VARIABILITY FOR YIELD AND RESISTANCE TO YELLOW VEIN MOSAIC VIRUS DISEASE IN OKRA

(*Abelmoschus esculentus* (L.) Moench)

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(2010-11-142)

DEPARTMENT OF PLANT BREEDING AND GENETICS

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VELLAYANI, THIRUVANANTHAPURAM- 695 522

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by

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THESIS

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KERALA, INDIA

2012

Dedicated

To

My Appa, Amma, Anna and

Dr. Arya. K

DECLARATION

I hereby declare that this thesis entitled **"Variability for yield and resistance to yellow vein mosaic virus disease in okra (*Abelmoschus esculentus* (L.) Moench)"** is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, fellowship or other similar title, of any other University or Society.

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CERTIFICATE

Certified that this thesis entitled "**Variability for yield and resistance to yellow vein mosaic virus disease in okra (*Abelmoschus esculentus* (L.) Moench)"** is a record of bonafide research work done independently by **Kishor D.S (2010-11-142)** under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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INTRODUCTION

1. INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) also known as lady's finger, bhindi and gumbo belonging to the family Malvaceae is an important vegetable crop of the tropics and subtropics.

Africa is considered as the centre of origin of okra and its progenitor is reported to be *A. tuberculatus*, with n = 29. The genus *Abelmoschus* (2n = 130) includes about thirty species in the old world, four in the new world and four in Australia. The genus *Abelmoschus* comprises of nine cultivated species (Anonymous, 1991). It is commercially cultivated in West Africa, India, South East Asia, Southern United States, Brazil, Turkey and Northern Australia.

In India, okra has been cultivated since time immemorial. The major okra producing states are West Bengal, Bihar, Orissa, Andhra Pradesh, Gujarat, Jharkhand and Karnataka. The area, production and productivity of bhindi in India is 4.32 lakh ha, 45 million tonnes and 10.5 million tonnes respectively (Kumar, 2009). This significant achievement could be attributed to the development of high yielding varieties and hybrids possessing resistance to biotic and abiotic stresses. It is widely cultivated as a summer crop in North India and as a winter crop in Gujarat, Andhra Pradesh, Karnataka and Tamil Nadu. Okra grows well in areas where day temperature remains between 25 and 40°C and that of night over 22°C.

Okra is specially valued for its tender, delicious green fruits which are cooked, canned and consumed in various forms in different parts of the country and for about 60 per cent of the export of fresh vegetables (Mehta, 2007). Nutritionally, it is low in saturated fat, cholesterol and sodium and high in dietary fibre, vitamin A, C, K, B6, Thiamin, Folate, Calcium, Magnesium, Phosphorus, Potassium, Manganese, Protein, Riboflavin, Niacin, Iron, Zinc and Copper. Aykryod (1963) reported that 100 g of edible okra contains about 1.9 g protein, 0.2 g fat, 6.4 g carbohydrate, 0.7 g minerals and 1.2 g fibre. Okra is also used in paper industry. Its leaves are used in medicine to smoothen and reduce inflammation.

The major problem in okra cultivation is the lack of location specific varieties/hybrids tolerant/resistant to biotic (diseases and pests) as well as abiotic stresses (low temperature in Rabi). In summer, when the environmental conditions are conducive for crop growth it is severely attacked by sucking pests and viral diseases.

Among the diseases, yellow vein mosaic virus (YVMV) transmitted by whitefly (*Bemisia tabaci* Gen.) is the most serious one. Infection of 100 per cent plants in a field is common and yield losses range from 30 to 94 per cent depending on the stage at which infection occurs (Ali *et al*., 2000). The disease also affects fruit quality.

Crop improvement by developing YVMV disease resistant varieties is more economical and environmentally safer than crop management using chemicals. Earlier efforts led to the development and release of cultivars like Pusa Sawani (Singh *et al*., 1962) and MDU-1 with field resistance to YVMV. During 1992, IIHR had released and notified two okra varieties, namely, Arka Anamika and Arka Abhay having high yield (20t/ha) and resistance to YVMV. These cultivars were widely cultivated in India which exhibited field resistance to YVMV. With the passage of time, the cultivars Pusa Sawani and MDU-1 have become susceptible to YVMV. Hence, there is an immediate need to identify stable sources of resistance and also to develop high yielding okra lines.

The ease in emasculation, very high per cent of fruit set and large number of seeds per fruit makes commercial exploitation of hybrid vigour easy in bhindi. Being an often cross-pollinated crop, out crossing to an extent of 5-9 per cent by insects is reported which renders considerable genetic diversity. Hence, the first step in okra improvement should involve evaluation of the germplasm for genetic variability. As a second step, it is required to generate crosses employing a suitable mating design to know the extent of heterosis for various economic traits and inheritance pattern of desired characters, which in turn, would help in deciding the breeding strategies as

well as identifying potential parents and crosses for further use in breeding programme. A sound breeding strategy for developing cultivars with enhanced fruit yield and resistance to YVMV hinges on a thorough knowledge on gene action of yield components and resistance to YVMV disease.

Keeping these points in mind, the present study was conducted with the aim to accomplish the following objectives

1. To assess the extent of variability for yield, yield attributes and yellow vein mosaic virus resistance among the germplasm
2. To assess the occurrence of vector population (white fly) and its association with YVMV disease
3. To confirm the resistance in glass house experiments in the selected genotypes through vector and graft transmission studies
4. To assess the association between yield and yield attributes
5. To study the combining ability and heterosis

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The literature available on various aspects of the present investigation reviewed and presented under the following headings.

2.1 GENETIC VARIABILITY

Breeders have realized the significance of variability, its heritable component i.e. heritability and genetic gain effected by the difference in phenotype resulting due to environment and human selection pressure. For different characters the literature on these aspects is cited below.

Robinson *et al.* (1949) emphasized that heritability of the characters is the main concern to the breeder, since it indicates the possibility and extent to which improvement is possible through selection. Johnson *et al.* (1955) suggested that heritability in conjunction with genetic advance was more effective and reliable in predicting the resultant effect of selection.

Singh and Singh (1979) worked out genetic variability in 30 strains of okra and reported high heritability, genetic advance and genotypic coefficient of variation for number of pods per plant, fruit yield per plant, number of pod bearing branches and first fruiting node.

From a study on variability existing for seven characters in six okra varieties, Murthy and Bavaji (1980) reported a significant variability and high heritability for all characters studied and highest heritability for pod length, yield per plot and plant height possessed the highest heritability. High genetic advance was noticed for pod length.

Vashistha *et al.* (1982) studied six characters in 25 genotypes of okra and reported that the genotypic coefficient of variation (GCV) vary for number of lobes per leaf and plant height. High heritability values were observed for number of fruits per plant, plant height and root length and low genetic advance for number of lobes per leaf.

Reddy *et al.* (1985) in a study on okra genotypes observed higher genotypic and phenotypic variances for fruit yield per plant and plant height indicating wide variability. The GCV was greatest for fruit yield per plant and was lowest for days to flowering. The traits such as number of branches and plant height exhibited relatively high GCV whereas days to flowering, fruit length and first fruiting node had low GCV. High heritability estimates were recorded for eleven traits. A high genetic advance as percentage of mean coupled with high heritability was reported for fruit yield per plant, number of branches and plant height.

Yadav (1985) studied six cultivars of okra and observed wide variation for plant height, yield per plant, seeds per pod and number of primary branches. High GCV, heritability and genetic advance were noticed for plant height, yield per plant and number of seeds per pod, whereas number of pods per plant and pod length showed moderate values.

In an evaluation of bhindi germplasm, Balkrishnan and Balkrishnan (1988) reported high phenotypic and genotypic variances for yield per plant followed by plant height and lower variances for number of ridges per fruit and fruit girth. High heritability coupled with high genetic advance was recorded for plant height, number of fruits per plant, fruit weight, number of seeds per fruit and yield per plant.

The variability studies for fifteen characters in 30 okra lines of diverse origin in two seasons showed that the variation exhibited by pod yield per plant, number of leaves per plant, duration of flowering and number of pods per plant differed from season to season. Number of branches per plant, edible pod weight, number of pods per plant and pod yield per plant exhibited relatively low heritability estimates (Ariyo, 1990).

Vijay and Manohar (1990) evaluated 55 genotypes of okra and found maximum coefficient of variation for pod yield per plant followed by number of pods per plant and days to fruit maturity. The traits pod yield per plant, plant height and number of seeds per pod showed the highest genotypic and phenotypic

variances. Number of ribs per pod gave the maximum heritability and genetic advance followed by number of branches per plant and plant height.

A high narrow sense heritability for first fruiting node and number of branches per plant and moderate estimate for 50 per cent flowering and plant height in okra accessions were reported by Yadav and Chonkar (1991). Further, they have also reported a higher phenotypic and genotypic variance for yield per plant followed by plant height and number of seeds per pod.

A wider coefficient of variation was noticed for yield contributing characters in bhindi genotypes. For hundred seed weight, pod weight and number of pods per plant a high genotypic coefficient of variation was recorded. The heritability and genetic advance were higher for yield per plant, number of pods per plant, pod weight and pod length (Jeyapandi and Balakrishnan, 1992).

Patel and Dalal (1992) from their study on heritability and genetic advance on nine yield components in seven okra genotypes and F_1 hybrids reported significant variation for all the traits. The traits, days to first flowering and number of branches per plant were reported to be highly influenced by the environment. However, pod attributes recorded moderate heritability.

Information on heritability derived by Mondal and Dana (1993) on nine yield components in ten okra genotypes grown during three seasons of 1990-91 in West Bengal indicated highly significant differences between seasons, genotypes and season x genotype for all the nine yield components. In pooled analysis most yield components reported high heritability; the highest heritability was for number of seeds per fruit and the lowest for number of nodes on main stem. The genotypic coefficient of variation was low for days to 50 per cent flowering and high for branches per plant. Genetic advance was highest for yield per plant and lowest for crude fibre content.

A high level of variability for eleven yield components in bhindi was observed by Gondane and Lal (1994). Moderate heritability coupled with high level of genetic advance for pods per plant, primary branches per plant and leaves per plant were noticed.

Patil (1995) from his variability studies on 171 genotypes of okra for 11 characters reported high variability for plant height and number of leaves per plant; low to moderate variability for 50 per cent flowering and pod length and low variability for nodal length and pod diameter. Low GCV and PCV were observed for 50 per cent flowering and plant height; while, all other characters registered moderate estimates. High heritability with moderate to high genetic advance was estimated for plant height, number of leaves, nodal length, pod diameter, pod length and number of pods per plant. Low heritability and low genetic advance were noticed for 50 per cent flowering.

Variability for 12 characters in okra showed that ridges per pod had high genotypic and phenotypic coefficient of variance, heritability, and genetic advance in a study conducted by Sood *et al.* (1995). A moderate heritability coupled with moderate genetic advance was recorded for the node of first fruit set, plant height and nodes per plant.

The estimates of variability, heritability and genetic advance in okra for ten characters were studied by Deo and his co workers in 1996 and the results revealed highest genotypic and phenotypic coefficients of variation for pod yield, number of pods, plant height and number of branches per plant. In addition, high heritability and genetic advance were observed for pod yield, plant height and number of seeds per pod.

Patil *et al.* (1996b) estimated genotypic and phenotypic variances, genotypic and phenotypic coefficients of variation and heritability for 11 characters in 171 okra genotypes. The results indicated considerable differences for some characters in two seasons. Number of pods per plant, weight of good pods per plant, number of borer infested pods and weight of borer infested pods per plant showed seasonal differences; in general, genotypic and phenotypic variance were higher in the kharif than rabi season. Estimates of PCV and GCV values ranged from 14.7 per cent for days to flowering (kharif) to 71.6 per cent for weight of borer infested pods (kharif). Relatively high genetic advance was observed for characters such as plant height, number of good pods per plant and

weight of good pods per plant indicating the effectiveness of selection for such characters.

The field trial conducted by Mohamed and Anbu (1997) with 15 genotypes of okra revealed wide variability for plant height, number of branches, number of fruits, fruit weight and yield per plant. The characters such as the number of branches and yield per plant registered high PCV and GCV estimates whereas plant height and weight of fruit recorded low estimates of PCV and GCV. High heritability was observed for plant height, number of branches, number of fruits, weight of fruits and yield per plant. The genetic advance, as per cent of mean was highest for number of branches, number of fruits and yield per plant.

In a variability study with six strains and thirty F_1 hybrids of okra, the highest PCV and GCV were for fruit yield per plant followed by leaf area; moderate to high PCV as well as GCV for leaf number, branch number, flower number, fruits per plant, fruit weight, plant height and percentage fruit set and low PCV and GCV for fruit girth, incidence of YVMV, days to first flower, first fruiting node, fruiting phase, fruit length (Rajani and Manju, 1997). A high estimate of heritability was observed for number of branches followed by first fruiting node. Other characters exhibited moderate to high heritability. However, despite high heritability, number of branches, first fruiting node exhibited low genetic variance.

Gandhi *et al.* (2001) evaluated 44 genotypes of okra collected from NBPGR for 13 different characters. Number of branches per plant, dry fruit yield per plant and height at first fruit set showed high GCV and PCV. Higher difference between GCV and PCV were observed by characters like number of branches per plant and seed yield per plant, indicating the role of environment in the expression of characters. Fruit length, height at first fruit set and fruit girth showed high heritability estimates. Additive genetic variance was reported by characters like plant height, height at first fruit set, internodal length, fruit length, number of fruits per plant and number of branches per plant.

Extent of variability, heritability and genetic advance of fruit yield and its components for number of fruits per plant, days to 50 per cent flowering, number

of branches per plant, plant height and first fruiting node on stem were estimated by Dhankhar and Dhankar (2002a) in 15 advanced lines of okra. All the characters studied reported low GCV and PCV. The fruit yield, number of fruits per plant and plant height showed high to moderate heritability. The genetic advance was reported to be medium to low for all the characters, indicating a limited scope for further improvement through selection in this material.

The genetic variability of 69 okra cultivars for different fruit and yield parameters showed that the genotypic and phenotypic variation and coefficients of variation were high for total yield per plant and number of seeds per fruit (Mulge *et al.,* 2004). Moderate GCV and PCV were observed for number of ridges per fruit, number of locules per fruit, number of fruits per plant, fruit length, fruit diameter and average fruit weight whereas fruit circumference exhibited low GCV and PCV. High heritability with high genetic advance over mean (GAM) was observed for total yield per plant, number of seeds per fruit, number of ridges per fruit, number of locules per fruit and number of fruits per plant. High heritability with low GAM was observed for fruit circumference.

Alam and Hossain (2006) studied the variability for ten yield contributing characters and their interrelation effects on green pod yield in 50 accessions of okra and reported a wide variation for weight of green pod per plant, days to first flowering and weight of individual green pods. Moderate variation for length of green pod, number of green pods per plant and yield of green pods, lower levels of variation for percentage of dry matter content, number of ridges per green pod and diameter of green pod was also reported. The highest GCV was observed for yield of green pods followed by weight of green pods per plant, weight of individual green pods, number of ridges per green pod, number of green pods per plant, dry matter content of green pods, diameter of green pods and length of green pods.

The field experiments on 69 okra genotypes by Jaiprakashnarayan *et al.* (2006) revealed high genotypic and phenotypic variations for plant height at 100 DAS. High GCV and PCV were noticed for number of branches per plant, plant height at 100 DAS and internodal length and moderate GCV and PCV for number of nodes on main stem, number of nodes at first flowering and number of leaves at

100 DAS. However, days to first flowering and days to 50 per cent flowering exhibited low GCV and PCV. High heritability with high genetic advance over mean was observed for plant height at 100 DAS, internodal length, number of nodes on main stem, number of nodes at first flowering and number of leaves at 45 DAS. High heritability with low genetic advance over mean was observed for days to first flowering and days to 50 per cent flowering.

The genetic variability was estimated by Mehta *et al.* (2006) in 22 diverse genotypes of okra for fruit yield and its components and showed that PCV was higher than that of GCV for all the seven traits indicating the influence of environment in the expression of these traits. The GCV, heritability and genetic advance as percentage of mean were higher for fruit yield, average fruit weight, plant height and fruit length, which attributed to additive gene action resulting in their inheritance. The fruit yield was significant and positively correlated with fruit length and average fruit weight.

In a study conducted at Sikkim with six popular okra cultivars (Pusa Sawani, Satdhari, Punjab-7, K-21, Parbhani Kranti and Arka Anamika) for yield performance, Arka Anamika recorded the highest plant height, number of nodes per plant and number of pods per plant followed by Parbhani Kranti .The cultivar Satdhari which recorded the highest pod weight and green pod yield had minimum disease incidence and hence proved to be the most promising cultivar of Sikkim(Sachan, 2006) .

Twenty five genotypes of okra were evaluated by Sarkar *et al.* **(**2006**)** during the kharif season of 2002 for their suitability in the alluvial agro climatic zone of West Bengal for 12 characters related to fruit quality, flowering pattern and yield. The highest yield was recorded for cultivar Sagun and the cultivars with high yield potential were Arka Anamika, HR Selection, Sungrow Selection and Varsa Upahar. Earliness in flowering was shown by Bankim Selection-2, Sungrow Selection, Nandini and Selection-5.

Sindhumole *et al.* (2006) evaluated 101 genotypes of okra for YVM resistance and yield traits and observed significant variation among genotypes. High phenotypic and genotypic coefficients of variation were observed for most

of the traits including yield and its major components. The maximum values of both PCV and GCV were noticed for protein content and fruit yield. Most of the traits possessed high heritability especially fruits per plant, fruit yield and ridges per fruit. High genetic advance was noticed for protein content and fruit yield. PCV and GCV values were high for incidence of Yellow vein mosaic.

Genetic variability, heritability and genetic advance for 15 characters in 19 diverse okra genotypes were evaluated by Singh *et al.* (2006) during the rainy season. Significant differences among genotypes were observed for all the characters. Estimates of phenotypic and genotypic coefficient of variation were high for internodal length, number of branches per plant, number of fruits per plant, number of seeds per pod and fruit yield per plant. The characters, number of seeds per pod, internodal length, number of branches per plant, fruit yield per plant, number of fruits per plant, plant height and 100-seed weight exhibited high heritability and high genetic advance, which indicated that there was more number of additive factors and further improvement could be brought about by selection. The fruit yield per plant was positively and significantly correlated with fruit length, fruit diameter, fruit weight and number of fruits per plant.

Singh and Singh (2006) reported that considerable amount of genetic variation was exhibited in bhindi by number of branches per plant, fruit yield per plant, plant height and fruit length. The closer magnitude of genotypic and phenotypic coefficients of variation indicated that a greater magnitude was played by genotype rather than environment. The heritability estimates were high for days to first flowering and first fruiting node length.

Genotypic and phenotypic variances, genotypic and phenotypic coefficients of variation and heritability were observed by Sood (2006) for different characters using 48 lines of diverse origin in okra. The estimates of phenotypic coefficients of variation and genotypic coefficients of variation were high for fruit yield per plant, node at which the first fruit set and plant height in market crop. The heritability was low for days to marketable maturity and high for ridges per pod for market crop. This highlighted the significance of genotypic environment interaction in breeding programmes of okra. High heritability

estimates for ridges per pod indicated that this character is more acquiescent for selection.

A high magnitude of genotypic and phenotypic coefficient of variation was observed for number of branches, plant height, number of fruits and fruit yield in okra by Singh *et al.* (2007). PCV was higher than the corresponding GCV. High values of heritability were also observed for most of the characters. The expected genetic advance as per cent of mean (genetic gain) was high for number of branches, plant height, number of fruits, fruit yield, fruit girth, fruit length and internodal length. High heritability coupled with high genetic gain was observed for all the characters, except for number of fruits per plant.

Saifullah and Rabbani (2009) evaluated 121 genotypes of okra and noticed high GCV and PCV for number of primary branches per plant, plant height, and number of internodes per plant and fruit yield. The estimate of heritability and genetic advance was high for number of primary branches per plant, plant height, and number of internodes per plant while high heritability coupled with moderate genetic advance for days to first flower, number of fruits per plant and number of seeds per fruit. Low heritability and genetic advance was estimated for fruit length.

The values of GCV and PCV were high for number of fruiting nodes, fruit yield per plant, moderate for plant height, internodal distance, number of nodes on main stem and weight per fruit and low for number of ridges per fruit, fruit diameter, fruit length and number of primary branches per plant in a germplasm evaluation experiment with okra (Akotkar *et al*., 2010). Heritability in broad sense were high for number of ridges per fruit followed by plant height and number of fruiting nodes and moderate for all the remaining characters except number of primary branches. High genetic advance was observed for number of fruiting nodes followed by fruit yield per plant, height, inter nodal distance and number of fruits per plant; and moderate for all the remaining characters except number of primary branches.

