruit^{-1}

L_2 x T_1, a resultant of crossing the two good combining parents was the only hybrid which outperformed all other hybrids with respect to all the three selection criteria. Though the hybrids L_3 x T_2, L_1 x T_3 and L_4 x T_3 exhibited highly significant standard heterosis and sca effects, their mean performance was low.

l. Plant duration

Considering the overall performance, L_2 x T_3 was superior to all other crosses. It was a product of crossing poor x good general combiners. Significant standard heterosis and *sca* effects were exhibited by L_3 x T_1 but with inferior mean value.

m. Fruit and shoot borer incidence

The only one hybrid superior with respect to all the three selection criteria was L_4 x T_3 which was a poor x poor combination indicating the predominance of *sca* effects. L_1 x T_1 though possessed high mean value as well as *sca* effects, failed to exhibit significant standard heterosis.

n. YVM incidence during final harvest

All the fifteen hybrids were superior for YVM incidence with respect to mean performance (except L_1 x T_2 and L_2 x T_3) as well as standard heterosis but with non-significant *sca* effects. Hence selection of YVM resistant hybrids which are superior for yield and its components must be selected for further breeding.

From the foregoing discussion, it was apparent that L_2 x T_1 (cross 1) stood much above all other hybrids, being outstandingly superior for majority of the traits under consideration *viz.*, day to first flower and leaf axil of first flower, leaf area, pollen fertility, fruits plant^{-1}, average fruit weight, fruit weight plant^{-1}, fruit length, fruit girth and seed number along with YVM resistance. L_5 x T_2 (cross 4) scored the second best position with superior overall performance for five characters *viz.*, number, average weight, yield and length of fruits and pollen sterility. Two crosses exhibited overall superiority for four traits each and they were L_3 x T_2 (cross 2) for days to first flower and number, yield and girth of fruits and L_4 x T_3 (cross 3) for average weight, yield and girth of fruits and fruit and shoot borer incidence. The four selected crosses possessed high resistance to YVM throughout the crop phase.

5.2.4 Proportional Contribution of Parents and Hybrids

In the present study, hybrids contributed the maximum towards majority of the traits investigated *viz.*, days to first flower, leaf area, fruit plant^{-1}, fruit length, fruit girth, seeds fruit^{-1}, plant duration and incidence of fruit and shoot borer and YVM during final harvest. Similar observations with respect to days to first flower and YVM incidence were reported by Sheela (1994).

Lines contributed the maximum to total variance of the remaining traits *viz.*, leaf axil bearing first flower, pollen sterility, average fruit weight, fruit weight plant^{-1} and ridges fruit^{-1}. However, Sheela (1994) put forth a contradictory view that testers accounted the maximum proportion of total variation in average weight, length, girth and yield of fruits.

5.3 GENERATION MEAN ANALYSIS

A sound understanding of the genetic architecture of genotypes and also their behaviour in differing genetic backgrounds is the basic requirement in adopting the most suited breeding strategy. Generation mean analysis assumes greater relevance in this context as it derives additional knowledge on epistasis (additive x additive, additive x dominance and dominance x dominance interactions) also.

The concept of generation mean analysis was formulated by Hayman (1958). Of the varying models available, six parameter model was utilised for the current study in which six generations (P_1, P_2, F_1, F_2, B_1 and B_2) were utilised and informations on six parameters were derived. The hybrids utilised were cross 1 (NBPGR/TCR-1498 x NBPGR/TCR-2060), cross 2 (NBPGR/TCR-2019 x Parbhani Kranti), cross 3 (MDU-1 x Varsha Uphar) and cross 4 (NBPGR/TCR-985 x Parbhani Kranti). Obviously, in all the crosses evaluated, high significance could be noticed for 'm' indicating considerable variation among the six generations utilised. Prevalence of duplicate epistasis compared to complementary in majority of the cases is broadly in agreement with the conclusion drawn by Lal *et al.* (1975).

a. Days to first flower

Significance observed for the scales B and C in cross 1 revealed the inadequacy of simple additive-dominance model and the presence of all the three types of epistatic interactions though none of them was significant on further assessment.

Cross 2 exhibited significance for scale D alone during joint scaling test, denoting the presence of only additive x additive interaction, which was acting significantly in desirable negative direction. Lal *et al.* (1975) also obtained similar results previously. This points out the possibility of obtaining early flowering types through direct selection.

Significant values of C and D scales in cross 3 pointed out the presence of dominance x dominance and additive x additive interactions respectively thereby indicating the absence of additive x dominance interactions. Though dominance x dominance interaction was not significant, dominant gene action assumed significance along with duplicate epistasis, similar to the reports of Kulkarni *et al.* (1978), Arumugam and Muthukrishnan (1979), Korla *et al.* (1985) and Pulliah *et al.* (1996). Additive x additive interaction had negative significance and greater magnitude than dominance effect. Improvement of this trait thus requires heterosis breeding and recurrent selection programmes.

Adequacy of additive-dominance model in cross 4 was clear from the non-significance of all the scales. Though additive effect exhibited significance, it acted in an undesirable positive direction. This trend was suggested earlier by Lal *et al.* (1975).

Duplicate interaction could be noticed in all the crosses except 4.

b. Leaf axil bearing first flower

Epistasis was found to be existing in cross 1 as evident from the significance of scale B. However, only the dominance x dominance component was significant which exerted in negative direction suggesting

the suitability of heterosis breeding for developing okra genotypes flowering at lower nodes.

Cross 2 registered the absence of epistasis as understandable from the non-significance of all the scales.

Significant value of scale A denoted that all types of digenic interactions are present in cross 3 and among them, additive x dominance (negative) component was prominent. Besides, additive effect also was significant. Therefore recombination breeding and isolation of desirable segregants in advanced generations is suggested.

Cross 4 witnessed the presence of only additive x additive type of epistasis as revealed by the significant scale D, though it acted in an undesirable positive direction. Among the significant estimates of additive and dominance components, only the former had negative value thereby indicating the feasibility of direct selection of desirable genotypes for improving this trait.

c. Leaf area

All the three kinds of digenic interactions along with dominance effect were significant in cross 1. However, only the dominance x dominance component possessed the positive value which was highest in magnitude also. Hence heterosis breeding would be suitable for improving leaf area as far as this cross is concerned.

Similar predominance of dominance x dominance effect in positive way was evident in cross 2 also suggesting the suitability of heterosis breeding.

Significant and positive values of additive and additive x dominance effects denotes that recombination breeding would be helpful

Only additive x additive interaction was present in cross 4 which was positively significant also. Simultaneously, both additive and dominance gene effects also exhibited positive significance. Among these, higher magnitude indicated the predominance of dominance effect. This indicates

that hybridisation followed by selection of genotypes with better leaf area might be beneficial.

d. Pollen sterility

Additive gene action and dominance x dominance interaction were prevalent in cross 1 in desirable negative direction. The higher magnitude noticed for the latter implies hybridisation followed by selection might be useful for the improvement of this character. Presence of complementary epistasis is also highly beneficial.

In the others three crosses, though various components displayed significance, only dominance x dominance effect was found to act in negative direction. Hence heterosis breeding is recommended.

e. Fruits plant^{-1}

Additive, additive x dominance and dominance x dominance components were significant in cross 1 and epistasis existed was of duplicate type. Involvement of additive and dominance components for fruit number could be located in the studies of Tripathi and Arora (2001). Importance of dominance effect and duplicate epistasis in the inheritance of fruit number was pointed out by Kulkarni *et al.* (1978), Arumugam and Muthukrishnan (1979), Korla *et al.* (1985) and Pulliah *et al.* (1996). Due to the predominance of dominance x dominance interaction, heterosis breeding would be useful. Selection of better types in segregating generations and also their intermating would be beneficial for the simultaneous exploitation of additive and epistatic gene effects.

All the gene effects and interaction effects were either absent or non-significant in the other three crosses. However, complementary epistasis could be observed in crosses 2 and 4.

f. Average fruit weight

Inheritance of average fruit weight was found to be in the control of additive and additive x dominance components of gene action in cross 1.

Though dominance x dominance effect was significant, its direction was negative. Direct selection and recombination breeding are recommended for this cross. Presence of epistasis and importance of additive and dominance components in the inheritance of average fruit weight had been observed by Tripathi and Arora (2001).

Cross 2 displayed significance for dominance and additive x additive components while cross 3 had significant additive x dominance gene interaction. However, all these were exerted in a negative way.

Significant and positive values for dominance and additive x additive components were noticed in cross 4 indicating heterosis breeding and recombination breeding approaches as beneficial for improving the average weight of fruits.

g. Fruit weight plant^{-1}

Cross 1 witnessed the presence of all the kinds of epistatic interactions as indicated by the significance of A and C scales. Involvement of epistasis and partial to complete dominant genes with additive gene effects was observed for fruit yield in okra by Korla and Sharma (1987a). Detailed analysis of cross 1 revealed the significance and positive values of additive and additive x dominance effects which was supported by Lal *et al.* (1975) who reported the prevalence of additive (negative) effect along with additive x dominance (positive) interaction for yield in okra. Direct selection and recombination breeding are expected to be useful for yield improvement in cross 1 in which complementary nature of epistasis is highly advantageous.

Epistasis was absent in cross 2 whereas acted in negative direction in cross 3. Both these crosses possessed negative and non-significant estimates for both additive and dominance effects.

The high positive significance of dominance effect in cross 4 points out the suitability of this hybrid for heterosis breeding. Though non-significant moderately high dominance x dominance interaction and the

complementary epistasis would be of high advantage in this process of yield improvement.

h. Fruit length

Absence of epistasis and adequacy of additive-dominance model in cross 1 were indicated by the non-significance of all the four scales during joint scaling test. Predominance of dominance gene action indicates the suitability for heterosis breeding.

Positive significance for dominance and additive x dominance components denote the suitability of cross 2 for heterosis breeding as well as recombination breeding.

Though epistasis was present , none of its components was significant in cross 3. However, the relative assessment of magnitude indicated the predominance of dominance gene action.