In an experiment on genetic variability of yield contributing characters in 44 genotypes of okra, Prakash and Pitchaimuthu (2010) observed high GCV and

PCV for plant height, inter-nodal length, first flowering node, first fruit producing node, height of first flowering node, average fruit weight and number of seeds per fruit. The estimate of heritability was highest for hundred seed weight (98.93 %), while it was least for stem girth (56.98 %). High magnitude of broad sense heritability was noticed for average fruit weight, number of seeds per fruit, days to 50 per cent flowering, first fruit producing node, yield per plant, plant height and hundred seed weight. . High heritability coupled with high GAM were observed for almost all the characters studied, except for days to 50 per cent flowering and days to 80 per cent maturity which showed high heritability with low GAM. Moderate heritability with moderate to low genetic advance as per cent of mean was recorded for inter-nodal length and height of first flowering node.

Reddy *et al*. (2012) observed high magnitude of genetic variability among 100 bhindi genotypes for 17 quantitative characters. The estimates of PCV were highest for number of branches per plant followed by marketable yield per plant and number of marketable fruits per plant, while lowest for days to 50 per cent flowering followed by fruit and shoot borer infestation on fruits and fruit width. The estimates of GCV were highest for marketable yield per plant followed by number of branches per plant and number of marketable fruits per plant, while lowest for fruit and shoot borer infestation on fruits followed by days to 50 per cent flowering and fruit width. The characters, plant height, number of branches per plant, internodal length, days to fifty per cent flowering, first flowering node, first fruiting node, fruit length, fruit weight, total number of fruits per plant, number of marketable fruits per plant, total yield per plant, marketable yield per plant and yellow vein mosaic virus infestation on fruits and plants, had high heritability (>60.00 per cent) coupled with high expected genetic advance (>20.00 per cent).

2.2 CORRELATION

Yield is a complex character governed by polygenic system. Moreover, it is highly influenced by environmental fluctuations. The information on nature and extent of association between pair of characters would strengthen the selection

programme, aiming at the improvement in crop yield. Hence, selection of plants based on only yield would be unreliable in many cases. Correlation studies provide better understanding of yield components, which helps the plant breeder during selection (Robinson *et al.,* 1951 and Johnson *et al.,* 1955).

Some of the reviews relevant to the study related to correlation studies in okra are presented below

Lerner (1958) stressed the importance of correlation of the various characters with yield. He found them useful in the construction of selection indices and predicting correlated response. Genotypic correlation coefficient provides a measure of genotypic association between characters and gives an indication of more useful character. The main genetic cause of such correlation is pleiotropic, which refers to manifold effects of gene (Falconer, 1981). Genotypic correlation provides basic information to breeders in understanding the nature of the species with which they work.

Korla and Rastogi (1978) worked out correlation in six varieties of bhindi and found that yield per plant was significantly correlated with fruits per plant, whereas, association with other characters was non-significant. Days taken to first picking showed a negative significant correlation with fruits per plant and fruit length.

Investigation on genetic association for different characters in okra showed that yield per plant was positively and significantly correlated with number of fruits per plant, number of branches per plant and plant height at genotypic level (Singh and Singh, 1979).

In a correlation study in bhindi, Murthy and Bavaji (1980) reported that yield per plant had a significant positive correlation with number of fruits per plant at both phenotypic and genotypic level. However, the correlation between yield and days to flowering was negative.

The character, pod yield in okra showed positive significant correlation with pods per plant, pod weight, pod length, 100-seed weight, plant height and nodes per plant at both genotypic and phenotypic level. However, yellow vein

mosaic incidence, seeds per pod and branches per plant registered significant negative association with yield as reported by Mishra and Singh (1985).

Correlation analysis with seven characters in okra by Reddy *et al.* (1985) reported that fruit yield per plant was positively and significantly correlated with all the traits like plant height, number of branches, days to flower, fruit length, fruit width and fruits per plant except first flowering node. Further, all the traits registered positive significant correlation among them except first flowering node.

Yadav (1985) reported that in okra, positive and highly significant association between yield per plant and length of pods, number of pods per plant and height of the plant was noticed whereas yield per plant was found to be non-significantly associated with number of seeds per pod. Significant negative correlation was noticed between fruit yield and days to 50 per cent flowering and number of nodes for first pod appearance.

Estimates for genetical parameters such as phenotypic and genotypic correlation were worked out in 36 genotypes of bhindi by Kale and his co workers (1989) and found that moderate to high correlation existed for number of branches, number of nodes, internodal distance, plant height and number of pods per plant. The heritability estimates were also found to be moderate to high for plant height, number of branches, number of nodes, internodal length and number of pods per plant. They observed that yield per plant was significantly and positively correlated with plant height, leaf area, days to flowering and number of fruits per plant.

High correlation value was found in okra between yield per plant and number of fruits per plant and fruit weight; and yield was negatively correlated with number of seeds per fruit (Balakrishnan and Balakrishnan, 1990).

In an association analysis in bhindi, Jeyapandi and Balakrishnan (1990) reported strong association between yield and plant height, number of nodes per plant, fruit length, and fruit girth, number of ridges per fruit, number of fruits per plant, fruit weight and hundred seed weight. A significant positive correlation was observed between yield per plant and pods per plant, pod weight and plant height in bhindi (Mishra *et al.,* 1990).

Vijay and Manohar (1990) reported that in okra, pod yield per plant had high positive and significant correlation with number of pods per plant, plant height and height at first flowering node. The trait pod yield per plant showed negative and highly significant correlation with days to 50 per cent flowering and days to first flowering.

Yield was positively correlated with all the traits in okra in a correlation study conducted by Patel and Dalal (1994). A higher magnitude of correlation was found between yield and pod weight, pod length, pod girth, number of pods per plant and plant height except days to flowering.

Association analysis in okra germplasm by Dash and Mishra (1995) revealed that fruit yield per plant was positively correlated with number of branches per plant, fruit length, fruit girth, fruit weight, number of seeds per fruit and seed weight per fruit.

Number of pods per plant, weight of edible pod, stem thickness and plant height were significantly and positively correlated with yield per plant in bhindi. Length of pod showed negative correlation with number of leaves per plant, days to 50 per cent flowering, nodes to first pod and number of branches per plant (Gondane *et al.,* 1995).

Many characters in okra such as nodes per plant, duration of availability of edible pods, plant height and pod length had strong positive correlation with yield. Duration of availability of pods also showed strong positive correlation with plant height, pod length and negative correlation with 50 per cent flowering as per the reports of Sood *et al.* (1995).

Deo *et al.* (1996) while studying the correlation between characters observed that plant height, 100-seed weight, number of seeds and length of pod in bhindi had a high significant and positive correlation among themselves.

In an association analysis, Yadav (1996) reported that yield per plant in okra had positive and significant correlation with plant height, number of pods per plant and number of nodes at first pod appearance.

Correlation in 48 lines of okra was conducted by Dhall *et al.* (2000). Significant differences among genotypes were reported for all the characters,

except for virus incidence. The report revealed yield per plant, fruit weight, fruit length, number of fruits per plant and plant height were positive and significantly correlated with the total yield per plant.

The correlation between the yield and yield attributes for 15 lines of okra was conducted by Dhankhar and Dhankhar (2002b). Crop yield showed strong positive association with number of fruits and branches per plant. First fruit node on the stem and number of days to 50 per cent flowering had positive association with yield. Plant height and number of days to 50 per cent flowering had negative association with yield. The number of fruits per plant had positive relationship with number of days to 50 per cent flowering, first fruiting node on the stem and number of branches per plant. The number of fruits per plant and days to 50 per cent flowering had the highest direct effects on fruit yield.

Sindhumole (2003) indicated higher genotypic correlation coefficient than phenotypic correlation coefficient for most of the characters in bhindi. The fruit yield displayed positive genotypic association with leaf area, fruits per plant, average fruit weight, fruit length, fruit girth, seeds per fruits, plant duration, and protein content and negative correlation with days to first flower, pollen sterility, and incidence of fruit and shoot borer and yellow vein mosaic disease.

Jaiprakashnarayan and Mulge (2004) reported inverse relationship between growth and earliness, but strong association between growth and yield characters in okra. Total yield per plant was positively and significantly correlated with number of fruits per plant, average fruit weight, number of nodes on main stem, fruit length, plant height at 60 and 100 days after sowing and number of leaves at 45 DAS and 100 DAS, but negatively and significantly correlated with number of locules per fruit, number of nodes at first flowering and first fruiting.

According to Akinyele and Osekita (2006) in okra, seed yield per plant showed significant positive correlation with number of pods per plant, height at flowering, pod width and weight of hundred seeds. Hence, number of pods per plant and height at flowering are the main determinants of seed yield per plant in the studied variety.

The correlation studies in bhindi involving quantitative characters (Patro and Sankar, 2006) showed that the estimates of genotypic correlation coefficient were higher than phenotypic correlation coefficient, indicating the inherent correlation among characters. Yield per plant showed a highly significant and positive correlation with germination percentage, number of branches per plant, number of ridges per fruit, fruit weight, number of seeds per fruit, 100 seed weight and ascorbic acid content.

In a correlation study with 101 genotypes of okra, Sindhumole *et al*. (2006) revealed that most of the character combinations had higher genotypic correlation coefficient than phenotypic, though both were in the same direction. Fruit weight per plant displayed significant and positive genotypic association with leaf area, fruits per plant, average fruit weight, fruit length, fruit girth, seeds per fruit, 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 Yellow vein mosaic (YVM) during final harvest.

Highly significant positive associations between yield per plant and number of nodes per plant and yield per plant with number of fruits per plant at both genotypic and phenotypic levels were noticed in bhindi by Yadav *et al.* (2007a).

According to Guddadamath *et al.* (2011), number of fruits per plant, 100 seed weight, average fruit weight, number of nodes per plant, number of branches per plant and plant height in okra exhibited positive significant association with fruit yield per plant except the characters days to 50 per cent flowering, fruit diameter and internodal length.

2.3 YELLOW VEIN MOSAIC VIRUS (YVMV)

The initial symptom of Bhindi yellow vein mosaic virus (BYVMV) of infected plants is vein clearing (Kulkarni, 1924; Upaal *et al.,* 1940; Raychaudhuri and Nariani, 1977). Vein clearing symptoms starts in the small veins and extends to the larger veins (Uppal *et al.*, 1940) sometimes yellow network of veins is

followed by the thickening of the veins and vein lets (Nariani and Seth, 1958; Raychaudhuri and Nariani, 1977).

Fernando and Uduravan (1942) reported that interveinal clearing and minute venation may follow yellow vein banding on axial side of the leaves. The fruits that are obtained from the diseased plants are malformed and bleached (Kulkarni, 1924; Fernando and Uduravan, 1942; Nariani and Seth, 1958 and Raychaudhuri and Nariani, 1977).

Gennadius (1889) first identified the holotype specimen of whitefly of tobacco from Greece. *B. tabaci* has become a severe problem all over the world producing 11 to 15 generations per years under conducive conditions (Hussain and Trehan, 1933; Butter *et al.,* 1983). *B. tabaci* is classified in the order Homoptera, family Aleyrodidae and subfamily Aleyrodinae (Mohanty and Basu, 1986 and Martin, 1987). Duffus (1992) reported that *B. tabaci* is rapidly increasing throughout the world as a pest of fiber, cultivated plants and ornamental crops and the magnitude of the problem is increasing with whitefly population densities.

Successful graft transmission of Bhindi yellow vein mosaic virus (BYVMV) was reported by Uppal *et al*. (1940) and Cappor and Varma (1949). Manjula Rao (1986) reported that side grafting resulted in 87 to 100 per cent transmission and inoculated plants took 15 to 20 days to express the symptoms.

Salehuzzaman (1985) reported that the resistant plant (scion) was contact grafted with susceptible infected stock and buds of resistant plant were grafted on infected plant. These buds later sprouted and developed into full plant, but in both contact and bud grafting, the resistant plant remained healthy although they continued to grow on infected plants. Grafting trials were also performed by Ali *et al.* (2000) in which resistant plants were the rootstock and susceptible ones the scion and by Sindhumole (2003) where resistant plants were the scion and susceptible were the rootstock.

BYVMV was transmitted exclusively by whitefly *B. tabaci* (Uppal *et al.,* 1940; Varma, 1952 and Raychaudhuri and Nariani, 1977).

Acquisition Access Period (AAP) of whiteflies was reported as 4 to 6 hours (Raychaudhuri and Nariani, 1977), and 12 to 24 hours (Varma, 1952). However, preliminary fasting markedly increased the efficiency of whiteflies as vectors (Varma, 1952). Similarly AAP of one hour has been reported for Bhindi Yellow Vein Mosaic Virus, Bhendi Pseudo Yellow Virus, Tobacco Leaf Curl Virus and Cotton Leaf Crumple Virus by Varma (1952). Murugesan and Chellaiah (1977) reported maximum percentage of infection occurred when the vector was given a pre-acquisition starvation of 3 hr. and acquisition feeding period of 24 hr. Mathew and Muniyappa (1991) found that AAP of 10 min by *B. tabaci* was sufficient for successful transmission of Indian Cassava Mosaic Virus.

A feeding period of 30 min. was found sufficient to transmit the virus, but five min probe was not sufficient for transmission (Varma, 1955a and Varma, 1955b). They also reported that whitefly *B. tabaci* is capable of harboring different viruses simultaneously and can readily cause infection to healthy host plants.

Kirkpatrick (1931) reported that minimum of 30 min. inoculation access was required for transmission of Cotton leaf curl virus. Similar time period was also reported for transmission of Bhindi yellow vein mosaic virus, tomato yellow leaf curl virus, tomato leaf curl virus and squash leaf curl virus by Varma (1952). High percentage of BYVMV infection resulted when the transmission feeding period of vector was 24 hr. (Murugesan and Chellaiah, 1977). Mandal (1989) reported that minimum of 10 min. inoculation access period was sufficient to transmit Croton Yellow Vein Mosaic Virus.

2.3.1 Screening for yellow vein mosaic virus resistance

Infection of okra plants by Bhindi yellow vein mosaic virus (BYVMV) decreased as the age of the inoculated plants increased. The plants inoculated when one week old showed 100 per cent infection, whereas inoculation of seven week old plants resulted in 31.7 per cent infection. The incubation period of the virus increased with increasing plant age. Plant growth and yield were adversely affected when the young plants were inoculated. The greatest loss in the yield of

fresh fruits was highest (95.7 %) when plants were inoculated at one week old (Pun and Doraiswamy, 1999).

Singh and Gupta (1991) screened 24 okra varieties for reaction to YVMV under field conditions. The result revealed that none of the varieties were highly resistant; however three were resistant, eight were moderately susceptible, three were susceptible and ten were highly susceptible.

In a field trial with 22 genotypes exposed to whiteflies (*B. tabaci*) carrying okra yellow vein mosaic virus, cv. Arka Anamika remained free from disease and five other genotypes were highly resistant (Bora *et al.,* 1992). Nath and Saikia (1992) screened 14 okra varieties for resistance to okra yellow vein mosaic virus by artificial inoculation and natural infection. None of the entries were immune to the disease.

A comparative study of six resistant/tolerant *A. esculentus* varieties from various regions of India with Pusa Sawani during rabi 1987, kharif 1988 and kharif 1989 was conducted by Mathew *et al*. (1993) and they reported that the lowest incidence of okra yellow vein mosaic virus was recorded in Sel 4 and Arka Anamika. Pusa Sawani and AROH1 were the most susceptible.

The relationship between crop age and yield losses in okra, caused by Bhindi yellow vein mosaic virus was analysed by Nath and Saikia (1993) and revealed that a maximum of 94.42 per cent and minimum yield losses 32.65 per cent were recorded for plants infected at 35 and 63 days after sowing, respectively. They also suggested that early infection caused heavy yield reductions compared with late infection and losses could be reduced by controlling early spread of the disease by controlling the vector *B. tabaci.* The incidence of yellow vein mosaic virus on some improved and hybrid varieties of okra were recorded under field conditions by Mohapatra *et al*. (1995). Weekly incidence of the disease was compared with severity index and a minimum variation in the severity index was observed among the varieties. Pusa Sawani was the most susceptible and recorded 100 per cent infection while varieties like HRB-9-2, DOV-91-4 and Pashupati showed tolerance at least under field conditions.

Dhankhar (1996) derived from the cross Lam Selection IX x Parbhani Kranti, a new variety of okra, Varsha Upahar, resistant to yellow vein mosaic Gemini virus. It is medium in height, with short internodes, produces 2-3 branches, and can give seed yields of 1.5 t/ha. In 3 rainy season trials, it yielded 9.8 t/ha, out yielding a local commercial cultivar (6.6 t/ha). Varsha Upahar is released for commercial cultivation in Haryana.

Screening of 51 okra hybrids and their 20 parents for yellow vein mosaic resistance was carried out under field conditions by Dhankhar *et al.* (1996) at 35 DAS, 50 DAS and 65 DAS. Only one parent was resistant to the disease whereas all other parents and hybrids were susceptible.

A field experiment for two consecutive years (1992 and 1993) on the incidence of bhindi yellow vein mosaic virus and its vector *B. tabaci* in the okra cultivars Pusa Sawani, Parbhani Kranti and M-31 was conducted by Mazumder *et al.* (1996). Lower disease incidence and whitefly populations were recorded in crops sown between February 25 and March 20 compared with sowing dates of April 15 to July 25. The number of whiteflies was lower on Parbhani Kranti and M-31 than on Pusa Sawani. The total and marketable yields were maximum in early sown crops rather than crops sown after 15 April. The number of unmarketable okra increased with delayed sowing. Simple correlation studies revealed a positive significant association between disease incidence and whitefly population, temperature, relative humidity, rainfall and numbers of rainy days. Marketable fruit yield of okra was negatively correlated with disease incidence and a positive correlation between disease incidence and unmarketable fruit yield was obtained.

In field trials conducted by Sannigrahi and Choudhury (1998) in seven okra cultivars (Arka Abhay, Arka Anamika, BO1, BO2, Parbhani Kranti, Punjab 7 and Pusa Sawani) were evaluated for growth and yield characteristics and virus resistance. Arka Anamika and Arka Abhay were the most suitable yellow vein mosaic virus resistant okra cultivars compared with Pusa Sawani, a popular, but highly YVMV susceptible cultivar.

Screening of okra genotypes for resistance against yellow vein mosaic virus disease was carried out by Ramesh *et al*. (1999) in six basic generations. It was observed that all male testers and female lines were moderately resistant to resistant except one female line i.e., Pusa Makhmali.

The effect of Bhindi yellow vein mosaic virus (BYVMV) on the growth and yield of three okra cultivars, Parbhani Kranti, Vaishali Vadhu and Pusa Sawani, was studied in the field by Bhagat (2000). A quantitative assessment of plant height, number of leaves, fruit per plant, fruit length, fruit girth, fruit weight and fruit weight per plant was made on healthy and diseased plants. The result revealed that the yield and other growth parameters were less affected in the resistant cultivar Parbhani Kranti in comparison with the susceptible cultivar and highly susceptible cultivars.

Ten okra genotypes and five F_1's derived from them were screened for resistance to yellow vein mosaic virus by Deo *et al*. (2000). The crosses obtained from highly resistant parents were highly resistant to the disease.

Ragupathi *et al.* (2000) evaluated twelve okra cultivars, including the highly-susceptible Pusa Sawani and MDU-1 for yield and resistance against YVMV. The disease was absent in the highly resistant cultivar BO1.

A study was conducted to determine the rate of dissemination of okra yellow vein mosaic virus in okra cultivars Pusa Sawani (highly susceptible), Vaishali Vadhu (susceptible) and Parbhani Kranti (resistant). The rate of infection was higher in Vaishali Vadhu and Pusa Sawani compared to Parbhani Kranti. The infection was almost five times in 40 day old plants Pusa Sawani. The maximum rate of disease development was between 35 and 45 days after sowing, irrespective of cultivars in both years. Based on the results, it may be recommended that the okra cultivar Parbhani Kranti should be sown during the kharif season. The susceptible stage of the crop from 35 to 50 DAS must be supplemented with systemic insecticide to reduce whitefly population and thereby reducing disease severity to obtain good harvest (Bhagat *et al.,* 2001).

Rajamony *et al*. (2002) stated that *A. ficulnetus*, *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. Twelve okra germplasm lines were screened for resistance to okra yellow vein mosaic virus under field conditions by Rashid *et al.* (2002). Lines OK-292 and OK-285 showed resistance to YVMV with high field tolerance and high yield potential.

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.

Singh *et al.* (2002a) conducted trials with twelve okra cultivars to determine the resistant one to yellow vein mosaic virus. Susceptible control was Pusa Sawani. Arka Abhay showed the lowest average YVMV incidence and was hence, classified as resistant. Arka Anamika was moderately resistant to YVMV. Disease severity was lowest in Arka Abhay, followed by Arka Anamika and Green Gold.