Though additive, additive x dominance and dominance x dominance components were significant in cross 4, only the third one acted in positive way thereby suggesting heterosis breeding as suitable for improving fruit length.

i. Fruit girth

Among the epistatic effects present in cross 1, additive x dominance was significant but exerted in the undesirable negative direction. The only type of interaction effect present in cross 2 was dominance x dominance, though non-significant and negative whereas epistasis was absent in cross 3.

Dominance x dominance effect was significant and acted in the desirable positive direction in cross 4 indicating the suitability of this cross for heterosis breeding.

j. Ridges $fruit^{-1}$

Significant and positive dominance and additive x additive genetic effects present in cross 1 denote heterosis breeding and selection of superior recombinants in advanced generations as useful for improving the trait.

Non-significance of all the scales indicate the adequacy of additive-dominance model in cross 2. Though non-significant, dominance effect was more pronounced.

Among the significant genetic components in cross 3, only dominance and additive x additive components acted in a desirably positive way, thereby suggesting heterosis as well as combination approaches to be beneficial. All the genetic components were non-significant in cross 4.

k. Seeds fruit^{-1}

Non-significance of all scales indicated the absence of epistasis in cross 1 whereas dominance and additive x additive genetic effects were positively significant in cross 2 indicating the usefulness of heterosis breeding and recurrent selection to improve the seed number.

Though epistasis was present, none of the significant effects acted in positive direction in both 3 and 4 crosses.

l. Plant duration

Additive and additive x dominance effects being negatively significant in cross 1 reveals that selection either directly or in advanced generations might be helpful in improving this trait. All the other crosses exhibited negatively significant dominance and additive x additive components indicating that the hybrid vigour could be fixed in advanced generations.

m. Crude fibre content

Adequacy of additive-dominance model was denoted by the non-significant scales during joint scaling test in cross 1 and 4. The desirable negative significance observed for additive effect implies the utility of direct selection of better genotypes with low fibre content.

All the genetic effects were non-significant in cross 2. Both additive and additive x dominance components assumed negative significance in

cross 3 indicating heterosis breeding as well as combination approach as useful.

n. Protein content

Significant positive estimates of additive x additive and additive effects in cross 1 and 2 respectively suggest that selection of desirable genotypes might be beneficial for improving protein content.

In cross 3, additive, additive x dominance and dominance x dominance acted in positive direction revealing heterosis breeding, recurrent selection and selection of better genotypes in subsequent generations as helpful.

The positive significance of additive, dominance, additive x additive and additive x dominance effects denote the utility of direct selection, heterosis breeding and combination breeding for developing better genotypes with high protein content.

o. Mucilage content

Positive significance of additive and additive x dominance genetic components in cross 1 implies the usefulness of selection either directly or in segregating generations in order to improve mucilage content. In cross 2, hybridisation alone or followed by selection would be desirable as indicated by the positively significant additive x dominance and dominance x dominance interactions.

In crosses 3 and 4, epistasis as well other gene effects were either absent, non-significant or acting in undesirable negative direction.

p. Fruit and shoot borer incidence

Desirable negative significance of additive x dominance and dominance x dominance interactions in cross 1 indicated heterosis breeding as more beneficial since the latter was predominant. However, recombination breeding also could be resorted to. Heterosis approach is applicable to cross 2 also in which only the dominance component showed

negative significance. In the other two hybrids, epistasis and other types of gene action were either absent or non-significant.

q. YVM incidence

Intra-allelic and inter-allelic gene actions were either absent or non-significant at 30 DAS and 50 DAS in all the four crosses. Significant additive effect present in all the crosses were in undesirable positive direction. Epistasis was absent in crosses 1 and 2 during 70 DAS and final harvest. Negatively significant dominance and additive x additive effects in crosses 3 and 4 suggest that heterosis breeding and selection of desirable segregants carrying YVM resistance would be highly beneficial. Contradictory to the duplicate epistasis observed in the present study, control of YVM resistance by two complementary dominant genes was reported by Thakur (1976) and Sharma and Dhillon (1983).

r. Leaf roller incidence

Negative significance observed for dominance and additive x additive effects in cross 1 indicates the heterosis breeding and combination breeding as beneficial for improving leaf roller resistance. Among the negatively significant additive x additive and additive x dominance interactions present in cross 2, the higher magnitude of the former suggest that the hybrid vigour could be easily fixed. Direct selection is also beneficial in this cross. No gene effect exhibited negative significance in cross 3. Feasibility of direct selection, heterosis breeding and selection of desirable recombinants in advanced generations was indicated by negatively significant estimates of additive, dominance, additive x additive and additive x dominance components.

s. Leaf spot incidence

Suitability of the direct selection of desirable genotypes resistant to leaf spot was indicated by the negative significance of additive gene action in crosses 1 and 3 while none of the genetic components was significant in

cross 2. In cross 3, additive x dominance and dominance x dominance effects also were negatively significant suggesting that heterosis breeding and recombination breeding also would be useful. Significant dominant x dominant interaction in cross 4 reveals its suitability of heterosis breeding.

5.3.1 Transgressive Segregants

Estimates of transgressive segregants (%) were the highest for fruit yield among all the traits in all the crosses except 4. This indicates the possibility for utilising these desirable segregants to develop superior varieties. Moreover, average fruit weight also exhibited high degree of transgressive segregants in all the crosses. Cross 3 produced the highest level of transgressive segregants for majority of the characters including leaf axil bearing first flower, leaf area, fruits plant^{-1}, fruit weight plant^{-1}, fruit length, fruit girth, ridges fruit^{-1}, protein content and incidence of fruit and shoot borer, YVM, leaf roller and leaf spot and it was followed by cross 2 with the highest values for days to first flower, average fruit weight, seeds fruit^{-1} and contents of crude fibre and mucilage. Cross 1 had the maximum transgressive segregants (%) for leaf area, pollen sterility and plant duration whereas cross 4 was with the maximum value for leaf axil bearing first flower.

Summary

6. SUMMARY

Okra has captured a prominent position among the vegetables due to its year round cultivation, export potential and high nutritive value. However, many of the okra cultivars now in vogue are highly susceptible to YVM disease which reduces the yield considerably. Hence it is essential to evolve varieties resistant to YVM disease. The present investigation was undertaken in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2001-2002 to study the genetic basis and inheritance pattern of yield, yield attributes and YVM resistance through generation mean analysis in order to develop high yielding disease resistant varieties in okra.

Okra germplasm consisting of 101 genotypes, collected from various parts of India including known YVM resistant varieties, types from NBPGR Regional Station, Vellanikkara, varieties released by KAU and local collections was evaluated simultaneously for YVM resistance and yield traits as two parallel experiments.

Screening for YVM resistance was carried out at four stages of the crop *viz*., 30 DAS, 50 DAS, 70 DAS and final harvest. ANOVA revealed significant variations among the genotypes during all the stages except at 30 DAS. The disease intensity increased gradually from 30 DAS to final harvest in various genotypes. Four genotypes *viz*., T34, T85, T86 and T91 exhibited high resistance to YVM throughout the crop phase.

The genotypes were scored for vector population of both white fly and leaf hopper in the morning and evening at 30 DAS, 50 DAS and 70 DAS. The genotypes differed significantly for white fly population during all the three crop stages while leaf hopper count had significance only during 50 DAS. Time of infestation differed significantly for white fly at 30 DAS whereas in all other cases, time mean square was non-significant.

Correlation coefficients of YVM incidence with vector population computed during the four crop stages revealed that morning and evening

population of both white fly and leaf hopper (except for morning population with YVM during final harvest) at 30 DAS had significant association with disease occurrence from 50 DAS to final harvest. Besides, white fly population during both the time at 50 DAS also had influenced on YVM incidence during final harvest.

Screening of germplasm (101 genotypes) for yield traits revealed significant variation among the genotypes, with respect to all the 22 characters studied except for YVM incidence at 30 DAS. Superior genotypes identified with respect to various characters were T15, T16, T34, T37, T82, T83, T85, T86 and T91.

Genetic parameters *viz.*, phenotypic and genotypic coefficients of variation, heritability (broad sense) and genetic advance were estimated for each character. The maximum values of both phenotypic and genotypic coefficients of variation were observed for protein content followed by fruit weight plant^{-1}. Majority of the characters possessed high heritability for fruits plant^{-1}, fruit weight plant^{-1}, ridges fruit^{-1}, days to first flower, leaf area, average fruit weight, fruit length, fruit girth and seeds fruit^{-1}. High genetic advance was displayed by all the traits except YVM incidence at 30 DAS and 50 DAS and the highest was for protein content followed by fruit weight plant^{-1}.

Correlation analysis indicated that most of the character combinations had higher genotypic correlation coefficient than phenotypic, though both were in the same direction. Environmental correlation coefficients were the lowest and in many cases in the opposite direction to that of genotypic. Fruit weight plant^{-1} displayed significant and positive genotypic association with leaf area, fruits plant^{-1}, average fruit weight, fruit length, fruit girth, seeds fruit^{-1}, plant duration and protein content and negative correlation with days to first flower, leaf axil bearing first flower, pollen sterility and incidence of fruit and shoot borer and YVM during final harvest.

The direct and indirect effects exerted on yield by the thirteen components, which had high association with fruit yield, were estimated

through path analysis. The maximum positive direct effect was exerted by plant duration followed by pollen sterility and average fruit weight. Direct effect in negative direction was the highest for days to first flower followed by leaf axil bearing first flower. Among the indirect effects, fruit girth exerted the highest positive value through days to first flower and plant duration. The highest negative indirect effect was noticed for leaf axil bearing first flower through days to first flower followed by fruit number through pollen sterility and YVM incidence through plant duration.

Selection indices were computed based on yield and thirteen component traits for 101 genotypes. Eight genotypes with high selection indices were chosen for hybridization programme to develop F_1 hybrids. Among these five high yielding but YVM susceptible types *viz.*, NBPGR/TCR-985, NBPGR / TCR-2019, MDU-1, NBPGR/TCR-2020 and NBPGR/TCR-1498 were utilised as lines and three highly resistant genotypes *viz.*, Varsha Uphar, Parbhani Kranti and NBPGR/TCR-2060 were employed as testers.