The performance of five okra hybrids DVR-1, DVR-2, Shree, HIHBO83 and HIHBO90 was evaluated in a field experiment conducted by Singh *et al.* (2003). DVR-2 recorded the longest pods and highest number of pods, plant height, stem diameter, dry weight of shoots and fresh and dry weight of roots per plant, whereas DVR-1 recorded the highest pod weight per plant and total pod yield per ha. The hybrids HIHBO090, DVR-1 and DVR-2 were free from nematode and yellow vein mosaic virus infection.

Ten okra genotypes viz., HRB-107-4, HRB-108-2, KS-410, NOH-15, NOL-101, VRO-5, VRO-6, JNDO-5, Arka Anamika and Parbhani Kranti were evaluated by Vijaya (2004) for their yields and resistance to yellow vein mosaic virus. VRO-5 and VRO-6 had the lowest mean disease incidence.

Nineteen okra genotypes, including the susceptible control Pusa Sawani were screened for their resistance to okra yellow vein mosaic virus conducted by Ahmed and Patil (2004). Arka Anamika recorded the lowest disease incidence and

the highest yield, while the susceptible control Pusa Sawani recorded the highest disease incidence and

the lowest yield. None of the genotypes were immune to the disease. Arka Anamika, Hybrid 8 and Hybrid 10 were resistant, while Soumya F_1 and Reshma were moderately resistant. Thirteen genotypes were susceptible.

Debnath *et al.* (2006) reported the resistance of okra cultivars Parbhani Kranti, Seven Dhari Green, Punjab Seven, Arka Abhay, AM-4-5, JNDO-5, VRO-5, VRO-6, VRO-3, VRO-4, KS-410, Lorm 1 and D-1-87-5 to okra yellow vein mosaic virus in a field experiment. Punjab Seven and Arka Abhay were tolerant of the disease, whereas AM-4-5 was resistant. All the other cultivars tested were susceptible to the disease.

Yellow vein mosaic possessed moderate heritability along with high genetic advance indicating the nature of additive gene effects in a study conducted with 101 genotypes of okra by Sindhumole *et al.* (2006)

Azad Bhindi 2, derived from the cross Pusa Sawani x P-7 through pedigree method, is a new bhindi cultivar released in Uttar Pradesh, India. This cultivar is characterized by its higher yield (110-140 q/ha), earlier fruiting (38-41 days) and higher resistance to okra yellow vein mosaic virus in comparison with Parbhani Kranti and Azad Bhindi 1 by Yadav *et al.* (2006).

Fifty five *Abelmoschus esculentus* cultivars and one *Abelmoschus caillei* cultivar Susthira were evaluated for their reaction to yellow vein mosaic virus during summer and kharif seasons of 2004 under field epiphytotic conditions by Prabu and Warade (2007) The *A. caillei* cultivar Susthira was found to be highly resistant to the virus during both the seasons while only one *A. esculentus* cultivar Varsha Upahar showed highly resistant reaction during kharif season only. However, the *A. esculentus* cultivars GK 4 and JNDO-5 expressed resistant reaction to the virus during kharif season, while the rest of the varieties were susceptible during both the season.

The reaction of 14 cultivars/lines of bhindi to okra yellow vein mosaic virus was studied by Biswas *et al*. (2008). None of the cultivars/lines were immune to the disease. The disease incidence varied from 18.25 to 64.96 per cent. Disease incidence was lowest in ZOH-3002 (18.25 %) and highest in VB-9801

(64.96 %). The population of whitefly was lowest in ZOH-3002, followed by BO-13 and US-7109, and highest in VB-9801. The entry, ZOH-3002 had the highest yield (85.43 q/ha). The lowest yield was registered by VB-9801 (13.20 q/ha). Of the 14 cultivars/lines evaluated, ZOH-3002, US-7109 and BO-13 were moderately resistant; NOH-147, HRB-108-2 and AROH-113 were moderately susceptible; HRB-107-4, P-7, Arka Abhay, IIVR-11, Parbhani Kranti, Pant Bhendi and local were susceptible; and VB-9801 was highly susceptible.

Fifty five genotypes of okra were screened for YVMV under field conditions by Prashanth *et al.* (2008). The per cent disease incidence and coefficient of infection ranged from 7.20 to 100 and 1.8 to 75.00, respectively. Out of 55 genotypes, five were highly resistant, thirteen resistant, seventeen moderately resistant, thirteen moderately susceptible, five susceptible and two highly susceptible based on the coefficient of infection. The per cent disease incidence coupled with disease severity (response value) is more useful in selecting genotypes resistant to YVM and higher yield.

Twelve okra entries were evaluated by Bhattiprolu and Rahman (2008) during the kharif season for three consecutive years. Mean disease incidence (PDI) of bhindi yellow vein mosaic virus disease during the three years of trial ranged from 3.63 to 75.09 per cent. Among the 12 entries evaluated, the entry VRO-4 showed minimum disease incidence (3.63 %) followed by P-7 (4.24 %), LORM-1 (4.49 %) and VRO-3 (4.63 %) respectively. While the control, Pusa Sawani, recorded the maximum of 75.09 per cent PDI. Mean yield ranged from 47.93 q/ha in KS-410 to 80.93 q/ha in HIGH-068. HIGH-068 recorded the maximum yield increase of 55.28 per cent, followed by Arka Abhay (45.52 %), VRO-6 (37.74 %) and VRO-5 (36.91 %). Disease reduction ranged from 84.75 per cent in Arka Anamika to 95.17 per cent in VRO-4. However, resistance was not correlated with increase in yield. While the High-yielding entry, HIGH-068, recorded 91.54 per cent reduction in disease VRO-4 with only 6.41 per cent increase in yield registered 95.17 per cent disease reduction.

2.4 COMBINING ABILITY

Combining ability analysis provides information on several valuable aspects of the genetic make-up of a quantitative character, such as the adequacy of additive-dominance model, average degree of dominance involved in the action of genes, preponderance of dominant and recessive genes among the parental lines and symmetrical or asymmetrical distribution of genes with positive and negative effects on the attribute. A critical survey of relative magnitude of *gca* and *sca* effects of parents and their crosses respectively, will provide valuable guidelines for choice of parents and for planning suitable breeding strategy. Moreover, the close relationship between the *per se* performance could be used as a criterion to select parents involved in breeding programme. Thus, combining ability is useful for choosing the desirable hybrid combination and in the choice of desirable parent.

From a study on 7 × 7 full diallel analysis in bhindi, Veeraragavathatham and Irulappan (1991) reported higher GCA variance than the SCA variance for all characters examined. The reciprocal effect was significant for individual fruit weight, length and girth and plant height at final harvest.

Information on combining ability effects derived on ten yield-related traits in six inbreds and their hybrids from a full diallel cross in okra by Sundhari *et al.* (1992a) revealed that the GCA/SCA ratios were lower than 1, indicating the role of non-additive gene action.

Mandal and Das (1992) conducted an 8 × 8 diallel cross (without reciprocals) in *A. esculentus* and data revealed highly significant GCA and SCA variances.

Investigations on the combining ability for yield and five yield components in nine okra parents and their progeny from a diallel cross (without reciprocals) indicated that GCA and SCA variances were highly significant for all characters and non-additive gene action was predominant for all characters, excepting days to 50 percent flowering which was governed by additive gene action (Chavadhal and Malkhandale, 1994).

Patel *et al.* (1994) estimated the combining ability for dry seed yield and its contributing traits from a 10 × 10 diallel cross (excluding reciprocals) in okra. Analysis of variance revealed significant *gca* and *sca* effects for all characters studied except fruiting branches per plant. The GCA : SCA ratio indicated predominance of non-additive gene action for dry seed yield per plant, number and weight of seeds per pod and 1000-seed weight, and additive for the remaining characters.

Combining ability analysis in okra from 8 × 8 diallel cross excluding reciprocals revealed that variances due to general combining ability and specific combining ability were highly significant for all the characters but variance due to *sca* being higher than *gca* indicated predominance of non-additive gene actions for all the characters except fruit girth (Ahmed *et al.,* 1997).

Pal and Hossain (2000) estimated the combining ability from a 7 × 7 diallel cross in okra for seed yield and its components and some quality traits and reported both additive and non-additive gene effects in the inheritance of most of the traits.

A study to estimate the combining ability of six genetically divergent parental strains of okra through diallel analysis with respect to yield and related attributes revealed that the parent NBPGR/TCR 861 was the best general combiner for single fruit weight and length and NBPGR/TCR 864 for yellow vein mosaic virus (YVMV) resistance (Rajani *et al.,* 2001).

Fifteen diverse genotypes of okra were crossed in a diallel fashion excluding reciprocals by Singh and his coworkers (2001). The analysis of variance revealed the predominance of non-additive gene action for most of the characters. No parent was a good general combiner for all the traits. Many hybrids showed significant positive *sca* effects for fruit yield per plant.

Nichal *et al.* (2001b) studied 21 okra F_1 hybrids and seven parental cultivars. The results indicated that the mean squares due to general and specific combining ability were highly significant for all characters except average fruit weight indicating the importance of additive and non-additive genetic components

of variation. However, the mean squares due to *gca* were greater, suggesting the greater role of additive variance in the inheritance of all characters.

Sonia and Pritam (2001) estimated the combining ability for ten characters in eight diverse and widely adapted parental lines in a diallel cross (excluding reciprocals) of okra. The variances due to general combining ability and specific combining ability indicated that the gene action was additive for all the characters except fruit yield per plant, fruits per plant and plant height for which non-additive gene action was important.

Liou-Minli *et al*. (2002) estimated the combining ability and heterosis for fruit yield and associated traits in a 6 × 6 diallel cross of okra. Days to flowering, number of fruits per plant, yield per plant, fruit diameter and fruit weight were reported to be under the control of additive and non-additive genes. The reciprocal effects were significant for days to flowering, number of fruits per plant, fruit length and fruit weight.

Mamta and Arora (2003) crossed and evaluated eight diverse and homozygous lines of okra in a diallel fashion without reciprocals to generate 28 F_1 hybrids. High *gca* and *sca* effects were exhibited for days to flowering, node at which the first flower appears, days to first picking, number of fruits per plant, total yield per plant, plant height; and for YVM virus incidence. The predominance of non-additive gene action was observed for all characters studied.

The high values of *gca* and *sca* effects were noticed for fruit yield and leaf area by Sindhumole (2003) among the hybrids. Many of them displayed good overall performance with respect to days to first flower, leaf axil bearing first flower, leaf area, pollen sterility, fruits per plant, average fruit weight, fruit weight per plant, fruit length, fruit girth, seeds per fruit and YVM incidence.

Sushmita and Das (2003) estimated the combining ability in okra with 10 × 10 diallel cross, excluding reciprocals. Variances due to general combining ability and specific combining ability were highly significant for all the characters; the variance due to GCA being higher than all the characters indicating the preponderance of additive gene action except for days to 50 percent flowering, number of branches per plant and number of fruits per plant.

Combining ability for yield and yield components were studied by Singh and Singh (2003) in 15 okra inbred lines. The general and specific combining abilities were found significant for most of the characters, indicating that both the additive and non-additive gene effects were involved in the inheritance of these traits. The lines 7310 and 6313 were good combiners for most of the traits.

The heterosis and combining ability studies conducted by Bendale *et al.* (2004) on eight okra lines and their 28 crosses revealed a significant *gca* and *sca* effects for fruit yield per plant and significant desirable heterosis for yield per plant over better parent among hybrids.

Significant general and specific combining ability for ten characters in okra were reported by Kumar *et al*. (2005). Most of the superior specific combiners for different attributes had a good *per se* performance and many cross combinations exhibited high heterosis in terms of yield.

While assessing the combining ability for 12 quantitative characters using 45 F_1'S of okra developed through diallel technique excluding reciprocals and from 10 parents, Shekhawat and his coworkers (2005) revealed that analysis of variances due to general and specific combining ability for both additive and non-additive gene effects were important for plant height, branches per plant, fruit length, number of fruits per plant and yield per plant. Seven superior heterotic crosses were selected due to high *sca* effects on yield and its components.

Dahake and Bangar (2006) studied the combining ability effects and variances in an 8 × 8 half diallel set on okra cultivars. The analysis of variance revealed highly significant differences among the parents and crosses for all the characters studied except number of fruits per plant. The mean sum of squares due to general combining ability and specific combining ability were significant for all the characters. Parents which were the best general combiners could be used in exploiting heterosis for fruit yield while crosses which produced significantly high *sca* effects for yield and yield contributing characters including number of internodes, number of fruits per plant and plant height can be exploited directly for heterosis.

Eight okra genotypes and their 28 crosses were studied by Borgaonkar *et al.* (2006a) to estimate the *gca* and *sca* effects for the selection of potential parents and crosses. The combining ability analysis revealed that mean squares due to *gca* and *sca* were highly significant for all the characters.

Combining ability and heterosis for yield and yield components were studied by Kumar and Anandan (2006) in six parental cultivars and 30 crosses. The additive and non-additive gene action was important in the inheritance of all the traits. The estimates of GCA variances were higher than the corresponding SCA variances. Significant positive *gca* effects for number of nodes, number of fruits, fruit yield, total green matter production and harvest index. The negative *gca* effects for number of days to first flowering were noticed. Several hybrids showed high heterobeltiosis for fruit yield per plant and favorable heterobeltiosis for the other traits. In the presence of additive and non-additive gene actions coupled with reciprocal differences, reciprocal recurrent selection may be used for the genetic improvement of okra.

In an experiment on heterosis for yield and yield components of okra, Eswaran *et al.* (2007) reported that the parents and hybrids differed significantly for all traits, suggesting significant genetic variation among the genotypes. Most of the cross combinations that exhibited high *sca* effects originated from parents characterized by high *gca* effects.

A total of 45 crosses excluding reciprocals, were made among 10 strains of okra, comprising popular cultivars and indigenous collections from different parts of India by Yadav *et al.* (2007b). The analysis of variance postulated highly significant variances for general and specific combining abilities both in the F_1 and F_2 generations for all the characters, except for fruit width. However, the relative magnitude of GCA and SCA variances revealed that the magnitude of GCA variance was higher than that of SCA variance, indicating thereby that the additive component was of major importance in the expression of all the characters in each generation, except for fruit width in F_2, which was found to be under the control of equal proportion or additive and non additive genes.

In an experiment on ten okra genotypes, Manivannan *et al.* (2007a) reported highly significant progeny variances. The mean squares due to GCA and SCA were significant for all the characters except for the fruit diameter, fruit weight and 100-seed weight in the case of GCA and days to 50 per cent flowering, fruit diameter, number of ridges per fruit, fruit weight and 100-seed weight in the case of SCA.

From an experiment to investigate the gene action for different quantitative traits and combining ability for yield and its components in a line x tester crossing programme comprising 24 hybrids produced by crossing 8 lines and 3 testers okra, Weerasekara *et al.* (2008) reported favorable *sca* effects for the various characters and the parents and hybrids differed significantly for *gca* and *sca* effects, respectively. They also reported that the variances due to line x tester interactions were significant for all traits except fruit length, diameter and weight. A predominance of non additive gene action which is an integral part of genetic architecture of different characters was noticed. Combining ability study conducted by Srivastava *et al.* (2008) in okra revealed the preponderance of additive gene for the expression of characters studied.

Singh and Vijai (2010) conducted an experiment in okra with 21 F_1s and F_2s developed through diallel hybridization technique excluding reciprocals along with seven parents in RBD with three replications. According to them multiple crossing with good general combiners resulted in high yielding varieties. They also revealed that the specific combining ability effects indicated that choice of parents could be based on per se performance. The selection in okra crop can be based on the combination of two characters, i.e., length of first fruiting node with length of fruit and length of fruit with width of fruit and number of fruits per plant for higher yield over straight selection.

2.5 HETEROSIS

Heterosis is the superiority of the F_1 hybrid over mid parent (relative heterosis) or better parent (heterobeltiosis) or a check variety/hybrid (standard / economic/ useful/ true heterosis). No other biological phenomenon is so much

shrouded in mystery as heterosis with respect to the probable cause of its manifestation. Modern approach to the understanding of heterosis makes finer distinctions of heterotic character expression at various stages of hybrid development necessitating cooperative intra-organism interactions between cells, cellular organelles, between nucleus and organelle and their subsequent effect on enzymatic reactions, energy supply and substance flow in cellular functions. Hence, to understand the causal mechanism of heterosis, the most accepted hypothesis states that dominance, over dominance and epistasis, all action appear to produce heterotic effect.

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). Sundhari *et al.* (1992b) developed and evaluated 30 hybrids of bhindi following full diallel mating design and analysis of variance revealed significant differences between the parents and hybrids, indicating the presence of relative heterosis (24.57 %) and heterobeltiosis (12.52 %) for fruit yield.

Kumbhani *et al.* (1993) crossed eight diverse genotypes in all possible combinations to find out the combination of parents manifesting the highest degree of useful heterosis. Significant differences were observed for all characters studied. High heterosis for yield per plant seemed to have resulted from the combined effect of heterosis for yield component characters such as number of pods per plant, pod length, pod girth, plant height and internodal length.

The F_1 and F_2 generations from a 6 × 6 diallel cross in okra, without reciprocals, were evaluated by Mandal and Dana (1993). Significant heterosis over the best parent was observed for earliness, plant height and fruits per plant. Inbreeding depression was observed in all 15 crosses for fruits per plant but in ten crosses for days to first flowering and in only three crosses for plant height.

Singh and Mandal (1993) recorded the data from the 15 hybrids derived from six varieties of *A. esculentus* for yield and eight component traits. Heterosis over the mid and better parental values, respectively, was highest for early yield, number of fruits per plant, number of branches per plant and total yield.

Information on combining ability and heterosis was derived from data on seven yield components in four parental okra genotypes and their four F_1 hybrids by Mohamed *et al.* (1994). Almost all hybrids showed heterosis for all characters except pod diameter.

Poshiya and Vashi (1995) conducted a heterosis study and reported highest heterosis for fruit yield over better parent. The hybrids exhibiting significant heterosis for fruit yield also exhibited heterosis for most of the other characters studied. The best heterotic hybrids were not the cross combinations that exhibited maximum *sca* effects. Mean performance of the hybrids showed close association with *sca* effects, indicating that selection of the hybrids based on *per se* response is equally effective.

Singh *et al.* (1996) estimated the heterobeltiosis on eleven yield-related traits in eight varieties of okra and their F_1 hybrids. The best performing hybrids gave higher marketable yields than the best parent.

Diallel crosses from ten varieties of okra were evaluated for heterosis for ten quantitative characters by Patil *et al.* (1996a). A high degree of heterosis was reported for all the characters studied especially with respect to marketable yield (weight of good pods per plant), earliness and pod borer (*Earias spp*.) resistance, earliness and optimum pod length (8-10 cm).

An experiment was conducted by More and Patil (1997) to study the extent of heterosis and inbreeding depression for seven quantitative characters in okra. Overall mean heterosis over mid parent and better parent was highest for fruit yield per plant, mostly owing to the heterotic effects of number of fruits per plant, number of fruits per picking and weight of fruit. The average values for inbreeding depression for fruit yield per plant and other characters were similar to those of heterosis, but lower in magnitude. A close relationship between heterosis and inbreeding depression was observed suggesting preponderance of non-additive gene action.

An experiment was conducted by Wankhade *et al.* (1997) with twelve parental diallel progenies (without reciprocals) of okra. An appreciable and significant useful heterosis over standard variety Pusa Sawani for yield and

significant heterobeltiosis for all the characters including yield and its contributing traits was obtained.

Ahmed *et al*. (1999) evaluated 28 F_1 crosses and eight parents and observed maximum heterosis for pods per plant (74.77 %) followed by average fruit weight (62.59 %) and branches per plant (952.50 %). Heterotic effects of six characters studied by Panda and Singh (1999) in twenty crosses of okra revealed the highest heterosis for pod yield (45 .62 %) and pods per plant (28.32 %).

Heterosis study in okra conducted by Sood (1999) indicated significant differences for all characters suggesting the presence of genetic variability among the material studied. Heterosis was exhibited in many crosses for different characters. Four crosses exhibited the maximum heterosis for fruit yield over the standard check showing the importance of non-additive genes. Two crosses had significant heterosis in F_1 and F_2 generation for fruit yield/plant and fruits/plant.

Heterosis in okra was estimated by Pawar *et al.* (1999) in a set of 10 × 10 diallel crosses excluding reciprocals. The magnitude of heterosis varied from cross to cross for all the characters. Degree of heterosis was higher for number of branches per plant, yield per plant, number of pods per plant and plant height; moderate for first fruiting node, pod girth, pod length and number of nodes per plant; while days to 50 per cent flowering and days to first picking exhibited low heterosis. Among the various crosses which exhibited significant relative heterosis and heterobeltiosis for yield per plant, Khoda-11 x Pusa Sawani was the best performer. (With values of 41.43 % and 35.42 % respectively).

Heterosis and gene action were studied by Sood and Sharma (2001) in the F_1 and F_2 generations for fruit yield and associated traits in a diallel cross of okra. The cross P-7 × Arka Abhay had the highest heterosis for yield over the better parent (68 %) and produced 80 per cent more fruit than the control cultivar, Pusa Sawani. Its yield advantage arose from heterosis for fruit number per plant, plant height and node number per plant. Some heterotic crosses also showed hybrid vigour for fruit yield and plant height, and they should provide transgressive segregants in later generations in a pedigree breeding programme. Non-additive

gene effects were larger than additive effects in both generations. Both over dominance and epistasis contributed to fruit yield.

Heterobeltiosis in okra was estimated by Nichal *et al.* (2001a) in a set of 7 × 7 diallel cross excluding reciprocals to isolate desirable F_1 hybrids. Heterobeltiosis to the extent of -20.11 per cent for days to first flowering, 23.21 per cent for plant height, 75.00 per cent for number of primary branches on main stem, 59.62 per cent for number of fruiting nodes on main stem, 87.90 per cent for number of fruits per plant, 22.32 per cent for average fruit weight, 23.28 per cent for fruit length and 129.22 per cent for yield per plant was observed. The best performing hybrids were VRO-3 × Arka-Abhay, VRO-3 × JNDO-5, VRO-3 × AKO-73, JNDO-5 × Arka-Abhay, Arka-Abhay × Arka-Anamika and AKO-16 × Pusa A-4, which gave 129.22, 106.24, 92.00, 69.85, 43.83 and 18.37% higher yield than the better parent involved in the cross, respectively, and could be exploited for heterosis breeding programme.

Heterobeltiosis in okra ranged from -141 per cent for length of fruits to 185 per cent for number of fruits per plant as reported by Singh *et al.* (2002b). In general, hybrids showed a wide range of heterotic effects for each character. It was further revealed that most of the high heterotic cross combinations for different characters showed high inbreeding depression in F_2 generation. This may be due to that the most part of heterobeltiosis was accounted for dominance and dominance × dominance type of epistatic interactions and less for additive × dominance type of gene effect.

A study was undertaken by Mamta-Rani *et al.* (2002) to assess the magnitude of heterobeltiosis in okra in an 8 × 8 diallel set excluding reciprocals. Highly significant and desirable heterobeltiosis was reported for all characters except for YVMV related characters. The cross Pusa Makhmali × HRB 9-2 showed significant and desirable heterotic response for node at which the first flower appeared, number of fruits per plant, average fruit weight, marketable yield and total yield, while the cross HRB 9-2 × Punjab-8 exhibited desirable heterosis for days to first flowering, days to first picking and plant height.

Indurani *et al.* (2003) developed four okra hybrids by crossing three parents in a diallel fashion for superior yield and resistance to yellow vein mosaic virus. Arka Anamika, the standard check and the cross PA4 × Varsha Upahar had no symptoms of YVMV incidence. PA4 × OHD-1 recorded minimum YVMV incidence of 24.13 per cent.

Rewale *et al.* (2003) found significant heterotic effects in the positive direction for all the yield and yield contributing characters of okra. Most of the high heterotic combinations were between geographically diverse parents. The crosses SOH-02 × P.K. and SOH-02 × G.F. exhibited desirable negative and significant heterotic effects for days to initiation of flowering, days to initiation of fruit and days to maturity for green fruit. The cross DVR-3 × G.G. recorded significant heterobeltiosis for yield per plant, fruits per plant, nodes per plant, branches per plant and plant height. The crosses JNDO-5 × P.K. (153.43 %) and NOL-101 × G.G. (147.79 %) also showed a higher magnitude of heterosis over better parent.

Heterosis for the characters of 15 hybrids with respect to their mid, standard, better and best parents were estimated by Sindhumole (2003) with relative heterosis being the highest for YVM incidence (-51.61 %) followed by fruit yield (51.34 %) whereas standard heterosis was maximum for fruit and shoot borer incidence (-165.69 %) followed by fruit yield (115.46 %) while highest heterobeltiosis was observed for pollen sterility (79.65 %) followed by fruit and shoot borer incidence (-41.85 %).

Pankaj-Tripathi *et al.* (2004) estimated heterosis in F_1 over standard parent Azad Bhindi-1 and inbreeding depression in F_2 for ten characters in okra. A significant amount of useful heterosis was observed for all the characters, except for yield per plant. However, the maximum heterosis with respect to fruit width was observed in cross Azad Bhindi-1 × Parbhani Kranti (131.57 %). Significant and desirable heterosis along with significant inbreeding depression was also reported for all the characters in most of the crosses, which indicated that the most part of heterosis was due to dominance and dominance × dominance type of interaction.

To study the extent of heterosis for yield and yield attributes in okra, an experiment was conducted by Bhalekar *et al.* (2004) with seven diverse pure-lines of okra. The heterosis in desirable direction was evident for fruit yield and its component characters, except for average fruit weight. The magnitude of the heterosis was higher for incidence of yellow vein mosaic virus and yield per plant.

Heterosis was estimated by Borgaonkar *et al.* (2005) in 28 hybrids of okra obtained through an 8 × 8 diallel mating design. Analysis of variance revealed highly significant differences for many traits indicating the presence of considerable genetic diversity among the genotypes. The degree of heterosis was higher for fruit length, internodal length, leaf area and yield per plant; moderate for number of nodes on the main stem and plant height; and low for number of days to 50 per cent flowering, number of days to first picking and fruit girth. The cross No. 129 × JNDO-5 exhibited the greatest heterobeltiosis (52.22 %) for yield per plant, followed by No. 74 × JNDO-5 (40.45 %) and No. 114 × JNDO-5 (37.96 %)

Results on heterosis worked out based on a field experiment by Nichal *et al.* (2006) revealed that, analysis of variance showed significant differences among the parental lines and their hybrids for many traits indicating genetic diversity of the materials tested. A field experiment was conducted by Borgaonkar *et al.* (2006b) to assess the extent of heterosis over mid and better parents for yield and its related attributes in okra. Out of 28 hybrids, 17 showed significant positive heterosis over mid and better parents. The cross No. 74 × JNDO 5 exhibited the maximum heterosis (51.33 %) for yield per plant, followed by No. 129 × JNDO 5 (40.45 %) over the better parent. Heterosis for yield was manifested through component heterosis and hybrid vigour of even a small magnitude for individual traits may have additive effects on yield per plant.

Combining ability and heterosis for yield and yield components in okra were studied by Kumar and Anandan (2006) for parental cultivars and 30 crosses. The additive and non-additive gene actions were important in the inheritance of all traits. The estimates of GCA variances were higher than the corresponding SCA variances. Arka Anamika exhibited significant positive *gca* effects for

number of nodes, number of fruits, fruit yield, total green matter production, and harvest index, and negative *gca* effects for number of days to first flowering. Punjab Padmini showed significant positive *gca* effects for all traits except the number of days to first flowering and number of branches, and negative *gca* effect for number of days to first flowering. Many hybrids showed high heterobeltiosis for fruit yield per plant and favorable heterobeltiosis for the other traits. In the presence of additive and non-additive gene actions coupled with reciprocal differences, reciprocal recurrent selection may be used for the genetic improvement of okra.

Singh and Syamal (2006) estimated the extent of heterosis over three better parents in relation to the genetic diversity of parents in bhindi. The manifestation of heterosis in F_1 hybrid over better parent ranged from 7.19 per cent and 45.71 per cent for plant height and the number of primary branches respectively. Some crosses showed negative heterosis over better parent ranging from -13.84 per cent to -26.36 per cent for days to flowering and -28.22 per cent to -29.21 per cent for days to first picking. Heterosis over better parents was to the extent of 53.28 per cent for the number of pods per plant.

Twenty-eight crosses from 8 × 8 diallel excluding reciprocals were developed by Dahake *et al.* (2007) to assess the magnitude of heterosis over better parent and standard check for fruit yield and its components in okra. An appreciable amount of heterosis was reported for almost all the characters. The cross Hissar Unnant × Duptari 45 exhibited the highest magnitude of heterosis to the extent of 24.36 per cent over better parent and 13.93 per cent over standard check for fruit yield plant-1, 22.13 per cent over batter parent and 11.80 per cent over standard check for number of internodes plant-1 and 17.87 per cent over batter parent and 15.37 per cent over standard check for number of fruits plant per plant.

In an experiment on okra to determine heterosis over standard parent Yadav *et al.* (2007c) desirable heterosis in a negative direction for days to flowering was noticed. A high magnitude of heterosis for plant height and number of branches per plant was observed in hybrids. Negative significant heterosis for

number of first fruiting node and internode length was also noticed whereas significant and positive heterosis fornumber of nodes per plant, number of fruits per plant, fruit length and width of fruit was observed. The estimate of heterosis for various yield components of the heterotic hybrids indicated that significant yield increase is largely attributed to increased plant height, number of branches per plant, number of fruits per plant and number of nodes per plant.

An estimation of heterosis on okra was made by Manivannan *et al.* (2007b). The crosses showed significant heterosis over better parent for plant height, plant spread, number of leaves, days to 50 percent flowering, fruits per plant, fruit weight, number of seeds per fruit, 100-seed weight and yield per plant.

During Line x Tester analysis in okra, the magnitude of heterosis over standard check was high for most of the characters studied. Out of 24 hybrids, 'IC-90044' X 'Parbhani Kranthi' can be exploited commercially as it exhibited earliness, high number of fruits and high yield per plant (Hosamani *et al*. 2008).

Heterosis in okra was reported by Pandey *et al*. (2008) for all the characters over both better and economic parents in several cross combinations. In general, hybrids showed a wide range of heterosis effects for each character. It was further revealed that most of the high heterotic cross combinations for different characters showed high inbreeding depression in F_2 generation which may be due to dominance type of gene effect.

Kumar and Sreeparvathy (2010) analysed the heterosis of 20 hybrids for eight characters. The hybrid MDU 1 x Hissar Unnath exhibited maximum significant positive standard heterosis for fruit yield per plant (65.23 %) and negative standard heterosis for days to 50 percent flowering. Positive significant relative heterosis and heterobeltiosis was observed for number of branches per plant and number of fruits per plant.

Magnitude of heterosis over better parent and standard check for fruit yield and its component traits for forty two crosses in okra was pointed out by Kumar (2011). The standard heterosis ranged from -23.95 to 55.96 per cent for fruit yield per plant among 42 hybrids. The cross Pusa A4 x Punjab Padmini exhibited the highest magnitude of heterosis to the extent of 43.23 per cent over

better parent and 55.96 per cent over standard check for fruit yield per plant, 14.81 percent over better parent and 52.44 over standard check for number of branches per plant and 13.52 percent over better parent and 29.78 percent over standard check for number of fruits per plant.

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The various materials used and the methods followed in carrying out the present investigation are presented below:

3.1 EXPERIMENTAL SITE

The field experiments were carried out in the field attached to the Department of Plant Breeding and Genetics and the confirmation of disease resistance studies was done in the insect proof Glass house of the Department of Plant Pathology, College of Agriculture, Vellayani during 2011-2012.

3.2 EXPERIMENTAL DESIGN

The experiment was conducted using 36 genotypes of okra during summer, 2011 to screen for yield and resistance to yellow vein mosaic virus disease in a Randomized Block Design with three replications at spacing of 60 x 45 cm with ten plants per treatment per replication. Scoring for yellow vein mosaic disease incidence was done as per the rating scale (0-5) developed by Rajamony *et al*. (1990) during three stages of the crop *viz.,* 30 days after sowing (30 DAS), 50 days after sowing (50 DAS) and 70 days after sowing (70 DAS). The vector population and number of leaves with disease symptoms were recorded from first, third and fifth leaves at the above three stages.

3.3 EXPERIMENTAL MATERIALS

The material for the study comprised of 36 accessions of okra collected from various parts of the country including accessions from Kerala Agricultural University and local collections from Kerala and Karnataka. The details of the genotypes used in the present study are given in Table 1.

3.4 CULTURAL PRACTICES

The field in which sowing was taken up was prepared to fine tilth by ploughing, harrowing and clod crushing followed by leveling. Ridges were taken 60 cm apart with 15 cm height and each entry was sown in a single row with spacing of 60 cm x 45 cm. Two to three seeds were dibbled at each hill and after germination and plant establishment, thinning was carried out to maintain a single healthy plant per hill. The crop was raised as per the package of practices recommendation of KAU (2007).

Table 1. List of varieties of okra used for evaluation

No	Name of variety	Place	Accession No.
1	IC 7119	NBPGR	AE-1
2	IC 1012-1	NBPGR	AE-2
3	Hosalli Local	Koratagere	AE-3
4	Punjab Phalgani	NBPGR	AE-4
5	HRB-9-2	UAS(B)	AE-5
6	AE-201	Vellanikkara	AE-6
7	Mara Bhendi	Khalaghatagi	AE-7
8	Thirumala local	Thiruvananthapuram	AE-8
9	Belagavi Local	Belagavi	AE-9
10	Mandya Local	Mandya	AE-10
11	Neyyar Local	Thiruvananthapuram	AE-11
12	Poovam Local	Panniyur	AE-12
13	Kattakada Local	Thiruvananthapuram	AE-13
14	Krishnarajapet Local	Krishnarajapet	AE-14
15	Kalliyur Local	Vellayani	AE-15

16	Nagamangala Local	Nagamangala	AE-16
17	Nedumangad local	Thiruvananthapuram	AE-17
18	PHS 9394	UAS(B)	AE-18
19	Cherthala local	Alleppey	AE-19
20	Varsha Upahar	Vellayani	AE-20
21	Mysore Local	Mysore	AE-21
22	Azhoor local	Pathanamthitta	AE-22
23	Neeleshwaram local	Kasargod	AE-23
24	Bhendi 070	Belagavi	AE-24
25	Karunagapally Local	Quilon	AE-25
26	Arka Anamika	IIHR	AE-26
27	AE-102	Vellanikkara	AE-27
28	Halu Bhendi	KVK, Brammavara	AE-28
29	AE-116	Vellanikkara	AE-29
30	Arka Abhay	IIHR	AE-30
31	IC 140910	NBPGR	AE-31
32	Kunnapuzha Local	Thiruvananthapuram	AE-32
33	Holavanahalli Local	Koratagere	AE-33
34	Mallapalli Local	Kottayam	AE-34
35	Tirur Local	Malapuram	AE-35
36	Vadakkumcheri Local	Palakkad	AE-36

3.5 RECORDING OF OBSERVATIONS

Five competitive plants per treatment in each replication were selected randomly and tagged. Observations with respect to different characters were recorded on these plants and the mean of five plants were considered for statistical analysis. Observations were recorded on the following characters.

A. Yield characters

3.5.1 Days to first flowering

Number of days taken from the date of sowing to date of first flowering of the plants was recorded and expressed in mean values.

3.5.2 Leaf axil bearing first fruit

The number of the leaf axils in which the first fruit was produced was recorded and mean was calculated.

3.5.3 Number of primary branches per plant

Number of primary branches arising from the main stem above the ground level was recorded in each observational plant at harvest and mean was calculated.

3.5.4 Plant height

Height of the plant was recorded in centimeters using a meter scale from the ground level to the tip of the plant at first harvest and was expressed as mean values.

3.5.5 Duration

The number of days from date of sowing to final harvest of each observational plant was recorded and expressed in means.

3.5.6 Number of fruits per plant

The total number of fruits from each plant was harvested, counted and mean was worked out.

3.5.7 Fruit weight

The average fruit weight was computed from the total fruit weight of five randomly selected plants and expressed in grams.

3.5.8 Fruit length

The length of fruits harvested per plant was measured in centimeters from the base to the tip of the fruit and mean value was calculated.

3.5.9 Fruit girth

The girth of the fruit was measured at the middle of the fruit and the mean recorded in centimeters.

3.5.10 Yield per plant

The green fruit weight per plant of all pickings was recorded and the same was expressed in grams.

B. Pest and Disease Incidence

3.5.11 Number of white flies on leaves

The total population of whitefly (*Bemisia tabaci*) was recorded on first, third and fifth leaves of the plant during 30, 50 and 70 DAS of the crop. The lower side of the leaves in each observational plant was observed and the total number of white flies was counted and means were calculated.

3.5.12 Number of leaves with disease Symptoms

The first, third and fifth leaves in each observational plant showing YVM symptoms were recorded during 30, 50 and 70 days of the crop and mean was calculated.

3.5.13 Scoring for virus resistance

Scoring for YVMV disease was done in each observational plant based on characteristic symptoms on leaves, fruits and stem. Screening for virus resistance was done by scoring the expression of symptoms on individual observational plant during 30, 50 and 70 DAS in the field based on 0-5 scale (Table 2) proposed by Rajamony *et al*. (1990).

Individual plant score was also utilized to work out the “severity index” or “vulnerability index" (V.I.) so as to measure level of the resistance. The index was calculated using the following equation adopted by Silbernagel and Jafri (1974) for measuring resistance.

$$V.I = \frac{(0n_o + 1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5)}{n_t (n_c - 1)} \times 100$$

Where, V.I = Vulnerability (severity) index

n0, n1---n5 = Number of plants in category 0, 1---5

nt = Total number of plants

nc = Total number of categories

The following scale was used:

Table 2. Disease rating scale (Rajamony *et al.,* 1990)

Scale	Description	Category
0	No symptoms	Highly Resistance (HR)
1	Slight vein clearing, very light mottling of light and dark green colour in younger leaves	Resistant (R)
2	Vein thickening and first-chlorosis	Medium Resistance (MR)
3	Yellowing of leaves (chlorosis of leaves, fruit and stem)	Medium Susceptible (MS)
4	Distortion of leaves	Susceptible (S)
5	Stunting of the plant with negligible or no flowering and fruiting	Highly Susceptible (HS)

3.6 TRANSMISSION STUDIES FOR CONFIRMATION OF DISEASE RESISTANCE

3.6.1 Screening of okra lines / accessions in insect proof glass house

The five selected resistant okra lines / accessions from field experiment were subjected to vector and graft transmission studies and were screened for resistance to *Bhindi yellow vein mosaic virus* (BYVMV) in glass

house to confirm disease resistance. The per cent severity indexes in each accession / lines after inoculation was recorded at weekly intervals and were grouped into different categories according to the scale given by Rajamony *et al*. (1990).

3.6.2 Vector transmission

All the five resistant seedlings were grown in pots filled with soil and compost mixture in 2:1 proportion and inoculated at two leaves stage with viruliferous indigenous *B.tabaci* (AAP: 24 hrs and IAP: 24 hrs) at the rate of 10-15 whiteflies per plant. The inoculated plants were transferred to insect proof glasshouse and observed for symptom expression.

3.6.2.1 Maintenance of whitefly culture

The type culture of *B.tabaci* used for inoculation was maintained on cotton, *Gossypium hirsutum* cv. Varalakshmi plants. Healthy cotton plants grown in pots filled with a mixture of soil and compost in 2:1 proportion were introduced into the cages. The cages were maintained at temperature of 28 to 30^0C in an insect proof polyhouse. The whiteflies colonized on the lower surface of young leaves of cotton were used as the source of vector.

3.6.2.2 Collection of whiteflies

An aspirator made of glass tube (30 x 0.5 x 40 cm) was used for the collection of whiteflies and later, they were gently blown into the insect cages. The disease free whiteflies were used for transmission studies.

3.6.2.3 Raising of healthy bhindi seedlings

For glasshouse studies, all the 5 resistant accessions selected from the first experiment were grown. Twenty sets of the genotypes were staggered planted. Pots were filled with a mixture of soil and compost in 2:1 proportion. These plants were kept in insect proof cages and used throughout the period of investigation.

3.6.2.4 Culture of Bhindi yellow vein mosaic virus

Bhindi plants which were naturally infected with the disease and showing conspicuous symptoms of yellow vein mosaic twigs were collected from the field of Instructional Farm, College of Agriculture, Vellayani and the reared healthy whiteflies were released on these twigs maintained inside an insect cage for acquisition of the virus. The whiteflies were allowed for 24 hr acquisition access and then transferred to eight days old healthy bhindi seedlings of different accessions in a glasshouse. The inoculation access was given for 24 hrs. *Bhindi yellow vein mosaic virus* culture was maintained in a glasshouse by frequently inoculating the healthy plants with the viruliferous whiteflies (*B.tabaci*).

3.6.2.5 Graft transmission

YVMV resistant accessions selected from the first experiment were used as root stock and were grafted by wedge grafting method. The diseased scion from YVMV infected okra plants were made into a 'V' shaped structure. The scion was inserted into a vertical cut made on the root stock plants. The grafted portion was tied with a polythene strip and scion was covered with a polythene bag. The inoculated plants were kept in a cool place in the glass house for symptom expression. Subsequently, further growth on the root stock was observed and the presence/absence of YVM disease symptoms on the new leaves was used as the criterion for the confirmation of disease resistance of the particular genotypes tested.