Line x tester analysis was performed for fourteen characters. Significant variation was observed among parents with respect to all traits except days to first flower and plant duration while crosses had significant variation except for YVM incidence. High values for *gca* effects and *sca* effects were noticed for fruit yield and leaf area. Heterosis for the characters of 15 hybrids with respect to their mid, standard, better and best parents were estimated. Relative heterosis was the highest for YVM incidence followed by fruit yield whereas standard heterosis and heterosis over best parent were maximum for fruit and shoot borer incidence followed by fruit yield. The highest heterobeltiosis was observed for pollen sterility followed by borer incidence and fruit yield. L_5 was the most superior line which excelled for number, average weight, length, girth and yield of fruits, leaf axil bearing first flower and low YVM incidence. Among the testers, T_2 was the best being superior for traits *viz.*, number, average weight, yield, length, girth, ridges and seeds of fruits.

With respect to *gca* effects also, L_5 was the best being a good general combiner for pollen sterility, average fruit weight, fruit yield and fruit length and an average combiner for leaf axil bearing first flower and YVM incidence. L_4 had good general combining ability for fruit yield and fruit number along with average *gca* effect for fruit girth.

T_2 exhibited the best general combining ability for majority of the traits *viz.*, fruit yield, fruit number, average fruit weight, days to first flower, leaf axil of first flower, leaf area, pollen sterility and fruit and shoot borer incidence along with average combining ability for ridges fruit^{-1} and fruit girth. T_1 displayed good *gca* effects for fruit length, ridges fruit^{-1} and seeds fruit^{-1} and negative (non-significant) *gca* effect for YVM incidence during final harvest.

Among the hybrids, overall performance was superior for L_2 x T_1 (cross 1) with respect to days to first flower, leaf axil bearing first flower, leaf area, pollen sterility, fruits plant^{-1}, average fruit weight, fruit weight plant^{-1}, fruit length, fruit girth, seeds fruit^{-1} and YVM resistance. Good overall performance was displayed by L_5 x T_2 (cross 4) with respect to pollen sterility, fruits plant^{-1}, average fruit weight, fruit yield and fruit length, L_3 x T_2 (cross 2) for days to first flower, fruit number, fruit yield and fruit girth and L_4 x T_3 (cross 3) for average fruit weight, fruit yield, fruit girth and fruit and shoot borer incidence. All these hybrids displayed high resistance to YVM disease.

The four superior crosses identified from line x tester analysis. viz., cross 1 (NBPGR/TCR-1498 x NBPGR/TCR-2060), cross 2 (NBPGR/TCR-2019 x Parbhani Kranti), cross 3 (MDU-1 x Varsha Uphar) and cross 4 (NBPGR/TCR-985 x Parbhani Kranti) were utilised for generation mean analysis. Six generations P_1, P_2, F_1, F_2, B_1 and B_2 were developed in the four selected crosses. The generation mean analysis was done to detect the gene action with respect to 22 characters including incidence of leaf roller and leaf spot. The generation means of the traits for all the crosses were computed and joint scaling test was conducted in order to detect the

presence of epistasis followed by the estimation of additive x additive, additive x dominance and dominance x dominance interactions. In all the crosses, high significance could be noticed for 'm' indicating considerable variation among the different generations and duplicate epistasis was more prevalent than complementary type in majority of the cases.

For days to first flower, epistasis was present in crosses 1 (non-significant), 2 (additive x additive) and 3 (additive x additive and dominance effect) thereby suggesting suitability of direct selection in cross 2 and heterosis breeding and recurrent selection in cross 3.

Epistasis existed in all the crosses except 2 for leaf axil bearing first flower. In cross 1, negatively significant dominance x dominance interaction suggested heterosis breeding whereas in cross 3, predominance of additive x dominance interaction along with additive effect denoted recombination breeding and isolation of desirable segregants in advanced generations. Direct selection of desirable genotypes is suitable for cross 4 due to the high additive (negative) gene action.

Crosses 1 and 2 recorded dominance x dominance interaction for leaf area thereby depicting heterosis breeding as useful. Significant and positive values of additive and additive x dominance effects denote the usefulness of recombination breeding in cross 3 while in cross 4, predominance of dominance effect along with additive and additive x additive effects indicate heterosis breeding, direct selection and recombination breeding as beneficial.

For pollen sterility, dominance x dominance interaction was prevalent along with additive gene action in cross 1 suggesting heterosis breeding and recombination breeding as useful. In all other crosses, heterosis breeding is recommended due to the negatively significant dominance x dominance effect.

Due to the predominance of dominance x dominance interaction, heterosis breeding would be useful to improve fruit number in cross 1. In the other crosses, all the effects were either absent or non-significant.

In the case of average fruit weight, additive and additive x dominance components were prevalent in cross 1 and hence direct selection and recombination breeding are recommended. In crosses 2 and 3 desirable gene action could not be noticed. Heterosis breeding and recombination breeding would be helpful in cross 4 as indicated by significant dominance and additive x additive components.

For fruit weight plant^{-1}, cross 1 had significant additive and additive x dominance effect implying direct selection and recombination breeding as useful. Epistasis was absent in cross 2 whereas negative in cross 3. Cross 4 was suitable for heterosis breeding due to the highly positive dominance effect.

Epistasis was absent and non-significant in crosses 1 and 3 respectively for fruit length. Positive significance for dominance and additive x dominance components denote the suitability of cross 2 for heterosis breeding as well as recombination breeding. In cross 4, positive significance for dominance x dominance interaction denotes the usefulness of heterosis breeding.

Epistasis was undesirable, non-significant and absent for fruit girth in crosses 1, 2 and 3 respectively. Cross 4 was suitable for heterosis breeding due to the positive significance of dominance x dominance interaction.

Heterosis breeding and recombination breeding would be useful in cross 1 owing to the positively significant dominance and additive x additive effects for ridges fruit^{-1}. Epistatis was absent in cross 2 and non-significant in cross 4. Cross 3 had positive dominance and additive x additive components indicating heterosis and combination breeding approaches to be beneficial.

Epistasis was absent in cross 1 whereas negative in crosses 3 and 4 for seeds fruit^{-1}. In cross 2, positive significance for dominance and additive x additive genetic effects indicated heterosis breeding and recurrent selection as useful.

Selection either directly or in advanced generations would be useful in cross 1 in the case of plant duration due to the negative significance for additive and additive x dominance effects, other three crosses showed negatively significant dominance and additive x additive components indicating that hybrid vigour could be fixed in advanced generations.

Epistasis was absent in crosses 1 and 4 and non-significant in cross 2 for crude fibre content. In cross 3, negative significance of additive and additive x dominance components suggested direct selection as well as combination approach as useful.

Positive significance for additive x additive and additive effects for crosses 1 and 2 respectively suggest selection as useful for improving protein content. In cross 3, additive, additive x dominance and dominance x dominance components were positively significant revealing heterosis breeding, recurrent selection and selection of better genotypes in subsequent generations as helpful. Cross 4 exhibited positive significance for additive, dominance, additive x additive and additive x dominance effects denoting the utility of direct selection, heterosis breeding and combination breeding.

In cross 1, selection directly or in segregating generations would be useful to improve mucilage content as implied by the positive significance of additive and additive x dominance genetic components. In cross 2, heterosis breeding and recombination breeding would be suited as it had significant additive x dominance and dominance x dominance interactions. All the gene effects were absent, non-significant or negative in crosses 3 and 4.

Heterosis breeding, would be more beneficial in crosses 1 and 2 due to the predominance of dominance x dominance and dominance component respectively for fruit and shoot borer incidence. In other crosses, epistasis was absent or non-significant.

Intra-allelic and inter-allelic gene actions were either absent or non-significant for YVM incidence in all the four crosses at 30 DAS and 50 DAS and in crosses 1 and 2 during 70 DAS and final harvest. In crosses 3 and 4, negatively significant dominance and additive x additive effects suggest that

heterosis breeding and selection of desirable segregants possessing YVM resistance would be beneficial.

Heterosis breeding and recombination breeding might be beneficial in cross 1 as indicated by the negatively significant dominance and additive effects for leaf roller resistance. Direct selection and recombination breeding are recommended in cross 2 owing to the negatively significant additive x additive and additive x dominance interactions. None of the gene effects was negatively significant in cross 3 whereas in cross 4, direct selection, heterosis breeding and selection of desirable recombinants would be feasible as denoted by desirable additive, dominance, additive x additive and additive x dominance components.

Direct selection would be useful in crosses 1 and 3 for improving leaf spot resistance due to desirable additive gene action while no genetic effect was significant in cross 2. Desirable dominance x dominance effects in crosses 3 and 4 suggest the utility of heterosis breeding for improving this character.

Predominance of additive and additive x dominance interaction in cross L_2 x T_1 for yield and average fruit weight suggests its suitability for direct selection and recombination breeding. Cross L_5 x T_2 could be utilised for heterosis breeding and selection, directly or in segregating generations, in order to improve yield, average fruit weight and YVM resistance owing to the prevalence of dominance and additive x additive components. The gene effects were absent, non-significant or undesirable in cross L_3 x T_2.YVM resistance in L_4 x T_3 could be improved through heterosis breeding, direct selection and recombination breeding due to the presence of negatively significant dominance and additive x additive components.