3.6.3 Development of F_1's

Five resistant types and three high yielding YVM susceptible types, identified from the trials on screening and evaluation of germplasm in both field and glasshouse experiments, were used as the parental lines and testers respectively for developing F_1. The five lines and three testers were raised in an L x T crossing block 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 were 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 on the next day 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 labeled. The covers were removed a day after pollination. The mature fruits were harvested separately and F_1 seeds were extracted. The five lines and three testers used for the experiment were as follows

a. Five Lines (Resistant to YVMV Disease)

1. IC 1012-1-(L_1 - AE-2)
2. Thirumala local-(L_2 - AE-8)
3. Halu Bhendi-(L_3- AE-28)
4. Kunnapuzha local-(L_4- AE-32)
5. Holavanalli local -(L_5- AE-33)

b. Testers (High yielding but susceptible to YVMV Disease)

1. Punjab Phalgani-(T_1- AE-4)
2. Kattakada local-(T_2- AE-13)
3. Mallapalli local-(T_3- AE-34)

3.6.4 Evaluation of F_1's and parents

The fifteen F_1 hybrids and their eight parents were evaluated along with one commercial check (Varsha Upahar) in a randomized block design with three replications at spacing of 60 x 45 cm and ten plants per treatment per replication during summer 2012. Observations on yield and yield attributes and severity index of YVMV disease (Rajamony *et al.,* 1990) were recorded from hybrids and parents.

3.7 STATISTICAL ANALYSIS

3.7.1 Germplasm evaluation

3.7.1.1 Evaluation for yield characters and pest and disease incidence

3.7.1.1.1 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 3).

Table 3 ANOVA for each character

Sources of variation	Degrees of freedom	Mean square	F
Replication	(r-l)	MSR	MSR/MSE
Treatment	(t-l)	MST	MST/MSE
Error	(r-1) (t-l)	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.

3.7.1.1.2 Estimation of genetic parameters

A. Genetic components of variance.

For each character, the phenotypic 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)

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

ii. Environmental variance (V_E)

$VE = MSE$

iii. Phenotypic variance (V_P)

$VP = VG + VE$

B. Coefficients of variation.

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

i. Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{V_p}}{\overline{X}} \times 100$$

ii. Genotypic coefficient of variation (GCV)

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

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

The coefficients of variation are categorized as:

The PCV and GCV were classified as, low (<10%), moderate (10-20%) and high (>20%)

C. Heritability

For each trait, heritability (broad sense) was calculated as the ratio of genotypic variance to phenotypic variance and expressed as percentage (Lush, 1937).

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

Heritability was categorized as low (< 30%), moderate (31-60%) and high (>60%) as suggested by Robinson *et al.* (1949).

D. Genetic Advance

Genetic advance which is the measure of genetic gain under selection depends upon standardized 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)

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

Genetic advance as percentage of mean was categorized as low (< 10%), moderate (11-20%) and high (>20%) as suggested by Robinson *et al.* (1949).

3.7.1.1.3 Correlation analysis

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

$$\text{Phenotypic correlation coefficients, } r_{PXY} = \frac{COV_P(X,Y)}{\sqrt{V_P(X).V_P(Y)}}$$

$$\text{Genotypic correlation coefficient, } r_{GXY} = \frac{COV_G(X,Y)}{\sqrt{V_G(X).V_G(Y)}}$$

Where, CoV_P (x, y) and CoV_G (x, y) denote the phenotypic and genotypic co-variances between the two traits x and y respectively. V_P (x) and V_G (x) respectively are the phenotypic and genotypic variance for x and V_P (y) and V_G (y) indicate the phenotypic and genotypic variance for y, in that order.

3.7.2 Line X Tester Analysis

3.7.2.1 Combining ability

Based on screening trials, five resistant lines and three susceptible but high yielding testers were identified and carried over for developing hybrids. 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 4.

Table 4 ANOVA for line x tester analysis

Sources	df	Mean square	Expected MS
Replication	(r-l)		
Line	(*l*-l)	M_1	MSE + r (Cov F.S. -2 Cov H.S.) + rf (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*-l) (*t*-l)	M_3	MSE + r (Cov F.S. – 2 Cov H.S.)
Error	(r-1) (*lt*-l)	M_4	MSE
Total	(r*lt*-l)		

Where,

r = Number of replications

g = Number of genotypes

l = number of lines

t = number of testers

a. Combining ability variance

The *gca* variance of lines and testers and *sca* variance for the hybrids were estimated as per the Singh and Choudhary (1985).

$$\text{GCA variances for lines and testers} = \frac{(M1 - M3) + (M2 - M3)}{r(\ell + t)}$$

$$\text{SCA} = \text{Variance for hybrids} = \frac{M3 - M4}{r}$$

Where,

M1= MSS due to lines

M2= MSS due to testers

M3= MSS due to lines and testers

M4= MSS for error

r = number of replication

l = lines

t= testers

b. Combining ability effects

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* effects of i^{th} line

g_i = *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:

$$\text{Mean} = \frac{X...}{r_{1t}}$$

i. *gca* effect of lines

$$g_i = \frac{X_{i..}}{r_t} - \frac{X...}{r_{1t}} \quad i= 1,2,...,I$$

ii. *gca* effect of testers

$$g_j = \frac{X_{j.}}{r_1} - \frac{X...}{r_{1t}} \quad j= 1,2,...,t$$

iii. *sca* effect of hybrids

$$S_{ij} = \frac{X_{ij.}}{r} - \frac{X_{i..}}{r_t} - \frac{X_{j.}}{r_1} + \frac{X...}{r_{1t}}$$

Where,

x = Total of all hybrids over ‘r’ number of replication

x_i = Total of all hybrids involving i^{th} lines as one parent over ‘t’ testers and ‘r’ replications.

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

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 *gca* 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.

3.7.2.2 Proportional Contribution

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

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

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

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

3.7.2.3 Heterosis

Extent of heterosis was computed for all the fifteen hybrids as relative heterosis (RH), standard heterosis (SH) and heterobeltiosis (HB) using the following formulae and expressed as percentage.

$$\text{i. Relative heterosis (RH)} = \frac{\overline{F_1} - \overline{MP}}{\overline{MP}} \times 100$$

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

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

Where,

$\overline{F1}$ = 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

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

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

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

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

Where,

MSE = Estimate of error variance

r = number of replication

RESULTS

4. RESULTS

An experiment entitled "Genetic variability for yield and resistance to yellow vein mosaic virus disease in okra (*Abelmoschus esculentus* (L.) Moench)" was undertaken at the Department of Plant breeding and Genetics, College of Agriculture, Vellayani, laboratory evaluation of the genotypes for reaction to YVMV resistance done in the insect proof glass house of the Department of Plant Pathology, College of Agriculture, Vellayani and F_1 evaluation was carried out in the field at Department of Plant breeding and Genetics, College of Agriculture, Vellayani. The results of the experiment are presented in this chapter under the following headings.

4.1 EXPERIMENT I: EVALUATION OF OKRA GERMPLASM

4.1.1 Mean Performance

4.1.2 Genetic variability parameters

4.1.3 Correlation analysis

4.1.4 Scoring for virus resistance

4.2 EXPERIMENT II: CONFIRMATION STUDIES FOR DISEASE RESISTANCE

4.3 EXPERIMENT III: DEVELOPMENT AND EVALUATION OF F_1'S

4.3.1 Combining ability analysis

4.3.2 Scoring for disease resistance

4.3.3 Estimation of heterosis

4.1 EXPERIMENT I: EVALUATION OF OKRA GERMPLASM

4.1.1 Performance

The mean performances of 36 okra collections for 12 characters are presented in Table 5. The results of the same are presented character wise.

Plate 1. General view of the experimental plot

Table 5. Performance of okra genotypes.

	DFF	LBFF	NPB	PH	DR	NFPP	FW	FL	FG	YPP
AE-1	38.00	5.66	2.46	86.53	90.73	17.40	13.40	12.43	6.38	233.07
AE-2	39.66	4.80	2.00	87.26	90.20	15.00	13.29	14.38	6.81	199.36
AE-3	45.33	4.53	4.26	57.20	84.00	15.20	17.09	13.50	7.01	259.86
AE-4	39.00	4.60	2.20	86.53	91.66	18.40	18.64	12.58	6.76	341.78
AE-5	43.13	3.86	1.53	67.00	92.93	18.26	15.60	14.22	6.84	283.90
AE-6	38.13	5.80	3.26	99.53	94.93	20.06	9.60	9.23	7.11	192.73
AE-7	38.20	5.26	2.13	111.33	98.93	10.33	12.46	11.66	6.21	128.36
AE-8	40.53	5.66	2.73	112.60	93.13	10.66	15.86	16.09	6.22	169.76
AE-9	36.33	5.60	1.40	88.93	90.66	20.53	13.91	13.90	6.54	285.00
AE-10	40.33	5.00	2.13	128.33	122.13	16.20	15.26	14.41	6.52	247.00
AE-11	40.66	6.20	1.20	104.26	90.46	16.13	15.43	13.25	6.86	249.10
AE-12	43.13	6.26	1.53	69.46	86.06	10.13	12.63	12.89	6.31	127.96
AE-13	43.40	6.13	3.53	123.93	90.46	19.93	16.71	13.60	7.00	331.95
AE-14	37.36	4.80	1.66	132.60	128.06	13.13	13.90	11.96	6.18	182.12
AE-15	45.00	5.40	1.00	90.13	80.40	16.33	13.80	13.44	6.09	225.14
AE-16	42.80	4.66	3.13	134.60	91.00	21.46	12.43	13.23	6.33	267.00
AE-17	38.33	5.66	2.06	45.73	92.26	14.00	12.16	14.69	6.20	170.18
AE-18	37.00	4.13	1.86	126.73	118.26	13.66	12.50	11.26	6.11	171.00
AE-19	42.20	6.60	1.00	82.60	90.33	12.00	15.36	13.46	6.32	184.19
AE-20	37.00	5.26	1.93	124.80	112.33	14.86	11.53	11.31	6.14	171.40
AE-21	44.46	5.40	2.06	141.83	127.33	17.53	16.35	13.02	6.58	286.41

AE-22	37.13	6.40	2.00	68.93	92.40	16.33	13.16	12.88	6.62	215.18
AE-23	36.86	2.60	2.33	55.80	105.66	15.40	16.70	14.39	6.68	257.00
AE-24	44.06	4.53	1.00	97.40	90.26	16.66	15.20	13.35	6.82	254.51
AE-25	39.66	5.66	2.13	82.53	90.73	17.86	12.30	12.03	6.34	219.57
AE-26	46.46	4.86	1.00	101.80	90.13	15.13	13.32	13.31	6.72	201.72
AE-27	46.53	5.00	1.20	92.46	92.26	14.46	11.21	13.63	6.28	162.18
AE-28	45.46	4.80	1.00	105.66	100.86	15.20	14.00	13.50	5.92	213.02
AE-29	38.33	5.40	2.06	107.93	91.13	16.40	16.06	13.62	6.60	263.52
AE-30	38.00	4.13	2.33	73.46	81.26	14.86	13.72	13.62	6.56	203.92
AE-31	45.66	5.20	3.06	70.40	80.46	16.46	10.33	12.23	5.32	170.41
AE-32	43.60	6.26	2.06	138.40	96.66	14.20	15.34	12.55	5.62	217.99
AE-33	38.86	5.00	2.46	107.26	122.46	18.46	15.40	13.98	7.36	284.31
AE-34	45.53	5.86	3.60	96.73	91.93	23.26	20.86	13.47	6.64	482.93
AE-35	39.66	6.73	2.46	89.40	80.26	17.26	13.16	13.25	6.20	227.48
AE-36	40.53	5.06	1.33	92.26	91.20	16.66	14.70	11.04	6.70	245.04
SE	0.25	0.07	0.04	1.01	0.39	0.18	0.14	0.10	0.06	3.40
CD	1.25	0.35	0.20	4.95	1.92	0.88	0.69	0.53	0.29	16.38

DFF = Days to first flowering
LBFF= Leaf axil bearing first fruit
NPB = Number of primary branches
PH = Plant height (cm)
DR = Duration
NFPP= Number of fruits per plant
FW = Fruit weight (g)
FL= Fruit length (cm)
FG = Fruit girth
YPP= Yield per plant

Table 6. Pest and disease incidence in okra genotypes.

						Number of leaves with disease symptom			
Genotypes	30 days	50 days	70 days	mean		30 days	50 days	70 days	mean
AE-1	0.01	0.52	0.16	0.23		0	0.73	2.55	1.09
AE-2	0.05	0.48	0	0.17		0	0	0.33	0.11
AE-3	0.07	0.66	0.22	0.31		0.06	1.86	2.66	1.52
AE-4	0.03	0.41	0.14	0.19		0	1.13	2.26	1.13
AE-5	0.15	0.74	0.21	0.36		0.13	1.73	2.73	1.53
AE-6	0.12	0.5	0	0.20		0.06	0.93	2.26	1.08
AE-7	0.22	0.78	0.31	0.43		0.2	1.93	3	1.71
AE-8	0.16	0.08	0	0.08		0	0	0	0.00
AE-9	0.08	0.33	0	0.13		0	0.6	1.46	0.68
AE-10	0.04	0.2	0	0.08		0	0.26	1.4	0.55
AE-11	0.26	0.46	0	0.24		0.26	1.33	2.73	1.44
AE-12	0.13	0.45	0	0.19		0.06	1.53	2.86	1.48
AE-13	0.16	0.5	0.04	0.23		0.13	1.06	2.46	1.21
AE-14	0	0.41	0.02	0.14		0	0.06	1	0.35
AE-15	0.33	0.48	0.08	0.29		0.2	1.46	2.46	1.37
AE-16	0	0.2	0	0.06		0	0.13	1.06	0.39
AE-17	0.2	0.42	0	0.20		0.2	1.46	3	1.55

AE-18	0.18	0.41	0	0.19		0.2	1.13	2.26	1.19
AE-19	0.18	0.45	0.06	0.23		0.13	1.33	3	1.48
AE-20	0.07	0.48	0.04	0.19		0	0.93	2.06	0.99
AE-21	0.01	0.13	0	0.04		0	0.46	1.66	0.70
AE-22	0.26	0.42	0.08	0.25		0.2	1.8	1.66	1.22
AE-23	0	0.28	0	0.09		0	0.33	1.6	0.64
AE-24	0	0.2	0	0.06		0	0.2	1.13	0.44
AE-25	0.11	0.48	0	0.19		0.06	1.86	3	1.64
AE-26	0.13	0.22	0	0.11		0.06	0.33	1.53	0.64
AE-27	0	0.25	0	0.08		0	0.53	1.26	0.59
AE-28	0	0.04	0	0.01		0	0	1.4	0.46
AE-29	0.04	0.2	0	0.08		0.06	0.26	1.66	0.66
AE-30	0.15	0.13	0	0.09		0.13	0.4	1.66	0.73
AE-31	0.08	0.42	0	0.16		0.06	1.13	2.6	1.26
AE-32	0.07	0.2	0	0.09		0	0	0	0.00
AE-33	0.1	0.2	0	0.10		0	0	0	0.00
AE-34	0.01	0.41	0.1	0.17		0.06	1.13	2.46	1.21
AE-35	0.24	0.48	0.06	0.26		0.26	1.46	3	1.57
AE-36	0.03	0.45	0.1	0.19		0.06	0.93	2.53	1.17
SE	-	-	-	0.03		-	-	-	0.15
CD	-	-	-	0.15		-	-	-	0.76

Table 7. Analysis of variance for various characters of okra genotypes.

Characters	Mean sum of square		
	Replication	Genotypes	Error
Days to first flowering	0.21	31.49**	0.59
Leaf axil bearing first fruit	0.07	2.13**	0.04
Number of primary branches	0.01	1.96**	0.01
Plant height (cm)	15.64	1813.57**	9.31
Duration (days)	2.55	507.34**	1.39
Number of fruits per plant	0.30	25.96**	0.29
Fruit weight (g)	0.30	15.61**	0.18
Fruit length (cm)	0.18	4.56**	0.10
Fruit girth (cm)	0.006	0.50**	0.03
Yield per plant (g)	230.38	13412.09**	104.19

*- Significant at 5% level

** -Significant at 1% level

4.1.1.1 Days to first flowering

Significant difference was noticed among the genotypes for days to first flowering with a general mean of 41.00 days. The genotype AE-9 took the minimum of 36.33 days for first flowering with five genotypes (AE-14, AE-18, AE-20, AE-22 and AE-23) on par with it and AE-27 took the maximum days with 46.53 days to complete first flowering. The genotypes AE-3, AE-26, AE-28, AE-31 and AE-34 were on par with AE-27.

4.1.1.2 Leaf axil bearing first fruit

The accessions differed significantly for the leaf axil bearing first fruit with a general mean of 5.24. The accession AE-23 recorded minimum value of 2.60. The maximum value of 6.73 was recorded for AE-35 followed by AE-19 and AE-22.

4.1.1.3. Number of primary branches

The genotypes AE-15, AE-24, AE-26 and AE-28 manifested the minimum number of primary branches of 1.00 per plant with two genotypes (AE-11, AE-27) being on par with them while the genotype AE-3 registered the maximum number of primary branches (4.26). Among the 36 genotypes evaluated, 16 genotypes had more branches than the general mean and 20 genotypes had fewer branches than general mean (2.08).

4.1.1.4 Plant height

Significant difference was noticed among the accessions for plant height with the general mean of 96.73 cm. The genotype AE-17 was the shortest with 45.73 cm height and the genotype AE-21 was the tallest growing up to 141.83 cm with AE-32 being on par with it.

4.1.1.5 Duration

The minimum duration of 80.26 was noticed in genotype, AE-35 and AE-15, AE-30 and AE-31 were on par with it. The maximum duration of 128.06 was recorded by the AE-14 followed by AE-21on par with it. Of the 36 genotypes, which differed significantly for this trait, 26 genotypes had duration of less than general mean.

4.1.1.6 Number of fruits per plant

Number of fruits per plant varied from the minimum of 10.13 for AE-12 to a maximum of 23.26 for the genotype AE-34 and the difference was significant. AE-7 and AE-8 were on par with AE-12. Compared to the general mean of 16.10, as many as 20 genotypes had more and 16 genotypes had less fruits than the general mean.

4.1.1.7 Fruit Weight

The genotypes differed significantly for fruit weight with the general mean of 14.26 g. The genotype AE-6 registered the minimum fruit weight of 9.60 g and AE-34 registered the maximum of 20.86 g. The general mean for this character was 14.26 g with 16 genotypes manifesting more weight and 20 genotypes had less weight than general mean.

4.1.1.8 Fruit length

Significant difference was noticed among the entries for fruit length with the entry AE-6 recording the tiny fruits (9.23cm) compared to the AE-8 that recorded longest fruit (16.09 cm). Out of 36 genotypes, 22 genotypes had longer fruits than the general mean of 13.09 cm; while 14 genotypes had shorter capsules than general mean.

4.1.1.9 Fruit girth

The genotype AE-31 registered the minimum fruit girth of 5.32 cm and the genotype AE-33 registered the maximum fruit girth of 7.36 cm and AE- 6 was on par with AE-33. Significant difference was noticed among the genotypes for fruit girth with the general mean of 6.46 cm and 19 genotypes possessed more capsule diameter than the general mean while 17 genotypes had less capsule diameter.

4.1.1.10 Yield per plant

A significant difference was noticed for yield per plant among the entries with the AE-12 registering the minimum yield of 127.96 g and AE-34 showed the maximum yield per plant of 482.93 g. Sixteen genotypes manifested more yield and twenty genotypes had less yield than general mean of 231.27 g. AE-7 was on par with AE-12.

4.1.1.11 Number of white flies on leaves

The 36 genotypes of okra were scored for vector population of white fly at 30, 50 and 70 DAS on first, third and fifth leaves and the total mean are presented in Table 6.

a. Total mean

Significant difference was observed among the 36 okra genotypes under study for number of white flies on leaves. The lowest value of 0.01 and the highest value of 0.43 were exhibited by AE-28 and AE-7 respectively. The general mean for this character was 0.17 with 18 genotypes possessing more mean value than the general mean while 16 genotypes had less mean value.

4.1.1.12 Number of leaves with disease symptom

The 36 genotypes of okra were observed for number of leaves with disease symptoms at 30, 50 and 70 DAS on first, third and fifth leaves and the total mean was calculated.

a. Total mean

Significant difference was observed among the 36 okra genotypes under study for number of leaves with disease symptom. The lowest value of 0.00 was observed for AE-8, AE-32 and AE-33. The highest value of 1.71 was exhibited by AE-7. The general mean for this character was 0.94 with 20 genotypes possessing more mean value than the general mean while 16 genotypes had less mean value.

4.1.2 Genetic Variability Parameters

In the present investigation, an attempt was made to study the genetic parameters such as PCV, GCV, heritability and genetic advance for 36 okra genotypes for 10 parameters, which will help in formulating breeding strategies for okra improvement for various characters. The analysis of variance was carried out and presented in Table 7.The estimates of genetic variability parameters are presented (Table 8 and Figures 1 and 2).