References

7. REFERENCES

Agarrado, R.E. and Rasco, E.T.Jr. 1986. The potential of F_1 hybrids in okra. *Philipp. J. Crop Sci.* 11 (Suppl.): 3B – 6a

Ahmed, N., Hakim, M. A. and Gandroo, M. Y. 1999. Exploitation of hybrid vigour in okra. *Indian J. Hort.* 56: 247 – 251

Ahmed, N., Hakim, M. A. and Zargar, G. H. 1997. Combining ability studies in okra (*Abelmoschus esculentus* (L.) Moench). *Veg. Sci.* 24: 95 – 98

Ahmed, N., Thakur, M. R., Bajaj, K. L. and Cheema, S. S. 1994. Biochemical basis of resistance to yellow vein mosaic virus in okra. *Pl. Dis. Res.* 9 : 20-25

Akoroda, M.D. 1986. Allogamy, varietal adulteration and the breeding of okra (*Abelmoschus esculentus* (L.) Moench) in Nigeria. *J. agric. Sci.* 106: 313-321

Alex, R. 1986. Progeny studies of interspecific crosses of *Abelmoschus*. M.Sc.(Ag). thesis, Kerala Agricultural University, Thrissur, p.112

Ali, M., Hossain, M. Z. and Sarker, N. C. 2000. Inheritance of yellow vein mosaic virus (YVMV) tolerance in a cultivar of okra. *Euphytica* 62: 205 – 209

Allard, R. W. 1960. *Principles of Plant Breeding*. John Wiley & Sons, New York, p. 485

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

Animon, G. 1996. Induced mutations in interspecific hybrids of *Abelmoschus* spp. M.Sc. (Ag) thesis, Kerala Agricultural University, Thrissur, p.112

Ariyo, O. J. 1990a. Measurement and classification of genetic diversity in okra (*Abelmoschus esculentus*). *Ann. appl. Biol.* 116: 335 – 341

Ariyo, O. J. 1990b. Variation and heritiability of fifteen characters in okra (*Abelmoschus esculentus* (L.)Moench). *Trop. Agric.(Trin.)* 67:213– 216

Ariyo, O. J. 1992. Factor analysis of vegetative and yield traits in okra (*Hibiscus esculentus*). *Indian J. agric. Sci.* 62 : 83 – 84

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

Arora, S.K. 1993. Diallel analysis for combining ability studies in okra (*Abelmoschus esculentus* (L.) Moench) *Punjab hort. J.* 33:116– 122

Arora, S.K., Dhanju, K.C. and Sharma, B.R. 1992. Resistance in okra (*Abelmoschus esculentus* (L.) Moench) genotypes to yellow vein mosaic virus. *Pl. Dis. Res.* 7 : 221 – 225

Arumugam, R. and Muthukrishnan, C.R. 1979. Gene effects on some quantitative characters in okra. *Indian J. agric. Sci.* 49: 602-604

Arumugam, R. and Muthukrishnan, C. R. 1981a. Association of metric traits in bhendi. *South Indian Hort.* 29: 1 – 3

Arumugam, R. and Muthukrishnan, C.R. 1981b. Studies on resistance to yellow vein mosaic in bhendi (*Abelmoschus esculentus* (L.). Moench). *Proceedings of International Seminar on disease resistance in crop plants, December 22-23, 1980*. Tamil Nadu Agricultural University, Coimbatore, pp. 105-108

Arumugam, R., Chelliah, S. and Muthukrishnan, C.R. 1975. *Abelmoschus manihot* : a source of resistance to bhendi yellow vein mosaic. *Madras agric. J.* 62: 310 – 312

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

Babu, K.V.S. and Dutta, O.P. 1990. Cytogenetic studies of the F_1 hybrids *Abelmoschus esculentus* x *A. tetraphyllus* and its amphidiploid. *Agric. Res. J. Kerala* 28: 22 – 25

Balachandran, P.V. 1984. Estimation of heterosis in bhindi (*Abelmoschus esculentus* (L.) Moench). M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, p.94

Balakrishnan, S. and Balakrishnan, R. 1988. Studies on variability in bhendi (*Abelmoschus esculentus* (L.) Moench). *South Indian Hort.* 36: 300 – 303

Balakrishnan, S. and Balakrishnan, R. 1990. Association and path analysis studies in bhendi (*Abelmoschus esculentus* (L.) Moench). *South Indian Hort.* 38: 274 – 275

Bas, T. and Koludar, J. 2001. Characterisation in okra (*Hibiscus esculentus* L.) germplasm in Turkey. *Acta Hort.* No.560: 133-136

*Bates, D. M. 1968. Notes on the cultivated Malvaceae. 2. *Abelmoschus*. *Baileya* 16 : 99 – 112

Batra, V.K. and Singh, J. 2000. Screening of okra varieties to yellow vein mosaic virus under field conditions. *Veg. Sci.* 27: 192-193

Bhagat, A.P. and Yadav, B.P. 1997. Biochemical changes in bhindi yellow vein mosaic virus infected leaves of bhindi. *J. Mycol. Pl. Path.* 27: 94–95

Bhagat, A.P., Yadav, B.P. and Prasad, Y. 2001. Rate of dissemination of okra yellow vein mosaic virus disease in three cultivars of okra. *Indian Phytopath.* 54: 488 – 489

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

Bindu, K.K., Manju, P. and Sreekumar, S.G. 1997. Genetic variability in bhendi (*Abelmoschus esculentus* (L.) Moench). *South Indian Hort.* 45: 286 – 288

Bisht, I.S., Mahajan, R.K. and Rana, R.S. 1995. Genetic diversity in South Asian okra (*Abelmoschus esculentus*) germplasm collection. *Ann. appl. Biol.* 126: 539 – 550

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

Bora, G.C., Saikia, A.K. and Shadeque, A. 1992. Screening of okra genotypes for resistance to yellow vein mosaic virus disease. *Indian J. Virol.* 8: 55-57

Bradford, M.M. 1976. A rapid and sensitive method for quantification of microgram quantities of protein utilising the principle of protein dye binding. *Ann. Biochem.* 72: 248

Bray, G.G. and Thorpe, W.V. 1954. Analysis of phenolic compounds of interest in metabolism. *Methods biochem. Anal.* 1: 27 – 52

*Burton, G.W. 1952. Quantitative inheritance in grasses. *Proc. Int. Grassland Congr.*6: 227-283

Capoor, S. P. and Varma, P. M. 1950. Yellow vein mosaic of *Hibiscus esculentus* L. *Indian J. agric. Sci.* 20: 217 – 230

Chander, M. S. 1990. Biochemical changes associated with yellow vein mosaic virus (YVMV) infection of okra. *Proceedings of the 42nd Annual Meeting, January 3-5, 1990.* Indian Phytopathological Society, Tirupati, pp.14-15

Chandran, M. 1996. Embryo rescue in interspecific crosses of *Abelmoschus*. M.Sc. (Hort.) thesis, Kerala Agricultural University, Thrisssur, p.96

Chandran, M. and Rajamony, L. 1997. Interspecific cross compatibility in *Abelmoschus. Proceedings of Nineth Kerala Science Congress, January 29-31, 1997.* (ed. Das, M.R.). Science Technology and Environment Committee, Government of Kerala, Thiruvananthapuram, pp. 186

Changan, N.B and Shukla, P.T. 1986. Heterosis and inbreeding depression for some yield components in okra (*Abelmoschus esculentus* (L.) Moench). *Madras agric. J.* 72: 276 – 280

*Charrier, A. 1984. *Genetic Resources of the Abelmoschus Med. (okra)*. International Board for Plant Genetic Resources, Rome, p. 81

Chavadhal, A.S. and Malkhandale, J.D. 1994. Combining ability studies in okra. *J. Soils Crops* 4: 10 – 14

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

Chelliah, S. and Srinivasan, K. 1983. Resistance in bhindi, brinjal and tomato to major insects and pests. *National seminar on Breeding Crop Plants for Resistance to Pests and Diseases. May 25 27, 1983*. Tamil Nadu Agricultural University, Coimbatore, pp. 16-18

Chelliah, S., Murugesan, S. and Murugesan, M. 1975. Influence of weather factors on incidence of yellow vein mosaic of bhindi. *Madras agric. J.* 62: 412 – 419

*Chevalier, A. 1940. L'origine, la culture et les usagis decing Hibiscus de la section *Abelmoschus*. *Rev. Bot. Appl.* (French) 20: 319 – 328

Chopra, S.L. and Kanwar, J.S. 1976. *Analytical Agricultural Chemistry*. Kalyani Publishers, Ludhiana, p. 341

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

Dash, G.B. and Mishra, P.K. 1995. Variation and character association of fruit yield and its component characters in okra (*Abelmoschus esculentus* (L.) Moench). *Curr. agric. Res.* 8: 123 – 127

Dayasagar, P. 1994. Studies on heterosis in bhendi (*Abelmoschus esculentus* (L.) Moench). *Ann. agric. Res.* 15: 321 – 326

Deo, C., Singh, K.P. and Panda, P.K. 1998. Inheritance of pod yield and its components in okra (*Abelmoschus esculentus* (L.) Moench.). *Orissa J. Hort.* 26(2): 18 – 22

Deo, C., Singh, K.P. and Panda, P.K. 2000. Screening of okra parental lines and their F_1S for resistance against yellow vein mosaic virus. *Veg. Sci.* 27: 78-79

Dewey, O.R. and Lu, K.H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *J. Agron.* 57: 515-518

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

Dhandapani, N. 1986. Consumption, digestion and utilisation of bhindi varieties by *Earias vittella* Fabricius. *Madras agric. J.* 73: 676 – 678

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

Dhawan, A.K. and Sidhu, A.S. 1984. Incidence and relative abundance of different species of spotted boll worms on okra at Ludhiana, Punjab. *J. Res. PAU* 21: 533 – 542

Dhillon, T.S. and Sharma, B.R. 1982. Interspecific hybridisation in okra (*Abelmoschus* sp.). *Genetica Agraria* 36: 247 – 256

Dubey, R.S. 1975. Combining ability in cigar filter tobacco. *Indian J. Genet.* 35: 76-92

Dutta, O.P. 1984. *Breeding Okra for Resistance to Yellow Vein Mosaic Virus and Leaf Curl Virus-Annual Report.* Indian Institute of Horticultural Research, Bangalore, p. 43

Dutta, O.P., Pitchaimuthu, M. and Ganeshan, G. 2000. New sources of resistance to yellow vein mosaic virus in okra (*Abelmoschus esculentus* (L.) Moench). *Annual Meeting and Symposium on Emerging Trends in Plant Disease Management. December 7 – 8, 2000.* Indian Institute of Horticultural Research, Bangalore, pp. 15-16

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

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

Duzyaman, E. 1997. Okra-Botany and Horticulture. *Hort. Rev* .21: 41 – 71

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

Elangovan, M., Muthukrishnan, C. R. and Irulappan, I. 1981. Hybrid vigour in bhindi (*Abelmoschus esculentus* (L.) Moench) for some economic characters. *South Indian Hort.* 29: 4 – 14

Elangovan, M., Muthukrishnan, C. R. and Irulappan, I. 1983. Evaluation of bhendi hybrids and their parents for crude fibre content. *South Indian Hort.* 31: 241 – 243

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

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

Engels, J.M.M. and Chandel, K.P.S. 1990. Conservation strategies : a historic approach with particular reference to *Abelmoschus* gene pool. *Int. Crop Network Ser.* 5: 119 – 123.