4.1.2.1 Days to first flowering

Mean number of days to first flowering ranged from 36.33 to 46.53 days. Low PCV and GCV values with a narrow difference between them (8.04% and 7.82% respectively) coupled with high heritability (94.58%) and a moderate genetic advance (15.67%) was evident for this trait.

4.1.2.2 Leaf axil bearing first fruit

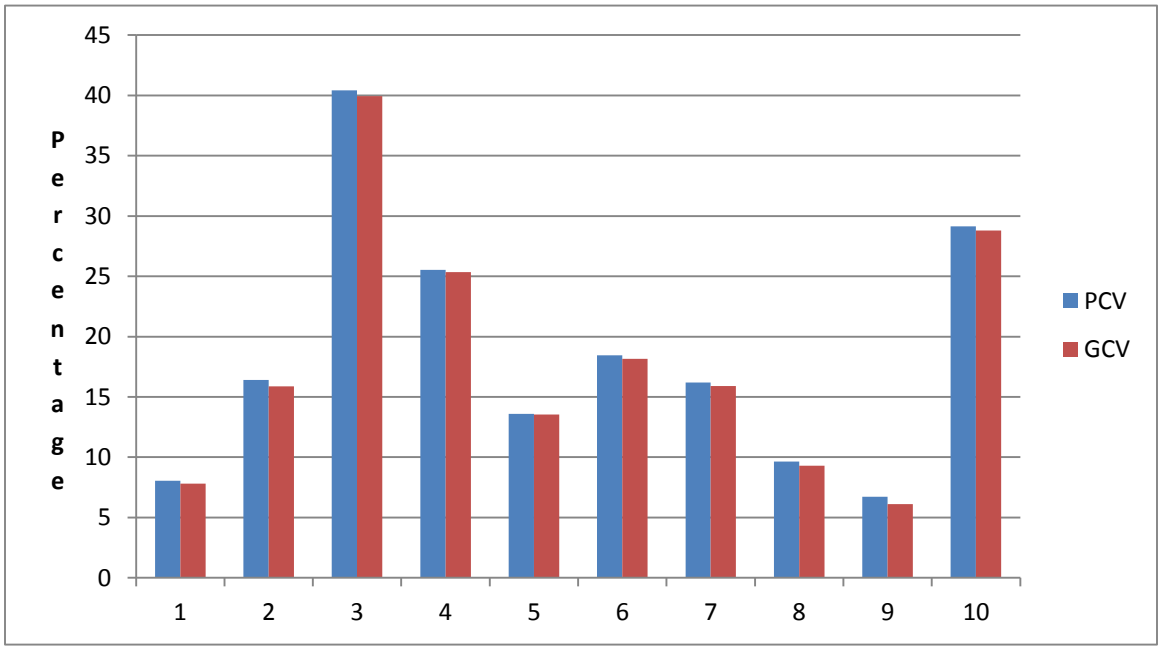
The mean value for the leaf axil bearing first fruit ranged from 4.13 to 6.73. A moderate PCV (16.41%) and GCV (15.88%) estimates coupled with higher estimate of heritability (93.24%) and genetic advance (31.65%) was recorded for this trait.

Plate 2: Variability in okra fruits

Table 8. Estimates of variability parameters for various characters of okra genotypes

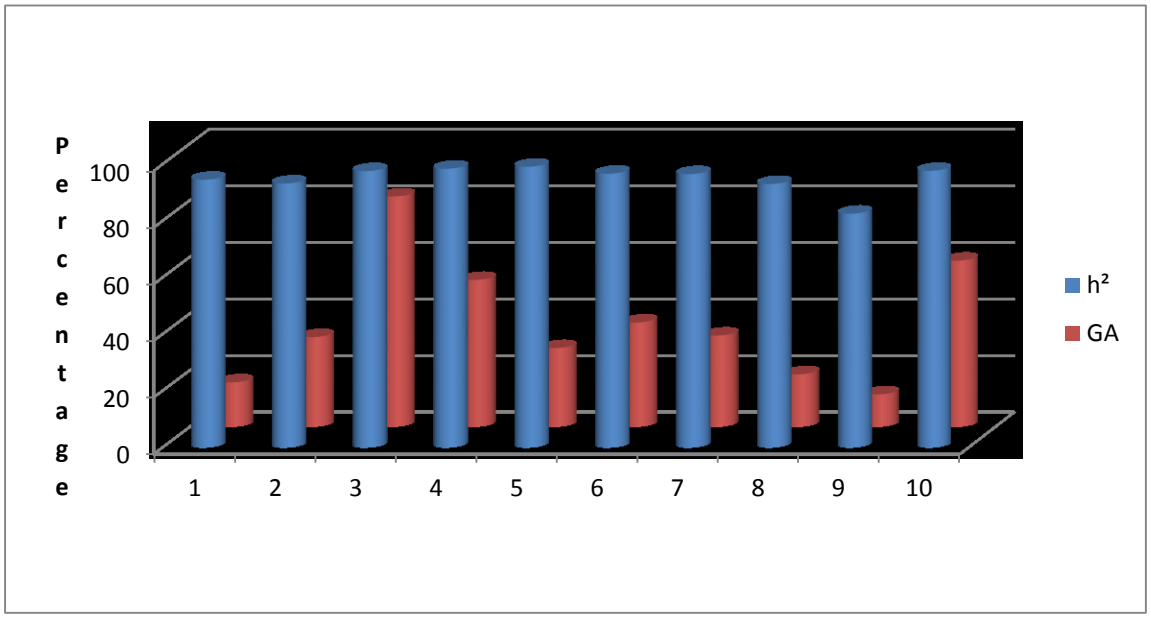
Characters	Mean	Range Min - Max	PCV	GCV	h^2	GA as % mean
Days to first flowering	41.00	36.33-46.53	8.04	7.82	94.58	15.67
Leaf axil bearing first fruit	5.24	4.13-6.73	16.41	15.88	93.24	31.65
Number of primary branches	2.08	1.00-4.26	40.43	39.95	97.61	81.30
Plant height (cm)	96.73	45.73-138.40	25.54	25.35	98.47	51.82
Duration (days)	95.94	80.26-128.06	13.59	13.53	99.17	27.76
Number of fruits per plant	16.10	10.13-23.26	18.46	18.15	96.69	36.78
Fruit weight (g)	14.26	9.60-20.86	16.18	15.90	96.56	32.19
Fruit length (cm)	13.09	9.23-16.09	9.64	9.30	93.08	18.51
Fruit girth (cm)	6.46	5.32- 7.36	6.72	6.11	82.59	11.44
Yield per plant (g)	231.27	127.96-482.93	29.13	28.79	97.71	58.63

Fig.1 PCV (%) and GCV (%) for various characters of okra genotypes



1. Days to first flowering
2. Leaf axil bearing first fruit
3. Number of primary branches
4. Plant height (cm)
5. Duration (days)
6. Number of fruits per plant
7. Fruit weight (g)
8. Fruit length (cm)
9. Fruit girth (cm)
10. Yield per plant

Fig.2 Heritability (%) and Genetic Advance (%) for various characters of okra genotypes



1. . Days to first flowering
2. Leaf axil bearing first fruit
3. Number of primary branches
4. Plant height (cm)
5. Duration (days)
6. Number of fruits per plant
7. Fruit weight (g)
8. Fruit length (cm)
9. Fruit girth (cm)
10. Yield per plant

4.1.2.8 Fruit length

The PCV (9.64%) and GCV (9.30%) values were low for fruit length but a high estimate of heritability (93.08%) and moderate genetic advance as per cent mean (18.51%) was recorded. The length of the fruits ranged from 9.23 to 16.09 cm.

4.1.2.9 Fruit girth

Mean fruit girth ranged from 5.32 to 7.36 cm. For this trait also, the PCV (6.72%) and GCV (6.11%) estimates were low and a high estimates of heritability (82.59%) and moderate genetic advance as per cent mean (11.44%) were noticed.

4.1.2.10 Yield per plant

Greater variability was evident by a wide range (127.96 to 482.93 g) noticed for this trait. The estimates of PCV (29.13%) and GCV (28.79%) were high coupled with a higher estimate of heritability (97.71%) and high genetic advance as percent mean (58.63%) for this trait.

In general, there was a narrow difference between GCV and PCV for all characters studied.

4.1.3 Correlation analysis

The correlation coefficients were worked out on all possible combinations among the characters under study at phenotypic and genotypic levels and the results pertaining to character association is presented in Tables 9and 10.

The association of yield per plant at both genotypic and phenotypic level exhibited a significant positive correlation for number of fruits per plant (0.7939 and 0.7921), fruit weight (0.7840 and 0.7801), fruit girth (0.4829 and 0.4305) and number of primary branches (0.3524 and 0.3490).

4.1.3.1. Days to first flowering

Days to first flowering showed a high positive and significant genotypic correlation with fruit length (0.7780) and leaf axil bearing first fruit (0.751) whereas a significant negative association was noticed with crop duration (-0.2878) at genotypic level. However, days to first flowering manifested a significant negative association (-0.2764) with the trait crop duration at phenotypic level.

4.1.3.2. Leaf axil bearing first fruit

Leaf axil bearing first fruit had positive significant correlations with days to first flowering (0.751) and number of leaves with disease symptom (0.3105) at genotypic level. A negative and significant correlation was noticed with duration (-0.2587 and -0.2532 respectively) at both genotypic and phenotypic level.

4.1.3.3. Number of primary branches

Number of primary branches per plant exhibited positive significant correlation with number of fruits per plant (0.3703 and 0.3661 respectively) and yield per plant (0.3524 and 0.3490 respectively) at both genotypic and phenotypic levels.

4.1.3.4. Plant height

It could be observed that, plant height exhibited positive and significant association with duration (0.5808) at genotypic level. A significant negative association was noticed with number of white flies on leaves (-0.8019) at genotypic level. The plant height (0.5752) manifested a significant positive association with duration and significant negative association noticed with number of leaves with disease symptom (-0.3673) and number of white flies on leaves (-0.2726) at phenotypic level.

Table 9. Genotypic correlations among various characters of okra

	DFF	LBFF	NPB	PH	DR	NFPP	FW	FL	FG	YPP	NWL	NLDS
DFF	**1**											
LBFF	0.751**	**1**										
NPB	-0.0225	-0.0194	1									
PH	0.0356	0.1315	-0.0254	**1**								
DR	-0.2878*	-0.2587*	-0.0822	0.5808**	**1**							
NFPP	0.0802	-0.0080	0.3703**	0.0741	-0.0828	1						
FW	0.1791	-0.1085	-0.1932	0.0525	0.0857	0.2617*	**1**					
FL	0.7780**	-0.1225	-0.0431	-0.2188	-0.1166	-0.0956	0.4408**	**1**				
FG	-0.1420	-0.1732	0.1829	-0.1237	0.0743	0.4123**	0.4008**	0.0946	**1**			
YPP	0.1795	-0.0577	0.3524**	0.0724	-0.0006	0.7939**	0.7840**	0.1979	0.4829**	**1**		
NWL	-0.1697	0.2292	0.1576	-0.8019**	-0.3789**	-0.1471	-0.1173	-0.3436**	0.1347	-0.1608	**1**	
NLDS	-0.0032	0.3105**	0.0233	-0.1933	-0.4490**	-0.0533	-0.2119	-0.3805**	-0.0255	-0.1441	1.0672**	**1**

* & ** indicates significant at 5% and at 1% level respectively

DFF = Days to first flowering
LBFF= Leaf axil bearing first fruit
NPB = Number of primary branches
PH = Plant height (cm)
DR = Duration
NFPP= Number of fruits per plant
FW = Fruit Weight (g)
FL= Fruit length (cm)
FG = Fruit girth (cm)
YPP= Yield per plant (g)

Table 10. Phenotypic correlations among various characters of okra

	DFF	LBFF	NPB	PH	DR	NFPP	FW	FL	FG	YPP	NWL	NLDS
DFF	1											
LBFF	0.0685	**1**										
NPB	-0.0158	0.0132	1									
PH	0.0401	0.1316	-0.0239	**1**								
DR	-0.2764*	-0.2532*	-0.0785	0.5752**	**1**							
NFPP	0.0799	-0.0117	0.3661**	0.0737	-0.0799	1						
FW	0.1719	-0.0963	0.1893	0.0537	0.0830	0.2539*	**1**					
FL	0.1846	-0.1179	-0.0398	-0.2091	-0.1126	-0.0944	0.4171**	**1**				
FG	-0.1439	-0.1597	0.1634	-0.1112	0.0705	0.3582**	0.3640**	0.0906	**1**			
YPP	0.1759	-0.0515	0.3490**	0.0733	0.0008	0.7921**	0.7801**	0.1858	0.4305**	**1**		
NWL	-0.0939	0.1760	0.0943	-0.2726*	-0.2426*	-0.1018	-0.0949	-0.1691	0.0492	-0.1221	**1**	
NLDS	-0.0095	0.2213	0.0121	-0.3673**	-0.3171**	-0.0227	-0.1208	-0.2367	-0.0408	-0.0790	0.5422**	**1**

* & ** indicates significant at 5% and at 1% level respectively

DFF = Days to first flowering
LBFF= Leaf axil bearing first fruit
NPB = Number of primary branches
PH = Plant height (cm)
DR = Duration
NFPP= Number of fruits per plant
FW = Fruit Weight (g)
FL= Fruit length (cm)
FG = Fruit girth (cm)
YPP= Yield per plant (g)

4.1.3.5. Duration

The association between duration and plant height was positive and significant (0.5808) and a significant negative association with number of leaves with disease symptom (-0.4490), number of white flies on leaves (-0.3789), days to first flowering (-0.2878) and leaf axil bearing first fruit (-0.2587) at genotypic levels. The trait had a significant positive correlation with plant height (0.5752) and significant negative correlation for number of leaves with disease symptom (-0.3171), days to first flowering (-0.2764), leaf axil bearing first fruit (-0.2532) and number of white flies on leaves (-0.2426) at phenotypic level.

4.1.3.6. Number of fruits per plant

Number of fruits per plant had highly significant positive correlation with yield per plant (0.7939 and 0.7921, respectively), fruit girth (0.4123 and 0.3582, respectively), number of primary branches (0.3703 and 0.3661, respectively), and fruit weight (0.2617 and 0.2539, respectively) at both genotypic and phenotypic levels.

4.1.3.7. Fruit weight

At both genotypic and phenotypic levels, the fruit weight manifested highly significant positive association with yield per plant (0.7840 and 0.7801, respectively), fruit length (0.4408 and 0.4171), and fruit girth (0.4008 and 0.3640, respectively) and number of fruits per plant (0.2617 and 0.2539, respectively).

4.1.3.8. Fruit length

The length of fruit showed significant association with many characters such as, a positive significant association with days to first flowering (0.7780) and fruit weight (0.4408) and a significant negative correlation with number of leaves with disease symptom (-0.3805) and number of white flies on leaves (-0.3436) at

genotypic level. A significant positive correlation was reported for fruit weight (0.4171) at phenotypic level.

4.1.3.9. Fruit girth

Fruit girth exhibited a significant positive correlation with number of fruits per plant (0.4123 and 0.3582, respectively) and fruit weight (0.4008 and 0.3640, respectively) at both genotypic and phenotypic levels.

4.1.3.10. Number of white flies on leaves

Number of white flies on leaves had significant negative correlation with plant height (-0.8019), duration (-0.3789) and fruit length (-0.3436) at genotypic level and significant positive correlation with number of leaves with disease symptom (0.5422) and negative correlation with plant height (-0.276) and duration (-0.2426) at phenotypic level respectively.

4.1.3.11. Number of leaves with disease symptom

It could be observed that, at genotypic level, the trait exhibited significant positive association with number of white flies on leaves (1.0672) and leaf axil bearing first fruit (0.3105) respectively and significant negative association with duration (-4490) and fruit length (-0.3805). At phenotypic level, the trait had significant positive correlation with number of white flies on leaves (0.5422) and negative association with plant height (-0.3673).

4.1.4 Scoring for Virus Resistance

All the 36 genotypes of okra were screened for reaction to yellow vein mosaic disease, and classified based on the scale given by Rajamony *et al*. (1990). The per cent vulnerability index (V.I) and the range of score are given in Table 11.

Plate 3: Symptoms of YVM

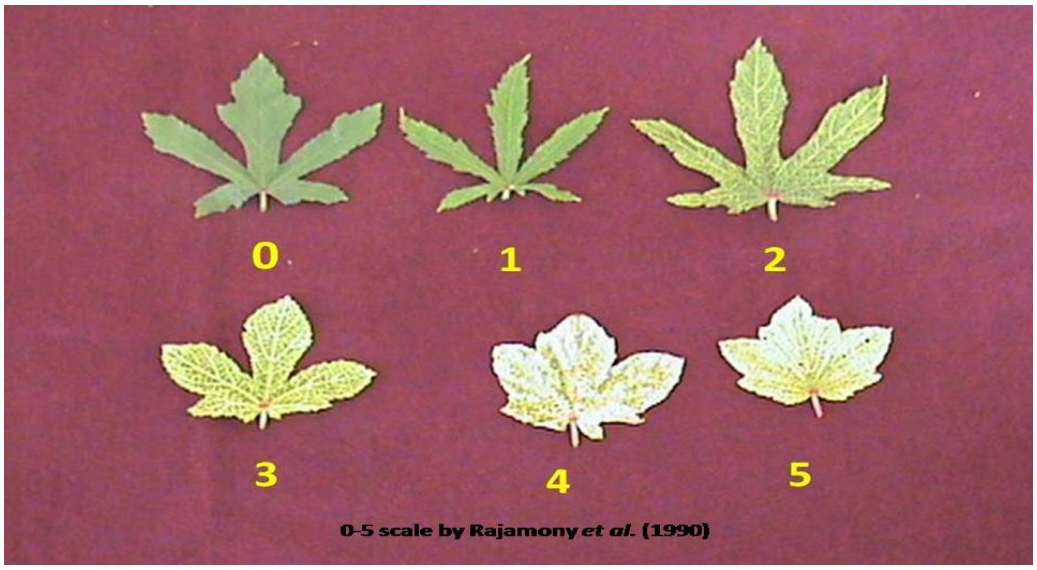


Plate 4: Okra YVM rating scale (0-5) proposed by Rajamony *et al.* (1990)

Table 11. Scoring for yellow vein mosaic virus resistance

	30 DAS				50 DAS				70 DAS			
Genotypes	No of plants	V.I	Range of score	Reaction	No of plants	V.I	Range of score	Reaction	No of plants	V.I	Range of score	Reaction
AE-1	15	0.00	0	HR	15	37.33	1-2	MR	15	44.00	2-3	MR
AE-2	15	0.00	0	HR	15	0	0	HR	15	4.00	0-1	R
AE-3	15	20.00	1	R	15	69.33	3-4	MS	15	74.66	3-4	S
AE-4	15	0.00	0	HR	15	41.33	2-3	MR	15	44.00	2-3	MR
AE-5	15	20.00	1	R	15	41.33	2-3	MR	15	44.00	2-3	MR
AE-6	15	20.00	1	R	15	21.33	1-2	R	15	54.66	2-3	MS
AE-7	15	57.00	2-3	MS	15	100	5	HS	15	100	5	HS
AE-8	15	0.00	0	HR	15	0.00	0	HR	15	0.00	0	HR
AE-9	15	0.00	0	HR	15	14.66	0-1	R	15	42.6	2-3	MR
AE-10	15	0.00	0	HR	15	1.33	0-1	R	15	37.33	1-2	MR
AE-11	15	20.00	1	R	15	48.00	2-3	MR	15	81.33	4-5	S
AE-12	15	20.00	1	R	15	72.00	3-4	S	15	100	5	HS
AE-13	15	20.00	1	R	15	45.3	2-3	MR	15	46.66	2-3	MR
AE-14	15	0.00	0	HR	15	20.00	1	R	15	58.66	2-3	MS
AE-15	15	25.00	1-2	R	15	50.66	2-3	MS	15	57.33	2-3	MS
AE-16	15	0.00	0	HR	15	1.33	0-1	R	15	24.00	1-2	R
AE-17	15	28.57	1-2	R	15	57.33	2-3	MS	15	77.33	3-4	S
AE-18	15	20.00	1	R	15	31.42	1-2	MR	15	51.33	2-3	MS
AE-19	15	20.00	1	R	15	60.00	3	MS	15	20.00	1	R

AE-20	15	0.00	0	HR	15	18.66	0-1	R	15	36.00	1-2	MR
AE-21	15	0.00	0	HR	15	16.00	0-1	R	15	40.00	2	MR
AE-22	15	20.00	1	R	15	48.00	2-3	MR	15	76.00	3-4	S
AE-23	15	0.00	0	HR	15	20.00	1	R	15	40.00	2	MR
AE-24	15	0.00	0	HR	15	20.00	1	R	15	38.66	1-2	MR
AE-25	15	20.00	1	R	15	52.00	2-3	MS	15	64.00	3-4	MS
AE-26	15	4.70	0-1	R	15	26.66	1-2	R	15	37.33	1-2	MR
AE-27	15	0.00	0	HR	15	13.3	0-1	R	15	37.33	1-2	MR
AE-28	15	0.00	0	HR	15	0.00	0	HR	15	20.00	1	R
AE-29	15	1.66	0-1	R	15	16.00	0-1	R	15	40.00	2	MR
AE-30	15	5.00	0-1	R	15	28.66	1-2	R	15	86.66	4-5	S
AE-31	15	20.00	1	R	15	33.33	1-2	MR	15	57.33	2-3	MS
AE-32	15	0.00	0	HR	15	0.00	0	HR	15	0.00	0	HR
AE-33	15	0.00	0	HR	15	0.00	0	HR	15	1.33	0-1	R
AE-34	15	23.33	1-2	R	15	54.66	2-3	MS	15	65.33	3-4	MS
AE-35	15	28.88	1-2	R	15	77.33	3-4	S	15	86.66	4-5	S
AE-36	15	20.00	1	R	15	40.00	2	MR	15	54.66	2-3	MS

0-no symptom (HR)
1-Resistant (R)
2-Medium resistant (MR
3-Medium susceptible (MS)
4- Susceptible (S)
5- Highly susceptible (HS)

a. 30 DAS

At 30 DAS, sixteen genotypes did not show any disease symptoms (Highly Resistant) while nineteen genotypes exhibited resistant reaction to the disease, as evident from Table 7.Only one genotype (AE 7) showed medium susceptibility to YVM with the highest vulnerability index (57.00 per cent).

b. 50 DAS

When the crop was at 50 days, only five genotypes had no symptom (Highly Resistant) while thirteen genotypes were resistant and medium resistant reaction was shown by nine genotypes. Medium susceptible reaction to YVM was noticed for six genotypes whereas two genotypes came in the category susceptible and one genotype showed highly susceptible reaction to YVM.

c. 70 DAS

At 70 DAS, only two genotypes were without symptom (Highly Resistant). Resistant and medium resistant reactions were shown by five and thirteen genotypes respectively. Medium susceptible reaction was noticed for eight genotypes whereas six genotypes were susceptible and two genotypes proved highly susceptible.