Evans, L.T. 1978. *Crop Physiology*. Cambridge University Press, Cambridge, London, p.355

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

Falconer, D.S. 1981. *Introduction to Quantitative Genetics*. Third edition. Longman, New York, p. 438

*Fisher, R.H. 1936. The use of multiple measurement in taxonomic problems. *Ann. Urgen.* 7: 179-188

*Ford, C.E. 1938. A contribution to a cytological survey of the Malvaceae. *Genetica* 20: 431 – 452

Fugro, P.A. and Rajput, J.C. 1999. Breeding okra for yellow vein mosaic virus resistance. *J. Mycol. Pl. Path.* 29: 25 – 28

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

Giriraj, K. and Rao, T.S. 1973. Note on simple crossing technique in okra. *Indian J. agric. Sci.* 43: 1089-1091

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

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

Gopimony, R. and Nair, V.G. 1982. An easy method for hybrid seed production in bhindi. *Agric. Res. J. Kerala* 20: 67 – 68

Grakh, S.S. and Chaudhary, M.S. 1985. Heterosis for early maturing and high yield in *Gossypium arboreum*. *Indian J. agric. Sci.* 55: 10-13

Grubben, G.J.H. 1977. *Okra-Tropical Vegetables and Their Genetic Resources*. International Board for Plant Genetic Resources, Rome, p. 211

Hamon, S. and Hamon, P. 1991. Future prospects of the genetic integrity of two species of okra (*Abelmoschus esculentus* and *A. caillei*) cultivated in West Africa. *Euphytica* 53: 101-111

Hamon, S. and Koechlin, J. 1991a. The reproductive biology of okra. 1. Study of the breeding systems in four *Abelmoschus* species. *Euphytica* 53: 41 – 48

Hamon, S. and Koechlin, J. 1991b. The reproductive biology of okra. 2. Self fertilisation kinetics in the cultivated okra (*Abelmoschus esculentus*) and consequences for breeding. *Euphytica* 53: 49 – 55

Handa, A. and Gupta, M. D. 1993. Management of bhindi yellow vein mosaic virus disease. *Indian Phytopath.* 46: 123 – 130

Hatchcock, B. R. and Mc Daniel. 1973. Yield and yield component heterosis in Avena hybrids. *Crop Sci.* 13: 8 – 18

Hayman, B. I. 1958. The separation of epistasis from additive and dominance variation in generation means. *Heredity* 12 : 371 – 390

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

Hirst, E.L. and Jones, J.K.N. 1955. The analysis of plant gums and mucilages. *Modern Methods of Plant Analysis* (eds. Paech, K. and Tracey, M.V.). Narosa Publishing House, New Delhi, pp. 275-294

Hooda, V.S. and Dhankhar, B.S. Dahiya, B.S. and Singh, R. 1999. Inheritance of resistance to leaf hopper (*Amrasca biguttula biguttula*) on okra. *Indian J. Hort.* 56: 73 – 76

Hossain, M. and Chattopadhyay, T. K. 1976. Morphological features of resistance to yellow vein mosaic virus disease of the F_1 interspecific hybrids of *Abelmoschus* species. *Pl. Sci.* 8: 49 – 51

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

IBPGR. 1990. *International Workshop on Okra Genetic Resources.* International Board for Plant Genetic Resources. Rome, p. 133

IIHR. 1991. Okra – resistant to yellow vein mosaic virus. *Indian Inst. Hort. Res. News* 1: 3

Indurani, C. 1999. Studies on the development of F_1 hybrids in okra (*Abelmoschus esculentus* (L.) Moench) with high yield and resistance to yellow vein mosaic virus. M.Sc.(Hort.) thesis. Tamil Nadu Agricultural University, Coimbatore, p. 141

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

Jalgaonkar, V.N., Patil, P.D., Munj, A.Y. and Naik, K.V. 2002. Screening of germplasm of okra, *Abelmoschus esculentus* L. against shoot and fruit borer *Earias vittella* and flea beetle, *Monolepta signata* O. *Pestology* 26(3): 21-25

Jambhale, N.D. and Nerkar, Y.S. 1981. Inheritance of resistance to okra yellow vein mosaic disease in interspecific crosses of *Abelmoschus*. *Theor. appl. Genet.* 60: 313-316

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

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

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

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

Jinks, J.L. and Jones, R.M. 1958. Estimation of the components of heterosis. *Genetics* 43: 223-234

John, S. 1997. Genetic analysis of segregating generations of irradiated interspecific hybrids in okra (*Abelmoschus* spp.). M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, p.84

John, S., Manju, P., Gopimony, R. and Saraswathy, P. 1999. Variability studies in F_3 generation of irradiated interspecific hybrids in okra (*Abelmoschus esculentus* L. Moench). *South Indian Hort.* 47: 210-212

Johnson, H.W., Robinson, W.E. and Comstock, R.F. 1955. Genotypic and phenotypic correlations in soyabeans and their implication in selection. *Agron. J.* 47: 447-483

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

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

Kashyap, R.K. and Verma, A.N. 1983. Relative susceptibility of okra to shoot and fruit borer (*Earias* spp.). *Indian J. Ecol.* 10: 303-309

KAU. 1996. *Package of Practices Recommendations: Crops. Eleventh Edition*. Kerala Agricultural University, Thrissur, p. 278

Kempthorne, O. 1957. *An Introduction to Genetic Statistics*. John Wiley and Sons, Inc, New York, p.126

Khan, M.A. and Mukhopadhyay, S. 1986. Screening of okra (*Abelmoschus esculentus*) varieties tolerant to yellow vein mosaic virus (YVMV). *Res. Dev. Rep.* 3: 86-87

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

Korla, B.N. and Sharma, P.P. 1987a. A note on genetics of yield in okra (*Abelmoschus esculentus* (L.) Moench). *Haryana J. hort. Sci.* 16: 304-307

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

Korla, B.N. and Sharma, P.P. 1988. Inheritance of seed characters in okra (*Abelmoschus esculentus* (L.) Moench). *Farm Sci. J.* 3: 9-13

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

Korla, B.N., Thakur, M.R. and Sharma, P.P. 1985. Genetics of yield components in okra. *South Indian Hort.* 33: 367-371

*Kulkarni, G.S. 1924. Mosaic and other diseases of crops in the Bombay Presidency. *Proceedings of Eleventh Science Congress.* 3:103

Kulkarni, R.S. 1975. Biometrical investigations in bhindi (*Abelmoschus esculentus* (L.) Moench). M.Sc.(Ag.) thesis, University of Agricultural Sciences, Bangalore, p. 83

Kulkarni, R.S., Rao, T.S. and Virupakshappa, K. 1978. Quantitative inheritance in okra. *Prog. Hort.* 10: 47-49

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

Lakshmi, G.V., Ravisankar, C. and Prasad, D.M. 1995. Heterosis and combining ability in okra. *Andhra agric. J.* 42:30-33

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

Lakshmiprasanna, J.R. 1996. Genetic studies in okra (*Abelmoschus esculentus* (L.) Moench). M.Sc.(Hort.) thesis, University of Agricultural Sciences, Dharwad, p. 100

Lal, G. 1986. Selection indices for improving earliness, pod yield and seed yield in okra. *Prog. Hort.* 18: 118: 123

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

Lal, S., Shekhar, C. and Srivastava, J.P. 1975. Genetical studies in bhindi (*Abelmoschus esculentus* (L.) Moench)-Gene effects and heterosis. *Indian J. Hort.* 32: 175-178

Lal, S., Shekhar, C. and Srivastava, J. P. 1977. A note on genetical studies in bhindi (*Abelmoschus esculentus* (L.) Moench)-Heritability and genetic advance. *Indian J. Hort.* 34:49-50

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

Madav, R.P. and Dumbre, R.B. 1985. Reaction of okra varieties to shoot and fruit borer. *J. Maharashtra agric. Univ.* 10: 276-277

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

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

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

Mamidwar, R.B., Nerkar, Y.S. and Jambhale, N.D. 1979. Cytogenetics of interspecific hybrids in the genus *Abelmoschus*. *Indian J. Hered.* 11:35-40

Mandal, M. and Dana, I. 1993. Heterosis and inbreeding depression in okra. *Env. Biol.* 11: 649-652

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

Martin, F.W. 1983. Natural outcrossing of okra in Rico. *J. agric. Univ. Puerto Rico* 67: 50-52

Martinello, G.E., Leal, N.R., Amarlal, A. T. Jr., Pereira, M.G. and Daher, R.F. 2001. Comparison of morphological characteristics and RAPD for estimating genetic diversity in *Abelmoschus* spp. *Acta Hort.* No. 546:101-104

*Masters, M.T. 1875. *Flora of British India*. Ashford Kent. p.350

*Mather, K. 1949. *Biometrical Genetics*. Methuen and Co. Ltd., London, p.153

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

Mathews, H. 1986. Evaluation of the F_2 generation interspecific hybrids of *Abelmoschus* with reference to yellow vein mosaic resistance and yield. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, p.86

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

Mishra, R.S. and Chhonkar, V.S. 1979. Genetic divergence in okra. *Indian J. agric. Sci.* 49:244-246

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

Mishra, R.S. and Singh, D.N. 1992. Interrelationships in some quantitative traits in okra. *Indian J. agric. Res.* 26:40-44

Mishra, R.S., Rath, U.K. and Sahy, G.S. 1990. Association of biometric characters in okra. *Orissa J. agric. Res.* 3:6-8

Mote, U.N. 1982. Studies on the varietal resistance of okra to fruit borer. *J. Maharashtra agric. Univ.* 7:188

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

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

Nariani, T. K. and Seth, M.N. 1958. Reaction of *Abelmoschus* and *Hibiscus* species to yellow vein mosaic virus. *Indian Phytopath.* 11: 137-143

Nath, P. 1970. Problem oriented breeding projects in vegetable crops. *SABRAO Newsl.* 2: 125-134

Nerkar, Y.S. and Jambhale, N.D. 1985. Transfer of resistance to yellow vein mosaic from related species to okra (*Abelmoschus esculentus*). *Indian J. Genet.* 45: 261-270

Ngah, A.W. and Graham, K.M. 1973. Heritability of some economic characters in okra (*Hibiscus esculentus* L.). *Malaysia agric. Res.* 2:5-21

Palaniveluchamy, K., Muthukrishnan, C.R. and Irulappan, I. 1982 Studies on heritability and genetic advance in bhendi (*Abelmoschus esculentus* (L.) Moench). *Madras agric. J.* 69: 597-599

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

Pal, A.K. and Hossain, M. 2000. Combining ability analysis for seed yield, its components and seed quality in okra (*Abelmoschus esculentus* (L.) Moench). *J. Interacademicia* 4 : 216-226

Pal, B.P., Singh, H.B. and Swarup, V. 1952. Taxonomic relationships and breeding possibilities of species of *Abelmoschus* related to okra (*Abelmoschus esculentus*). *Bot. Gaz.* 13: 455-464

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

Panda, P.K. and Singh, K. P. 1999. Heterosis and inbreeding depression for yield and pod characters in okra. *J. Maharashtra agric. Univ.* 23: 249-251

Panda, P.K. and Singh, K.P. 2000. Modified triple test cross analysis for yield and yield components in okra (*Abelmoschus esculentus* (L.) Moench). *Indian J. Genet.* 60: 569-571

Pandey, A., Tiwari, A.K. and Mall, P. 2002. Screening of okra (*Abelmoschus esculentus* (L.) Moench) for yield performance and susceptibility to fruit borer, *Earias vitella* Fabricius. *Pestology* 26: 32-34

Panse, V.G. and Sukhatme, P.V. 1985. *Statistical Methods for Agricultural Workers*. Indian Council of Agricultural Research, New Delhi, p.359

Partap, P.S. and Dhankhar, B.S. 1980a. Combining ability in okra (*Abelmoschus esculentus* (L.) Moench). *Genetica Agraria* 34: 76-74

Partap, P.S. and Dhankhar, B.S. 1980b. Heterosis studies in okra (*Abelmoschus esculentus* (L.) Moench). *Haryana agric. Univ. J. Res.* 10: 336-341

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

Partap, P.S., Dhankhar, B.S. and Pandita, M.L. 1981. Heterosis and combining ability in okra (*Abelmoschus esculentus* (L.) Moench). *Haryana J. hort. Sci.* 10: 122-127

Patel, J.N. and Dalal, K.C. 1992. Variability in okra. *GAU Res. J.* 18: 132-134

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

Patel, S.S., Kulkarni, U.G. and Nerkar, Y.S. 1994. Combining ability analysis for dry seed yield and its attributing traits in okra. *J. Maharashtra agric. Univ.* 19: 49-50

Pathak, R., Syamal, M.M. and Singh, A.K. 2001. Line x tester analysis for yield and its components in okra (*Abelmoschus esculentus* (L.) Moench). *Ann. agric. Res.* 22: 22-24

Patil, C.S., Maholkar, P.R. and Ajri, D.S. 1986. Studies on moth attraction and egglaying preference of shoot and fruit borer (*Earias vittella* Stoll.) on different varieties of okra (*Abelmoschus esculentus* L.). *Curr. Res. Reporter, Mahatma Phule agric. Univ.* 2: 289-291

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

Pawar, V.Y., Poshiya, V.K. and Dhaduk, H.L. 1999a. Combining ability analysis in okra. *GAU Res. J.* 25: 106-109

Pawar, V.Y., Poshiya, V.K. and Dhaduk, H.L. 1999b. Heterosis studies in okra (*Abelmoschus esculentus* (L.) Moench). *GAU Res. J.* 25: 26-31

Peter, K.V. 1998. *Genetics and Breeding of Vegetables*. Indian Council of Agricultural Research, New Delhi, p. 333

Philip, A.M.C. 1998. Genetic evaluation of F_4 and F_5 generations of irradiated interspecific hybrids in okra (*Abelmoschus* spp.). M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, p. 101

Philip, A.M.C. and Manju, P. 2002. Correlations studies in F_5 generation of irradiated interspecific hybrids in okra (*Abelmoschus esculentus* (L.) Moench). *Proceedings of 14th Kerala Science Congress, January 29-31, 2002*, (Ed. Das, M.R.), Science Technology and Environment Committee, Government of Kerala, Kochi, pp. 271-273

Philip, A.M.C., Manju, P. and Rajagopalan, B. 2000. Variability in F_4 generation of irradiated interspecific hybrids in okra (*Abelmoschus esculentus* (L.) Moench). *J. trop. Agric.* 38: 87-89

Pillai, U.P.R. 1984. Evaluation of interspecific hybrids of bhindi with reference to yellow vein mosaic resistance and heterosis. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, p. 92

Pitchaimuthu, M. and Dutta, O.P. 2002. Combining ability using gene male sterile lines in okra (*Abelmoschus esculentus* (L.) Moench). *International Conference on Vegetables, November 11-14, 2002.* Prem Nath Agricultural Science Foundation, Bangalore, Abstract: p.109

Poopathi, G., Manivannan, M. and Ramaswamy, N. 1996. A note on the comparative performance of bhendi cultivars for yield and YVM disease. *Prog. Hort.* 28: 143-146

Poshiya, V.K. and Shukla, P.T. 1986a. Combining ability analysis in okra. *GAU Res. J.* 12(1): 25-28

Poshiya, V.K. and Shukla, P.T. 1986b. Heterosis studies in okra (*Abelmoschus esculentus* (L.) Moench). *GAU Res. J.* 12(2): 21-25

Prakash, M., Kannan, K., Kumar, J.S., Bharathiveeramani, B., Balaji, P. and Ganesan, J. 2001. Studies on the genetics of certain quantitative characters with particular reference to seed production in okra (*Abelmoschus esculentus* (L.) Moench). *Ann. agric. Res.* 22: 80-82

Pulliah, N., Reddy, T.B., Resdisekhar, M. and Reddy, B.M. 1996. Inheritance of yield components in okra (*Abelmoschus esculentus* L. Moench). *Veg. Sci.* 23: 52-56

Pulliah, N., Reddy, T.B., Moses, G.J., Reddy, B.M. and Reddy, D.R. 1998. Inheritance of resistance to yellow vein mosaic virus in okra (*Abelmoschus esculentus* (L.) Moench). *Indian J. Genet.* 58: 349-352

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

Pun, K.B., Doraiswamy, S. and Jeyarajan, R. 1999. Immunological detection of okra yellow vein mosaic virus. *Indian J. Virol.* 15: 93-96

Purewal, S.S. and Randhawa, G.S. 1947. Studies in *Hibiscus esculentus*. Chromosome and pollination studies. *Indian J. agric. Sci.* 17: 129-136

Radhika, D. 1988. Genetic analysis of yield components in bhindi (*Abelmoschus esculentus* (L.) Moench). M.Sc.(Ag.) thesis. Andhra Pradesh Agricultural University, Hyderabad, p. 86

Rajamony, L., Celine, V. A. and Rajmohan, K. 2002. Evolution of okra (*Abelmoschus esculentus* (L.) Moench) resistant to yellow vein mosaic virus in humid tropics. *International Conference on Vegetables, November11-14, 2002*, Prem Nath Agricultural Science Foundation, Bangalore, *Abstract* :p.67

Rajamony, L., Jessykutty, P.C. and Mohanakumaran, N. 1995. Resistance to yellow vein mosaic virus of bhindi in Kerala. *Veg. Sci.* 22: 116-119

Rajani, B. 1995. Combining ability in bhindi (*Abelmoschus esculentus* (L.) Moench). M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, p.148

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

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

Rajani, B., Manju, P., Nair, P.M. and Saraswathy, P. 2001. Combining ability in okra (*Abelmoschus esculentus* (L.) Moench). *J. trop. Agric.* 39: 98-101

Ramu, P.M. 1976. Breeding investigation in bhindi (*Abelmoschus esculentus* (L.) Moench). *Mysore J. agric. Sci.* 10: 146

Randhawa, J.S. 1989. Genetics of economic characters in an intervarietal cross of okra (*Abelmoschus esculentus*). *Indian J.agric. Sci.* 59: 120-122

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

Rao, T.S. 1977. Line x tester analysis of heterosis and combining ability in bhindi. *Agric. Res. J. Kerala* 15: 112-116

Rao, T.S. and Bidari, V.B. 1976. New selections of bhindi-early, high yielding and resistant to yellow vein mosaic disease. *Curr. Res.* 5: 49-50

Rao, T.S. and Ramu, P.M. 1975. Genetic analysis of three pod characters in bhendi (*Abelmoschus esculentus* (L.) Moench). *Madras agric. J.* 62: 331-337

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

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

Ravisankar, J. 2002. Development of yellow vein mosaic virus (YVMV) resistant hybrids in okra (*Abelmoschus esculentus* (L.) Moench). M.Sc.(Hort.) thesis, Kerala Agricultural University, Thrissur, p. 85

Ravisankar, J., Babu, K.V.S., Gopalakrishnan, T.R., Mathew, S.K. and Krishnan, S. 2002. Development of yellow vein mosaic virus (YVMV) resistant F_1 hybrids in okra (*Abelmoschus esculentus* (L.) Moench). *International Conference on Vegetables, 11-14 November, 2002*, Prem Nath Agricultural Science Foundation, Bangalore, *Abstract* :p.93

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

Rojas, B.A. and Sprague, G.F. 1942. A comparison of variance components in corn yield trials. III. General and specific combining ability and their interaction with locations and years. *Agron J.* 44: 462-466

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

Saha, A. and Kabir, J. 2001. Economic heterosis of some commercial hybrids of bhindi (*Abelmoschus esculentus* (L.) Moench). *Crop Res. Hisar* 22: 271-273

Salehuzzman, M. 1985. Screening of world germplasm of okra (*Abelmoschus esculentus*) for resistance to yellow vein mosaic virus. *Bangladesh J. Agric.* 10: 1-8