Out of 36 germplasm accessions screened for YVMV incidence, only five genotypes *viz.,* AE-2, AE-8, AE-28, AE-32 and AE-33 exhibited 0-1 range of score and showed resistance to YVMV during all the crop stages. These five genotypes were screened for confirmation of disease through vector and graft transmission studies.

4.2 EXPERIMENT II – CONFIRMATION STUDIES FOR DISEASE RESISTANCE

All the five resistant genotypes of okra were screened for reaction to yellow vein mosaic disease under glass house condition and classified based on the scale

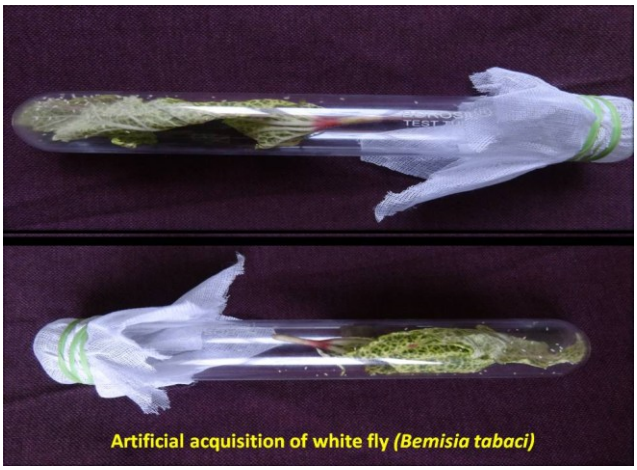


Plate 5: Artificial acquisition of white flies

Plate 6: Vector (white fly) transmission

Plate 7: Graft transmission

	Vector transmission				Graft transmission			
Genotypes	No of plants	V.I	Range of score	Reaction	No of plants	V.I	Range of score	Reaction
AE-2	10	0.00	0	HR	10	4.00	0-1	R
AE-8	10	0.00	0	HR	10	0.00	0	HR
AE-28	10	20.00	1	R	10	20.00	1	R
AE-32	10	0.00	0	HR	10	0.00	0	HR
AE-33	10	0.00	0	HR	10	0.00	0	HR

Table 12. Vulnerability index and disease score (Experiment II)

0-no symptom (HR)

1-Resistant (R)
2-Medium resistant (MR)
3-Medium susceptible (MS)
4-Suceptible (S)
5-Highly susceptible (HS)

given by Rajamony *et al*. (1990). The per cent vulnerability index (V.I) and the range of score is given in Table 12.

4.2.1. Vector transmission

Among the five genotypes, no symptom (Highly Resistant) was exhibited by 4 types *viz.,* AE-2, AE-8, AE-32, AE-33 while AE-28 showed resistant reaction to YVM disease with a vulnerability index of 20.00.

4.2.2. Graft transmission

The three genotypes *viz.,* AE-8, AE-32 and AE-33 showed no symptom of the disease (Highly Resistant).However, resistant group included two genotypes *viz.,* AE-2 and AE-28. Out of five genotypes used in transmission studies for confirmation of disease resistance under glass house condition, only one genotype (AE-28) exhibited resistant reaction at both vector and graft transmission studies while AE-2 showed resistant reaction only in graft transmission studies. The genotype AE-8, AE-32 and AE-33 did not showed any disease symptom in both vector and graft transmission studies.

4.3 EXPERIMENT III- EVALUATION OF F_1'S

4.3.1 Line x tester analysis

Fifteen F_1 hybrids derived from five resistant lines and three high yielding susceptible testers were evaluated using Line x Tester analysis with one check variety (Varsha Upahar).Significant variation was observed among treatments for all the characters (Table13). Line x tester interaction mean squares was significant for all the characters. Lines varied significantly for days to first flowering and fruit girth while testers exhibited non-significant variation for all 10 characters. The results obtained in the investigation are presented under following subheadings.

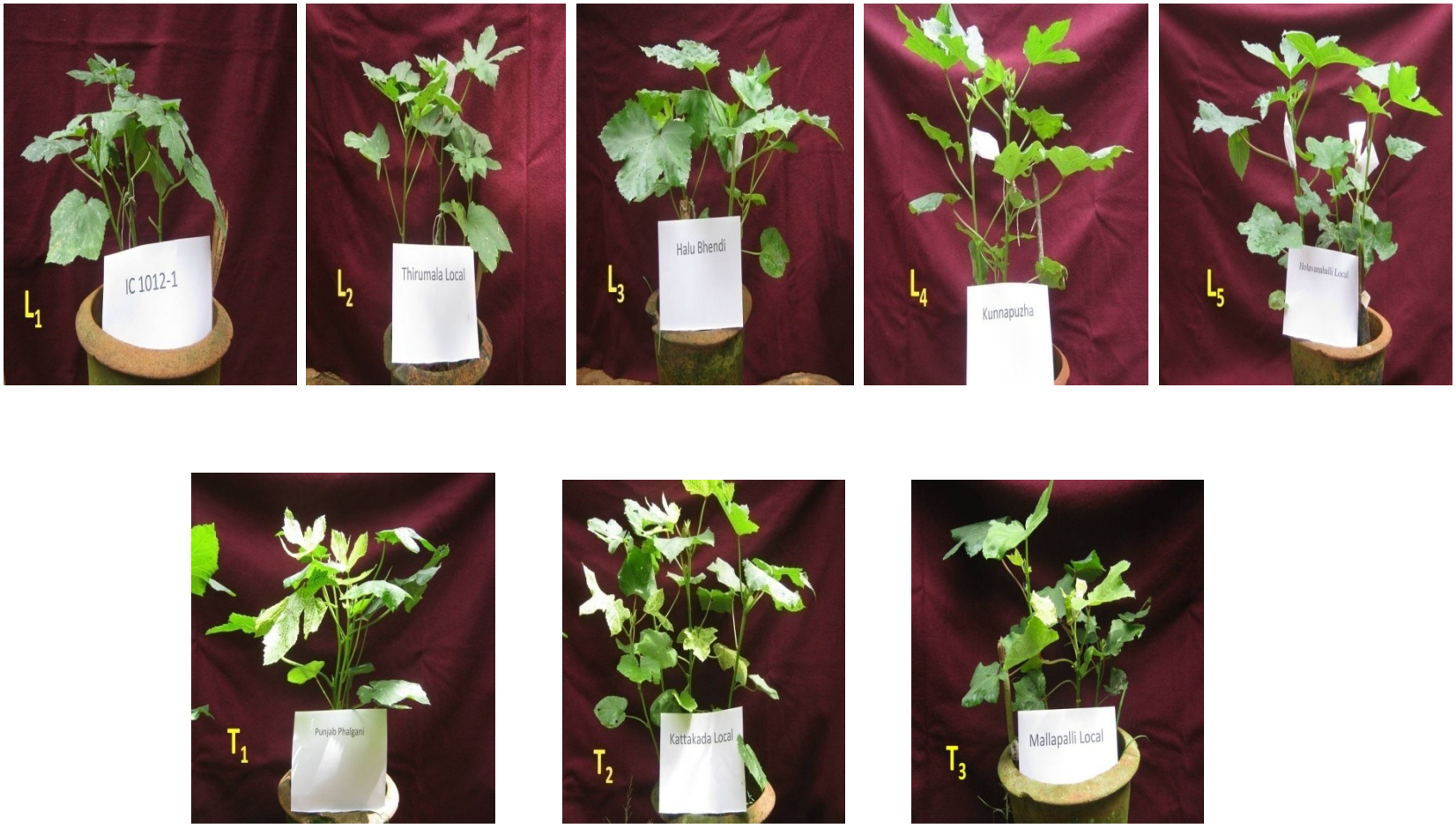


Plate 8: Selected lines and tester

Table 13. ANOVA for line x tester analysis in okra

Source	Df	Mean square									
		Days to first flower	Leaf axil bearing first fruit	Number of primary branches	Plant height (cm)	Duration	Number of fruits per plant	Fruit weight	Fruit length	Fruit girth	Yield per plant (g)
Replication	2	0.35	0.63	0.45	25.62	13.60	7.37	0.27	8.20	0.10	14.25
Treatment	22	29.52**	3.51**	1.18**	484.59**	244.53**	59.87**	24.78**	14.20**	1.35**	45057.12**
Lines	4	86.46**	0.15	0.83	45.49	37.53	42.81	41.70	18.69	4.32**	48816.00
Testers	2	13.99	3.48	1.69	339.81	17.67	14.03	0.66	0.66	0.85	8173.25
Lines x testers	8	7.28**	6.10**	0.72**	193.84**	53.35**	79.17**	31.56**	11.13**	0.74**	63871.47**
Error	44	0.79	0.30	0.18	11.20	4.57	0.39	0.21	0.75	5.72	142.69

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

Plate 9: General view of the F1 evaluation field

4.3.1.1 Per se performance of parents and hybrids

Per se performance of five lines, three testers and their fifteen hybrids with respect to ten characters is presented in Tables 14 and 15.

4.3.1.1.1 Days to first flowering

The earliest flowering line and tester were L_5 and T_1 (39. 6 days and 40. 6 days respectively) while L_3 (46. 93 days) and T_3 (47.46 days) took maximum days for flowering within their respective groups. Among the hybrids, minimum days for flowering was observed for the cross, L_2 x T_1 (40. 2 days) which was on par with L_5 x T_3, L_1 x T_2, L_2 x T_2 and L_5 x T_1 whereas the maximum days was recorded for L_3 x T_3 (50.8 days).

4.3.1.1.2 Leaf axil bearing first fruit

L_1 (4.93) and L_4 (7.06) possessed the lowest and the highest number of leaf axils bearing first fruit respectively among lines while it was T_1 and T_3 among testers (4.60 and 6.33) respectively. Minimum value for this trait among hybrids was observed for L_3 x T_3 (3.53) and it was on par with L_5 x T_1, L_4 x T_1, L_1 x T_1, L_2 x T_1 and L_3 x T_2 where as maximum value was exhibited by L_3 x T_1 (7.00) which was on par with L_5 x T_3.

4.3.1.1.3 Number of primary branches

The number of primary branches produced by the plant was maximum for L_2 (2.73) and minimum for L_3 (1.13) among lines while these positions among testers were occupied by T_2 (3.33) and T_1 (2.2) respectively. The highest number of primary branches was noticed for L_5 x T_3 (3.1) which was homogeneous with L_3 x T_2, L_1 x T_2 and L_4 x T_2 among hybrids while the lowest value was recorded for three hybrids viz.,L_1 x T_3, L_3 x T_1 and L_3 x T_3 (1.33) which was on par with L_2 x T_3, L_4 x T_3, L_2 x T_1 and L_5 x T_1.

4.3.1.1.4 Plant height

Minimum and maximum values of plant height were observed respectively for L_1 (85.4 cm) and L_4 (126 cm) among lines and for T_1 (90 cm) and T_2 (116.33 cm) among testers. When the hybrids were considered, the lowest plant height was recorded for L_5 x T_2 (83.33 cm) which was on par with hybrids viz., L_3 x T_1, L_1 x T_2, L_4 x T_3, L_5 x T_1, L_1 x T_1, L_2 x T_1 and L_3 x T_2 and the highest plant height was in L_5 x T_3 (113.26 cm).

4.3.1.1.5 Duration

Duration was the shortest and longest for L_1 (90.06 days) and L_5 (114 days) among lines, T_2 (82 days) and T_1 (88.33 days) among testers and L_5 x T_2 (74.00 days) and L_4 x T_1 (85.87 days) among hybrids respectively.

4.3.1.1.6 Number of fruits per plant

Among lines, the highest and the lowest number of fruits per plant was noticed for L_5 (17.93) and L_2 (11.4) respectively. T_3 (24.66) and T_1 (18.2) produced the maximum and minimum number of fruits among testers and the best hybrid with respect to fruit production was L_5 x T_3 (25.96) whereas the lowest producer was L_4 x T_3 (9.5) which was on par with L_5 x T_1 and L_3 x T_1.

4.3.1.1.7 Fruit weight

The maximum fruit weight among the lines was obtained in L_4 (16.13 g) while minimum fruit weight was in L_1 (13.02 g). Among testers, T_3 (20.73 g) and T_2 (17.06 g) possessed the maximum and minimum values within their group. Fruit weight among hybrids was highest for L_5 x T_3 (24.00 g) while it was lowest for L_3 x T_3 (10.6 g).

Table 14. *Per se* performance of parents for various characters in okra

Parents	Days to first flowering	Leaf axil bearing first fruit	Number of primary branches	Plant height (cm)	Duration (days)	Number of fruits per plant	Fruit weight (g)	Fruit length (cm)	Fruit girth (g)	Yield per plant (g)
Lines										
L_1	41.13	4.93	2.22	85.4	90.06	14.8	13.02	14.35	6.31	192.93
L_2	42.00	5.86	2.73	120.66	94.33	11.4	15.66	15.86	6.36	179.27
L_3	46.93	5.16	1.13	104	101.2	15.13	15.46	13.42	5.80	233.85
L_4	46.13	7.06	2.53	126	97.66	13.93	16.13	12.66	6.00	225.34
L_5	39.6	5.46	1.6	114	114	17.93	15.66	17.80	5.92	281.14
SE	0.29	0.18	0.14	1.11	0.71	0.21	0.15	0.28	7.97	3.98
CD 5%	0.84	0.52	0.40	3.18	2.03	0.59	0.44	0.82	0.22	11.35
Testers										
T_1	40.6	4.6	2.2	90	88.33	18.2	19.43	12.52	6.65	355.2
T_2	45.46	6.33	3.33	116.33	82	20.06	17.06	13.50	7.00	342.16
T_3	47.46	6.00	3.26	101	82.33	24.66	20.73	13.53	6.62	502.03
SE	0.22	0.14	0.10	0.86	0.55	0.16	0.11	0.22	6.17	3.08
CD 5%	0.65	0.40	0.31	2.46	1.57	0.46	0.34	0.63	0.17	8.79

Table 15. *Per se* performance of okra hybrids for various characters

Hybrids	Days to first flowering	Leaf axil bearing first fruit	Number of primary branches	Plant height (cm)	Duration (days)	Number of fruits per plant	Fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Yield per plant (g)
L_1xT_1	42	3.80	2.06	88	74.62	11.33	14.13	13.88	4.86	160.28
L_1xT_2	41.2	5.93	2.6	85.46	77.57	11.93	15.08	16.02	5.23	179.16
L_1xT_3	44.66	5.03	1.33	91.33	84.44	11.66	15.66	16.62	5.08	182.80
L_2xT_1	40.2	4.00	2.00	88.26	84.58	16.21	17.76	19.00	6.4	288.63
L_2xT_2	41.53	5.66	2.13	94.00	84.34	20.14	20.8	20.00	7.14	414.96
L_2xT_3	43.6	5.49	1.73	95.73	83.81	14.2	18.93	17.66	7.00	265.69
L_3xT_1	47.86	7.00	1.33	85.33	81.33	10.53	16.02	17.60	5.4	168.9
L_3xT_2	46.56	4.07	2.43	88.33	83.46	12.27	16.2	15.66	5.54	198.34
L_3xT_3	50.8	3.53	1.33	98.95	78.53	14.66	10.6	15.53	7.02	155.48
L_4xT_1	45.97	3.73	2.33	94.73	85.87	18.13	20.06	16.01	6.22	362.33
L_4xT_2	48.33	5.11	2.93	94.8	81.8	14.74	17.00	16.25	5.2	251.06
L_4xT_3	46.98	5.87	1.73	86.13	79.46	9.5	15.13	13.46	5.96	141.2
L_5xT_1	41.54	3.7	2.00	86.33	81.22	10.15	15.26	14.62	6.60	155.08
L_5xT_2	43.78	4.93	2.26	83.33	74.00	11.27	16.2	15.00	6.46	182.35
L_5xT_3	41.13	6.93	3.1	113.26	85.7	25.96	24.00	19.66	6.54	621.66
SE	0.51	0.32	0.24	1.93	1.23	0.36	0.26	0.50	0.13	6.89
CD 5%	1.46	0.91	0.69	5.50	3.52	1.03	0.76	1.43	0.39	19.66

4.3.1.1.8 Fruit length

The lines which produced the longest and the shortest fruits were L_5 (17.80 cm) and L_4 (12.66 cm) respectively while among testers, these positions were occupied by T_2 (13.53 cm) and T_1 (12.52 cm), respectively. Fruit length among the hybrids was maximum for L_2 x T_2 (20.00 cm), which was on par with L_2 x T_1 and L_5 x T_3 and minimum observed was for L_4 x T_3 (13.46 cm) which was homogeneous with L_1x T_1 and L_5 x T_1 .

4.3.1.1.9 Fruit girth

The highest fruit girth was recorded for L_2 (6.36 cm) while it was lowest for L_3 (5.80 cm). Among testers, T_2 (7.00 cm) and T_3 (6.62 cm) possessed the highest and the lowest value for this character, respectively. The hybrid with maximum fruit girth (7.14cm) was L_2 x T_2 while minimum fruit girth was displayed by L_1 x T_1 (4.86 cm) which was on par with L_1 x T_2, L_1 x T_3 and L_4 x T_2.

4.3.1.1.10 *Yield per plant*

The best yielding line and tester were L_5 (281.14 g) and T_3 (502.03 g) respectively while L_2 (179.27 g) and T_2 (342.16 g) were the lowest yielders among their respective groups. Yield among the hybrids was maximum for L_5 x T_3 (621.66 g) whereas the minimum yield was in L_4 x T_3 (141.2 g) which was homogeneous with L_5 x T_1, L_3 x T_3 and L_1 x T_1.

4.3.1.2 Combining Ability

4.3.1.2.1 Combining ability variance

The GCA and SCA variance have been worked out and presented in Table 16. Variance due to SCA was observed to be more than the variance due to GCA for all the characters except days to first flowering and fruit girth.

Table 16 Magnitude of combining ability variances and proportional contribution of lines, testers and hybrids to total variance

Character	Variance (σ^2) of GCA	Variance(σ^2) of SCA	σ^2GCA / σ^2SCA	Proportional contribution %		
				Lines (l)	Testers (t)	Hybrids (l x t)
Days to first flower	3.53	2.16	1.63	80.04	6.47	13.48
Leaf axil bearing first fruit	0.35	1.93	0.18	1.10	12.34	86.54
Number of primary branches	0.045	0.18	0.25	26.64	27.00	46.35
Plant height (cm)	0.09	60.87	0.0014	7.54	28.17	64.28
Duration (days)	2.14	16.26	0.13	24.52	5.77	69.70
Number of fruits per plant	4.22	26.25	0.16	20.56	3.37	76.06
Fruit weight (g)	0.86	10.44	0.08	39.66	0.29	60.03
Fruit length (cm)	0.12	3.46	0.03	45.26	0.80	53.92
Fruit girth (cm)	0.95	0.22	4.31	69.23	6.84	23.91
Yield per plant (g)	2948.07	21242.93	0.14	27.02	2.26	70.71

4.3.1.2.2 Combining ability effects

The estimates of general combining ability (*gca*) effects of lines and testers are presented in Table17 and figures 3 and 4 and specific combining ability (*sca*) effects of hybrids are furnished in Table18 and figure 5.