Samnotra, R.K., Gupta, A.K., Kaul, R. and Tripathi, V. 2002. Leaf shapes in okra (*Abelmoschus esculentus* (L.) Moench). *Env. Ecol.* 20: 245-246

Sandhu, G.S., Sharma, B.R., Singh, B. and Bhalla, J.S. 1974. Sources of resistance to jassids and whitefly in okra germplasm. *Crop Improv.* 1: 77-81

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

Sannigrahi, A.K. and Choudhary, K. 1998. Evaluation of okra cultivars for yield and resistance to yellow vein mosaic virus in Assam. *Env. Ecol.* 16: 238-239

Sardana, H.R. and Dutta, O.P. 1989. Field response of okra (*Hibiscus esculentus*) germplasm to infestation by shoot and fruit borer. *Indian J. agric. Sci.* 59: 391-392

Sastry, K.S.M. and Singh, S.J. 1974. Effect of yellow vein mosaic virus infection on growth and yield of okra crop. *Indian Phytopath.* 27: 294-297

Sharma, B.R. and Arora, S.R. 1993. Improvement of okra. *Vegetable Crops* (eds. Chadha, K.L. and Kalloo, G.). Malhotra Publishing House, New Delhi, pp.243-264

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

Sharma, B.R. and Gill, B.S. 1984. Genetics of resistance to cotton jassid, *Amrasca biguttula biguttula* (Ishida)in okra. *Euphytica* 33: 215-220

Sharma, B.R. and Sharma, O.P. 1984. Field evaluation of okra germplasm against YVM virus. *Punjab Hort. J.* 24: 131-133

Sharma, B.R., Arora, S.K., Dhanju, K.C. and Ghai, T.R. 1993. Performance of okra cultivars in relation to yellow vein mosaic virus and yield. *Indian J. Virol.* 9: 139-142

Sharma, B.R., Sinha, U.K. and Chauhan, S.K. 1985. Relationship of bhindi (*Abelmoschus esculentus*) yellow vein mosaic virus and leaf surface mycoflora. *Indian Phytopath.* 38: 20-24

Sharma, J.R. 1994. *Principles and Practices of Plant Breeding*. Tata Mc Graw Hill, New Delhi, p.615

Sharma, N.K. and Dhankhar, B.S. 1989. Evaluation of okra (*Abelmoschus esculentus* (L.) Moench) genotypes against shoot and fruit borer (*Earias* spp.) under field conditions. *Haryana J. hort. Sci.* 18: 123-129

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

Sheela, M.N. 1986. Evaluation of bhindi hybrids for yield and its components. M.Sc.(Ag.) thesis, Kerala Agricultural University, Thrissur, p. 150

Sheela, M.N. 1994. Induction of genetic recombination in interspecific crosses of *Abelmoschus*. Ph.D thesis, Kerala Agricultural University, Thrissur, p.182

Sheela, M.N., Nair, P.M. and Nair, V.G. 1988a. Association of yield and its components in bhindi. *Agric. Res. J. Kerala* 26: 121-126

Sheela, M.N., Nair, P.M. and Nair, V.G. 1988b. Heterosis in bhindi. *Agric. Res. J. Kerala* 26: 23-28

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

Shukla, A.K. and Gautam, N.C. 1990. Heterosis and inbreeding depression in okra (*Abelmoschus esculentus* (L.) Moench). *Indian J. Hort.* 47: 85-88

Shukla, A.K., Gautam, N.C., Tiwari, A.K. and Chaturvedi, A.K. 1989. Heterosis and combining ability in okra. *Veg. Sci.* 16: 191-196

Siemonsma, J.S.1982. West African Okra-morphological and cytogenetical indications for the resistance of a natural amphidiploid of *Abelmoschus esculentus* (L.) Moench x *Abelmoschus esculentus* (L.) Medikus. *Euphytica* 31: 241-252

Singh, A.K. and Sood, S. 1999. Heterosis and inbreeding depression in okra. *Indian J. Hort.* 56: 67-72

Singh, D. 1983. Biometrical and genetical studies in okra, *Abelmoschus esculentus* (L.) Moench. Ph.D thesis, Punjab Agricultural University, Ludhiana, p. 152

Singh, D.K., Lal, G. and Rai, P.N. 1993. Performance of okra cultivars under Tarai conditions of Uttar Pradesh. *Ann. agric. Res.* 14: 220-222

Singh, D.K., Lal, G. and Tewari, R.P. 1994. Effect of sowing time on virus incidence and seed yield in okra. *Ann. agric. Res.* 15: 374-375

Singh, G.N. and Singh, S.P. 1984. Fractional diallel analysis for some quantitative characters in okra. *Indian J. agric. Sci.* 54: 205-208

Singh, H.B. and Bhatnagar, A. 1975. Chromosome number in an okra from Ghana. *Indian J. Genet.* 36: 26-27

Singh, H.B., Joshy, B.S., Khanna, P.P. and Gupta, P.S. 1962. Breeding for field resistance to YVM in bhindi. *Indian J. Genet.* 22: 137-144

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

Singh, K., Malik, Y., Kalloo, S. and Mehrotra, N. 1974. Genetic variability and correlation studies in bhindi (*Abelmoschus esculentus* (L.) Moench). *Veg. Sci.* 1: 47-54

Singh, K.B. and Singh, H.N. 1979a. Path coefficient analysis for yield in okra. *Indian J. agric. Sci.* 49: 244-246

Singh, M. and Thakur, M.R. 1979. Nature of resistance of yellow vein mosaic in *Abelmoschus manihot* ssp. *manihot*. *Curr. Sci.* 48: 164-165

Singh, N., Arora, S.K., Ghai, T.R. and Dhillon, T.S. 1995. Gene action in okra (*Abelmoschus esculentus* (L.) Moench). *Veg. Sci.* 22: 98-100

Singh, R., Singh, H.C. and Singh, R.R. 1983. Effect of yellow vein mosaic virus on nitrogen and carbohydrate metabolism of bhindi. *Indian J. Mycol. Pl. Path.* 13: 179-182

Singh, R.K. and Chaudhary, B.D. 1985. *Biometrical Methods in Quantitative Genetic Analysis*. Kalyani Publishers, New Delhi, p. 304

Singh, R.K. and Mandal, G. 1993. Studies on heterosis in okra (*Abelmoschus esculentus* (L.) Moench). *Ann. agric. Res.* 14: 429-433

Singh, R.P. and Singh, L.N. 1986. Studies on the varietal resistance of okra (*Abelmoschus esculentus* L. Moench) to yellow vein mosaic virus under conditions. *J. Indian bot. Soc.* 65(suppl): 23

Sinha, S.N. and Chakrabarti, A.K. 1976. Effect of YVM virus infection on okra seed production. *Seed Res.* 6: 67-70

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

Singh, S.P. and Singh, H.N. 1979b. Line x tester analysis in okra. *Indian J. agric. Sci.* 49:500-504

Sivakumar, S., Ganesan, J. and Sivasubramanian, V. 1995. Combining ability analysis in bhendi. *South Indian Hort.* 43: 21-24

Sivakumar, S., Ganesan, J. and Sivasubramanian, V. 1996. Genetic analysis in bhendi. *South Indian Hort.* 44: 143-146

Smith, H.F. 1936. A discriminant function for plant selection. *Ann. Eugenics* 7: 240-250

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

Sood, S. 2001. Genetics of number of pods in okra (*Abelmoschus esculentus* (L.) Moench). *Adv. Hort. For.* 8: 123-128

Sood, S. and Sharma, S.K. 2001. Heterosis and gene action for economic traits in okra. *SABRAO J. Breed. Genet.* 33: 41-46

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

Sprague, G.F. and Tatum, L.A. 1942. General vs specific combining ability in single crosses of corn. *J. Am. Soc. Agron.* 34: 923-932

Srinivasa, N. and Sugeetha, G. 2001. Field screening of certain okra varieties for resistance against major pests. *Insect Env.* 7: 74-76

Srivastava, P.K., Srivastava, K.J., Sharma, H.K. and Gupta, R.P. 1995. Evaluation of different varieties of okra against yellow vein mosaic virus (YVMV). *Newsl. Natl. hort. Res. Dev. Foundation* 15(4): 8-10

Subhasini, K., Ravisankar, C. and Rao, N.P. 1996. Correlation and path coefficient analysis in okra. *Scienti. Hort.* 5: 81-85

Sujatha, V.S., Madan, T.R. and Seshadri, V.S. 1986. Oil content and its quality in seeds of wild and cultivated species of *Abelmoschus*. *Indian J. agric. Sci.* 56: 657-660

Sundhari, S.S., Irulappan, I., Arumugam, R. and Jayasankar, S. 1992. Combining ability in okra (*Abelmoschus esculentus* (L.) Moench). *South Indian Hort.* 40: 21-27

Teli, V.S. and Dalaya, V.P. 1981. Studies on varietal resistance in okra (*Abelmoschus esculentus* (L.) Moench) to the shoot and fruit borer, *Earias vittella* Fabricius. *South Indian Hort.* 29: 54-60

*Thaker, D.N., Desai, K.B., Tikka, S.B.S. and Patel, K.K. 1981a. Combining ability for fruit yield and its components in okra. *Gracia de orta Estudos Agronomicos (*German) 8: 17-20

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

Thaker, D.N., Tikka, S.B.S. and Patel, K. 1982. Hybrid vigour and inbreeding depression for fruit yield and its components in okra (*Abelmoschus esculentus* (L.) Moench). *GAU. Res. J.* 8(1): 1-4

Thakur, M.R. 1976. Inheritance of yellow vein mosaic in a cross of okra species *Abelmoschus esculentus* x *A. manihot* ssp. *manihot*. *SABRAO J. Breed. Genet.* 8: 69-73

Tripathi, V. and Arora, S.K. 2001. Detection of epistasis and estimation of components of genetic variation in okra (*Abelmoschus esculentus* (L.) Moench). *Veg. Sci.* 28: 109-112

Ugale, S.D., Patil, R.C. and Khupse, S.S. 1976. Cytogenetic studies in the cross between *Abelmoschus esculentus* and *A. tetraphyllus*. *J. Maharashtra agric. Univ.* 1: 106-110

Uppal, B.N., Varma, P.M. and Capoor, S.P. 1940. Yellow vein mosaic of bhindi. *Curr. Sci.* 9: 227-228

Varma, P.M. 1952. Studies on the relationship of bhindi yellow vein mosaic virus and its vector, the whitefly (*Bemisia tabaci*). *Indian J. agric. Sci.* 22: 75-91

Varma, P.M. 1955. Persistance of yellow vein mosaic virus of *Abelmoschus esculentus* (L.) Moench in its vector *Bemisia tabaci*. *Indian J. agric. Sci.* 25:293-302

Varma, P.M. and Mukherjee, S.K. 1955. Studies on the varietal classification and virus resistance in lady's finger, *Abelmoschus esculentus* (L.). Proceeding of 42nd Indian Science Congress, Part III, pp. 371-372

Vashist, V.A. 1990. Genetic analysis of reaction of yellow vein mosaic virus in okra (*Abelmoschus esculentus* (L.) Moench). Ph.D thesis, Punjab Agricultural University, Ludhiana, p.138

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

Vasline, Y.A. 1993. Heterosis and combining ability for certain characters in bhendi crop improvement. M.Sc.(Ag.) thesis, Annamalai University, p.86

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

Veeraraghavathatham, D. 1989. Genetic analysis in okra. Ph.D thesis, Tamil Nadu Agricultural University, Coimbatore, p. 203

Veeraraghavathatham, D. and Irulappan, I. 1990. Genetic analysis in okra (*Abelmoschus esculentus* (L.) Moench). *South Indian Hort.* 38: 75-82

Veeraraghavathatham, D. and Irulappan, I. 1991. Combining ability analysis in certain okra (*Abelmoschus esculentus* (L.) Moench) hybrids and parents. *South Indian Hort.* 39: 193-199

Venkitaramani, K.S. 1952. A preliminary study on some intervarietal crosses and hybrid vigour in *Hibiscus esculentus* (L.). *J. Madras Univ.* 22: 183-200

Verma, A. 2000. Okra (Ladies finger)- A popular vegetable. *Pl. Horti Tech.* 2: 62-64

Vijay, O.P. and Manohar, M.S. 1986a. Combining ability studies in okra. *Indian J. Hort.* 43: 133-139

Vijay, O.P. and Manohar, M.S. 1986b. Heterobeltiosis in okra (*Abelmoschus esculentus* (L.) Moench). *Indian J. Hort.* 43: 252-259

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

Vinod, J.P.M., Pathak, R., Kumar, N. and Gupta, M.D. 2000. Evaluation of okra genotypes for yellow vein mosaic resistance. *Indian J. Pl. Genet. Resources* 13: 194-197

Vyas, S.H. and Patel, J.R. 1990. Relative susceptibility of some lady's finger cultivars to *Earias vittella* Fab. *Indian J. Pl. Prot.* 18: 115-118

Vyas, S.H. and Patel, J.R. 1991. Intensity and damage of *Earias vittella* Fab. on various cultivars of bhendi. *GAU Res. J.* 17: 140-141

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

Wankhade, R.V., Kale, P.B. and Dod, V.N. 1995. Combining ability analysis in okra. *PKV Res. J.* 19: 121-124

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

Yadav, J.R., Singh, B. and Srivastava, J.P. 2002. Combining ability analysis in okra (*Abelmoschus esculentus* (L.) Moench). *International Conference on Vegetables, November 11-14, 2002.* Prem Nath Agricultural Science Foundation, Bangalore, *Abstract*: p.61

Yadav, S.K. and Dhankhar, B.S. 2001. Seed production and quality of okra (*Abelmoschus esculentus* (L.) Moench) cv. Varsha Uphar as

affected by sowing time and position of fruit on plant. *Seed Res.* 29: 47-51

Yadav, S.P. and Murthy, B.R. 1966. Heterosis and combining ability of different height categories in bread wheat. *Indian J. Genet.* 36: 184-196

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

Zala, S.P., Patil, J.R. and Patel, N.C. 1991. Impact of weather on magnitude of *Earias vittella* infesting okra. *Indian J. Ent.* 61: 351-355

Zelleke, H. 2000. Combining ability for grain yield and other agronomic characters in inbred lines of maize (*Zea mays* L.). *Indian J. Genet.* 60: 63-70

*- Originals not seen

GENETIC ANALYSIS FOR YIELD AND RESISTANCE TO YELLOW VEIN MOSAIC IN OKRA

(*Abelmoschus esculentus* (L.) Moench)

P. SINDHUMOLE

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Department of Plant Breeding and Genetics
COLLEGE OF AGRICULTURE
VELLAYANI, THIRUVANANTHAPURAM- 695 522

8. ABSTRACT

The most dreaded disease affecting okra (*Abelmoschus esulentus* (L.) Moench) is yellow vein mosaic (YVM), which affects at all stages of the crop growth. Being a viral one, the best way to tackle this disease is to use resistant varieties. Thus it is essential to identify the sources of YVM resistance and study the inheritance of resistance to develop high yielding YVM resistant varieties of okra. Hence an investigation was undertaken to reveal the genetic variability and to identify the resistant genotypes in a collection of germplasm, to estimate the combining ability and heterosis by line x tester analysis and to assess the inheritance pattern of YVM resistance and yield using generation mean analysis in order to formulate an appropriate breeding programme for improving the economic characters.

Okra germplasm consisting of 101 genotypes was evaluated simultaneously for YVM resistance and yield traits as two parallel field experiments in RBD with two replications during summer 2000. Screening for YVM resistance was carried out at four crop stages *viz*., 30 DAS, 50 DAS, 70 DAS and final harvest. ANOVA revealed significant variation among genotypes during all the stages except at 30 DAS. Number of susceptible genotypes as well as disease intensity increased gradually from 30 DAS to final harvest. Four genotypes exhibited high resistance to YVM throughout the crop phase. All the genotypes were observed for vector population of white fly and leaf hopper in the morning and evening at 30 DAS, 50 DAS and 70 DAS and they varied significantly for white fly population during all the crop stages whereas for leaf hopper count only at 50 DAS. Morning and evening populations of both vectors at 30 DAS had significant association with disease occurrence during 50 DAS to final harvest.

During the evaluation of yield traits, ANOVA revealed significant variation among the genotypes for the traits *viz*., days to first flower, leaf axil bearing first flower, leaf area, pollen sterility, fruits plant^{-1}, average

fruit weight, fruit weight plant^{-1} (yield), fruit length, fruit girth, ridges fruit^{-1}, seeds fruit^{-1}, plant duration, crude fibre content, protein content, mucilage content, fruit and shoot borer incidence, YVM incidence (except at 30 DAS). Besides, colour and pubescence of fruits also were scored for each genotype.

The maximum values of both phenotypic and genotypic coefficients of variation were noticed for protein content and fruit yield. Most of the traits possessed high heritability especially fruits plant^{-1}, fruit yield and ridges fruit^{-1}. High genetic advance (% mean) could be noticed for majority of the traits, the highest being for protein content and fruit yield.

Correlation analysis indicated that most of the character combinations had higher genotypic correlation coefficients than phenotypic, though both had the same direction. Fruit yield displayed positive genotypic association with leaf area, fruits plant^{-1}, average fruit weight, fruit length, fruit girth, seeds fruit^{-1}, plant duration and protein content and negative correlation with days to first flower, pollen sterility and incidence of fruit and shoot borer and YVM (except at 50 DAS).

Among the thirteen component traits which had high association with fruit yield the maximum positive and negative direct effects were exerted by plant duration and days to first flower respectively. Maximum indirect effects were exerted by fruits plant^{-1} in positive direction and by leaf axil bearing first flower in negative direction and both these were through days to first flower.

Selection indices were computed utilising yield and its thirteen components and eight genotypes were chosen. Among these, five high yielding but YVM susceptible types *viz.*, NBPGR/ TCR-2020 (L_1), NBPGR/TCR-1498 (L_2), NBPGR/TCR-2019 (L_3), MDU-1 (L_4) and NBPGR/TCR-985 (L_5) were used as lines and NBPGR/TCR-2060 (T_1), Parbhani Kranti (T_2) and Varsha Uphar (T_3) were used as testers for crossing programme.

During line x tester programme, high values of *gca* and *sca* effects were noticed for fruit yield and leaf area. L_5 was the most superior line which excelled with respect to mean performance and general combining ability for yield average weight and length of fruits and leaf axil bearing first flower along with low YVM incidence. Among the testers T_2 was the best being superior for yield, number, average weight, girth and ridges of fruits.

Out of the fifteen hybrids, overall performance with respect to *per se* performance, standard heterosis and *sca* effects was superior for $L_2 \times T_1$ (NBPGR/TCR-1498 x NBPGR/TCR-2060) with respect to days to first flower, leaf area, pollen sterility, fruits plant^{-1}, average fruit weight, fruit weight plant^{-1}, fruit length, fruit girth, seeds fruit^{-1} and YVM resistance. Other excellent hybrids were $L_5 \times T_2$ (NBPGR/TCR-985 x Parbhani Kranti) $L_3 \times T_2$ (NBPGR/TCR-2019 x Parbhani Kranti) and $L_4 \times T_3$ (MDU-1 x Varsha Uphar).

These four selected crosses were utilised for generation mean analysis in order to detect the gene action with regard to 22 traits including incidence of leaf roller and leaf spot. Presence of epistasis was tested and subsequently interaction effects *viz.*, additive x additive, additive x dominance and dominance x dominance effects were computed. Duplicate epistasis was more prevalent than complementary in majority of the cases.

Predominance of additive and additive x dominance interaction in cross $L_2 \times T_1$ for yield and average fruit weight suggests its suitability for direct selection and recombination breeding. Cross $L_5 \times T_2$ could be utilised for heterosis breeding and selection, directly or in segregating generations, in order to improve yield, average fruit weight and YVM resistance owing to the prevalence of dominance and additive x additive components. The gene effects were absent, non-significant or undesirable in cross $L_3 \times T_2$. YVM resistance in $L_4 \times T_3$ could be improved through heterosis breeding, direct selection and recombination breeding due to the presence of negatively significant dominance and additive x additive components.