4.3.1.2.2.1 Days to first flowering

Among the lines, significant negative *gca* effects were observed for L_1 (-1.79), L_2 (-2.63) and L_5 (-2.25) whereas positive significant *gca* effects were expressed by L_3 (3.99) and L_4 (2.68). In the tester group, significant negative effect was shown by T_1 (-0.89) and a positive significance by T_3 (1.02). Significant positive *sca* effects were exhibited by L_4 x T_1 (1.75), L_3 x T_3 (1.36) and L_5 x T_1 (1.36) whereas significant negative *sca* effects were noticed for L_5 x T_3 (-2.04), L_3 x T_2 (-1.71), L_2 x T_3 (-1.29) and L_5 x T_2 (-1.13).

4.3.1.2.2.2 Leaf axil bearing first fruit

None of the lines possessed significant *gca* effects but significant *gca* effects were exhibited by two testers *viz.*, T_3 (1.02) and T_1 (-0.89) among the testers. Significant positive *sca* effects were exhibited by L_1 x T_3 (2.67), L_5 x T_3 (1.35) and L_2 x T_3 (0.85) whereas significant negative *sca* effects were expressed by L_5 x T_1 (-1.72), L_3 x T_2 (-0.95) and L_2 x T_2 (-0.94).

4.3.1.2.2.3 Number of primary branches

Among the five lines, significant positive *gca* effects was exhibited by L_5 (0.36) while L_3 (-0.38) had negative values. In the tester group, T_2 (0.38) and T_3 (-0.24), had significant *gca* effects. Positive significant *sca* effects were observed for L_4 x T_3 (1.97) and L_5 x T_3 (0.88) and whereas negative significant *sca* effects were expressed by L_4 x T_1 (-0.57).

Table 17. General combining ability effect of okra parents for ten characters

Parents	Days to first flowering	Leaf axil bearing first fruit	Number of primary branches	Plant height (cm)	Duration (days)	Number of fruits per plant	Fruit weight (g)	Fruit length (cm)	Fruit girth (cm)	Yield per plant (g)
Lines										
L_1	-1.79**	-6.40	-8.86	-3.33**	-2.50**	-2.53**	-1.89**	-0.95**	-0.98**	-74.44**
L_2	-2.63**	6.48	-0.13	1.06	2.86**	2.66**	2.30**	2.42**	0.80**	74.56**
L_3	3.99**	-0.11	-0.38**	-0.72	-0.27	-1.69**	-2.58**	-0.20	-5.68	-74.28**
L_4	2.68**	-8.17	0.24	0.28	0.99	-5.51	0.54**	-1.22**	-0.25**	3.00
L_5	-2.25**	0.20	0.36*	2.70*	-1.07	1.61**	1.63**	-4.00	0.49**	71.17**
SE	0.29	0.18	0.14	1.11	0.71	0.21	0.15	0.28	7.97	3.98
Tester										
T_1	-0.89**	-0.54**	-0.14	-3.06**	0.14	-0.90**	-0.20	-0.24	-0.14*	-21.48**
T_2	-0.12	0.15	0.38**	-2.41**	-1.14*	-0.10	0.19	0.12	-0.12*	-3.35
T_3	1.02**	0.38**	-0.24*	5.48**	1.00	1.01**	8..44**	0.12	0.27**	24.83**
SE	0.22	0.14	0.10	0.86	0.55	0.16	0.11	0.22	6.17	3.08

*- significant at 5% level

**-Significant at 1% level

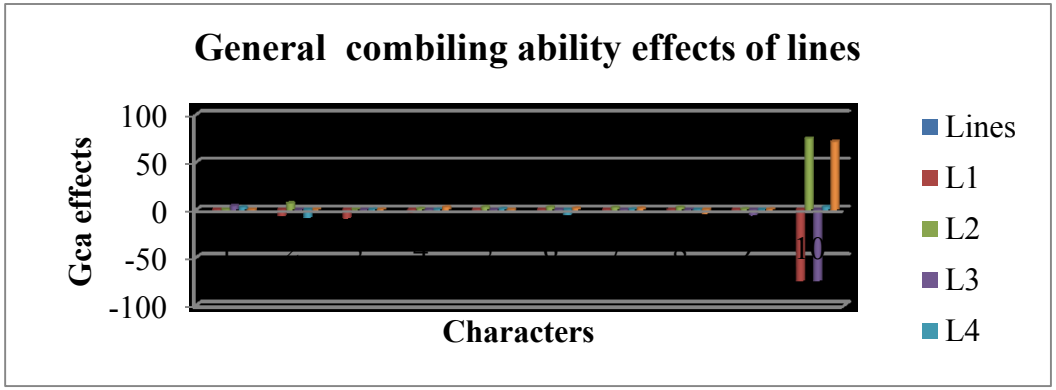


Fig.3. General combining ability effects of lines

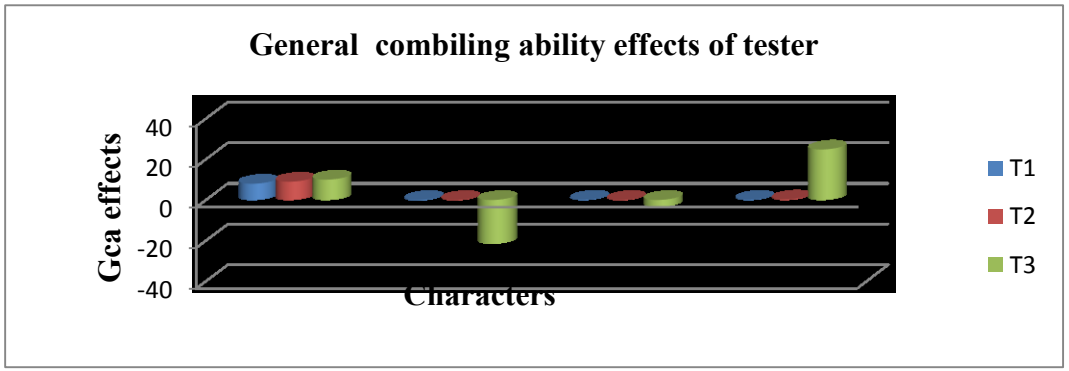


Fig.4. General combining ability effects of testers

1. Days to first flower
2. Leaf axil bearing first fruit
3. Number of primary branches
4. Plant height
5. Duration
6. Number of fruits per plant
7. Fruit weight (g)
8. Fruit length (cm)
9. Fruit girth
10. Yield per plant (g)

4.3.1.2.2.4 Plant height

Among the lines with significant *gca* effects, L_5 (2.70) had positive values while L_1 (-3.33) had negative values. In the testers, T_3 (5.48), T_1 (-3.06) and T_2 (-2.41), exhibited significant *gca* effects.

In the hybrid category, positively significant *sca* effect were observed for L_5 x T_3 (13.47) and L_2 x T_1 (5.91) whereas the *sca* effects were negatively significant for L_5 x T_2 (-11.23), L_4 x T_1 (-8.56), L_2 x T_2 (-4.90) and L_3 x T_2 (-0.12).

4.3.1.2.2.5 Duration

L_2 (2.86) and L_1 (-2.50) exhibited significant *gca* effects among the five lines for duration while T_2 (-1.14) had significant *gca* effect within the tester group. Among crosses, significant negative *sca* effects were noticed for L_4 x T_1 (-5.15), L_1 x T_1 (-4.39), L_5 x T_2 (-3.92) and L_5 x T_1 (-3.58) whereas positively significant *sca* effect were observed for L_4 x T_2 (4.55), L_5 x T_3 (4.38), L_3 x T_2 (3.50) and L_2 x T_1 (3.35).

4.3.1.2.2.6 Number of fruits per plant

Significant positive *gca* effect was noticed for the lines L_2 (2.66) and L_5 (1.61) while L_1 (-2.53) and L_3 (-1.69) had significant negative *gca* effect. In the tester group, T_3 (1.01) and T_3 (-0.90) possessed significant *gca* effects for number of fruits per plant. The *sca* effects were significant and positive for L_5 x T_3 (9.14), L_2 x T_1 (4.91), L_3 x T_1 (3.39) and L_5 x T_1 (1.15) and negative for L_5 xT_2 (-5.64), L_2 x T_2 (-4.73), L_4 x T_1 (-4.41), L_4 xT_3 (-3.66), L_1 x T_3 (-1.04) and L_4 x T_2 (-0.99).

4.3.1.2.2.7 Fruit weight

All the lines displayed significant *gca* effects and among these the highest positive value was noticed for L_2 (2.30) followed by L_5 (1.63) and L_4 (0.54) whereas

Table 18. Specific combining ability effects of okra hybrids for various vegetative and yield characters

Parents	Days to first flowering	Leaf axil bearing first fruit	Number of primary branches	Plant height (cm)	Duration (days)	Number of fruits per plant	Fruit weight (g)	Fruit length (cm)	Fruit girth (g)	Yield per plant (g)
$L_1 \times T_1$	0.27	-0.57	0.20	2.80	-4.39**	0.59	-0.62*	-1.38**	-4.75	7.68
$L_1 \times T_2$	-0.68	-0.51	0.18	-1.33	0.19	0.27	-1.19**	0.35	-0.30*	-12.97
$L_1 \times T_3$	0.35	2.67**	-0.22	-2.47	8.08	-1.04**	1.95**	1.58**	-0.44**	16.14*
$L_2 \times T_1$	-0.22	-0.63	0.14	5.91**	3.35**	4.91**	2.87**	1.01*	0.57**	132.28**
$L_2 \times T_2$	0.28	-0.94**	-0.31	-4.90*	0.77	-4.73**	-3.01**	-1.56**	0.21	-143.13**
$L_2 \times T_3$	-1.29*	0.85*	0.21	0.38	-0.16	0.39	-0.07	0.39	0.30*	8.43
$L_3 \times T_1$	-0.11	0.45	-0.20	3.74	1.24	3.39**	1.43**	0.99	0.42**	95.22**
$L_3 \times T_2$	-1.71**	-0.95**	0.34	-0.12**	3.50**	-0.10	1.72**	-0.72	-0.31*	27.45**
$L_3 \times T_3$	1.36*	5.11	0.21	5.32	0.56	0.72	-0.59*	0.88	-0.46**	2.88
$L_4 \times T_1$	1.75**	-0.41	-0.57*	-8.56**	-5.15**	-4.41**	-2.48**	-1.54**	5.20	-133.99**
$L_4 \times T_2$	1.02	-0.27	-0.42	-2.41	4.55**	-0.99*	0.69*	0.99	-0.25	-16.11*
$L_4 \times T_3$	0.79	5.51	1.97**	-2.41	-1.44	-3.66**	-0.23	-1.34**	-0.12	-82.24**
$L_5 \times T_1$	1.36*	-1.72**	-0.12	2.59	-3.58**	1.15**	-3.68**	-0.85	0.75**	-43.59**
$L_5 \times T_2$	-1.13*	0.58	-0.35	-11.23**	-3.92**	-5.64**	-2.27**	-1.90**	-0.11	-135.17**
$L_5 \times T_3$	-2.04**	1.35**	0.88**	13.47**	4.38**	9.14**	5.50**	3.11**	-0.26	277.12**
SE	0.51	0.32	0.24	1.93	1.23	0.36	0.26	0.50	0.13	6.89

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

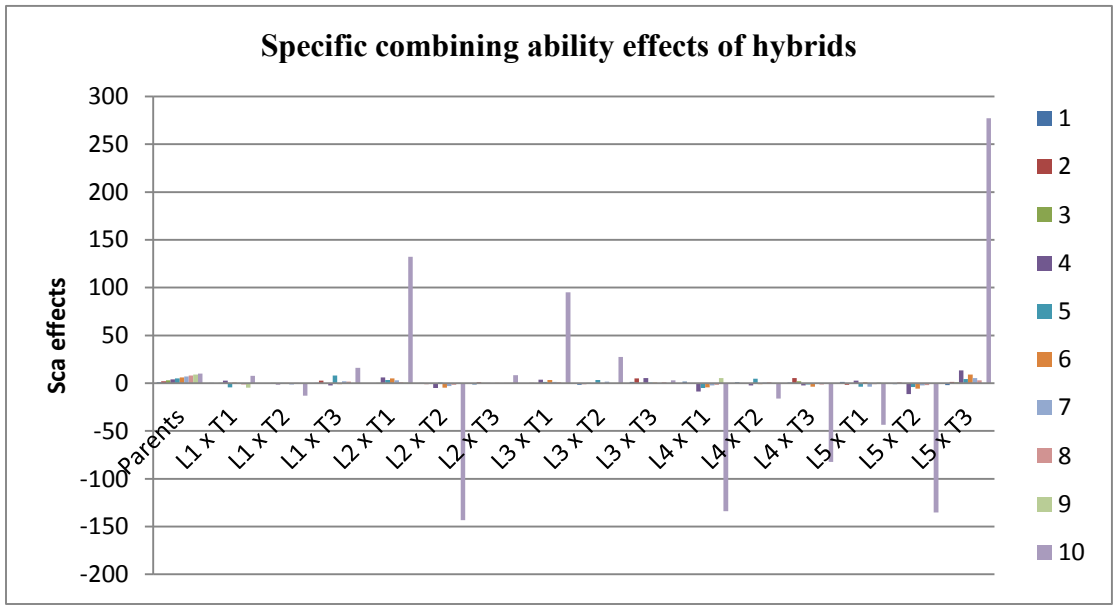


Fig.5. Specific combining ability effects of hybrids

1. Days to first flowering
2. Leaf axil bearing first fruit
3. Number of primary branches
4. Plant height
5. Duration
6. Number of fruits per plant
7. Fruit weight
8. Fruit length
9. Fruit girth
10. Yield per plant

L_3 (-2.58) and L_1 (-1.89) had negative values. Only T_3 (8.44) had positively significant *gca* effects whereas none of other testers had significant *gca* effect.

Significant positive *sca* effect was expressed by six hybrids of which the highest was observed for L_5 x T_3 (5.50) followed by L_2 x T_1 (2.87), L_1 x T_3 (1.95), L_3 x T_2 (1.72) L_3 x T_1 (1.43) and L_4 x T_2 (0.69). Out of the seven hybrids with significant negative *sca* effects, maximum was noticed for L_5 x T_1 (-3.66) followed by L_2 x T_2 (-3.01), L_4 x T_1 (-2.48), L_5 x T_2 (-2.27), L_1 x T_2 (-1.19), L_1 x T_1 (-0.62) and L_3 x T_3 (-0.59).

4.3.1.2.2.8 Fruit length

The *gca* effect was significant and positive for L_2 (2.42) whereas negative for L_4 (-1.22) and L_1 (-0.95). Among the testers, none of the testers exhibited significant *gca* effect.

Significant positive *sca* effect was displayed by three hybrids with the maximum being L_5 x T_3 (3.11) followed by L_1 x T_3 (1.58) and L_2 x T_1 (1.01) and the hybrids with negative values were L_5 x T_2 (-1.90), L_2 x T_2 (-1.56), L_4 x T_1 (-1.54), L_1 x T_1 (-1.38) and L_4 x T_3 (-1.34).

4.3.1.2.2.9 Fruit girth

Among the lines and testers, L_2 (0.80) and L_5 (0.49) displayed positively significant *gca* effect whereas negatively significant *gca* was observed for L_1 (-0.98) and L_4 (-0.25). Among the tester, positively significant *gca* value was noticed for T_3 (0.27) while significant negative *gca* value was exhibited by T_1 (-0.14) and T_2 (-0.12).

Significant and positive *sca* effect was exhibited by four hybrids with the maximum value of L_5 x T_1 (0.75) followed by L_2 x T_1 (0.57) L_3 x T_1 (0.42) and L_2 x T_3 (0.30) whereas negative values were observed for L_3 x T_3 (-0.46), L_1 x T_3 (-0.44) L_3 x T_2 (-0.31) and L_1 x T_2 (-0.30).

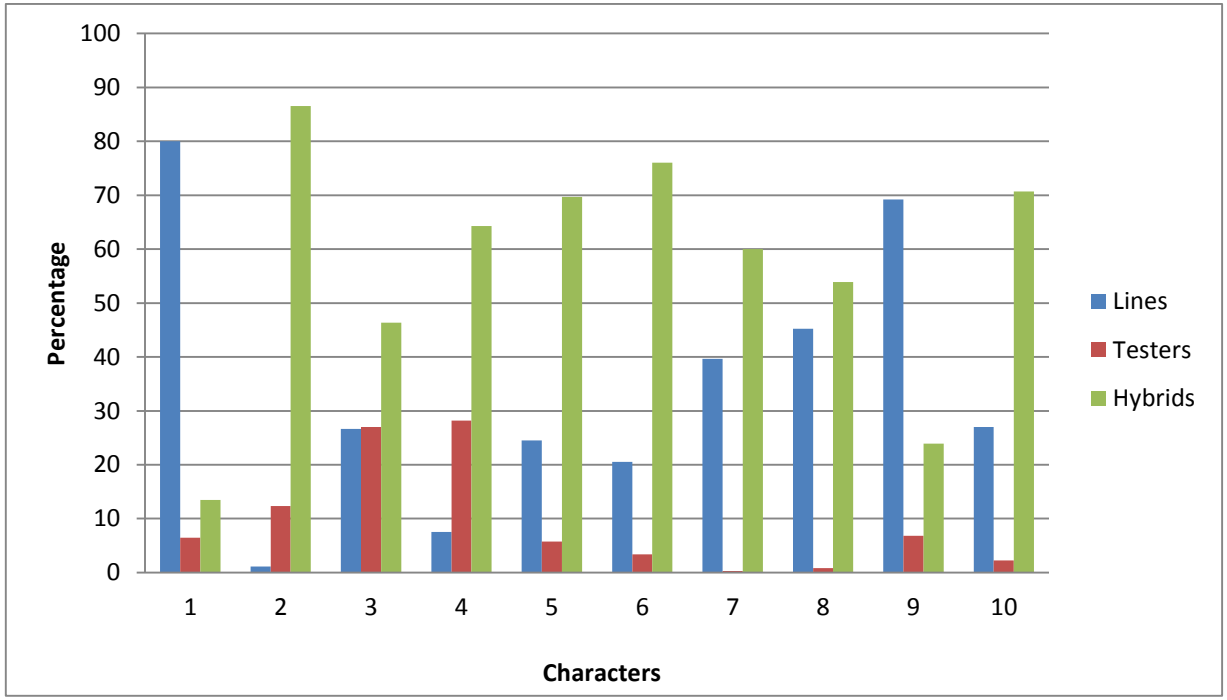


Fig.6 Proportional contribution of parents and hybrids

1. Days to first flowering
2. Leaf axil bearing first fruit
3. Number of primary branches
4. Plant height
5. Duration
6. Number of fruits per plant
7. Fruit weight
8. Fruit length
9. Fruit girth
10. Yield per plant

4.3.1.2.2.10 Yield per plant

Four lines had significant *gca* effects for yield per plant with, L_2 (74.56) and L_5 (71.17) having positive values while L_1 (-74.44) and L_3 (-74.28) had negative values. In the tester group, T_3 (24.83) and T_1 (-21.48) exerted significant *gca* effects.

All the hybrids except L_1 x T_1, L_1 x T_2, L_2 x T_3 and L_3 x T_3 exhibited significant *sca* effects. Among these, maximum positive *sca* effect was exhibited by L_5 x T_3 (277.12) followed by L_2 x T_1 (132.28), L_3 x T_1 (95.22), L_3 x T_2 (27.45) and minimum by L_1 x T_3 (16.14) whereas maximum negative *sca* effect was noticed for L_2 x T_2 (-143.13) followed by L_5 x T_2 (-135.17), L_4 x T_1 (-133.99), L_4 x T_3 (-82.24), L_5 x T_1 (-43.59) and L_4 x T_2 (-16.11).

4.3.1.3 Proportional contribution of parents and hybrids to total variance

The proportional contribution of lines, testers and line x tester interaction to the total variance is presented in Table 16 and Figure 6.

The proportional contribution of lines was high for days to first flowering. Most of the characters namely, leaf axils bearing first fruit, number of fruits per plant, yield per plant, duration, fruit girth, plant height, fruit weight, fruit length and number of primary branches showed higher contribution due to line x tester interaction.

4.3.2 Scoring for virus resistance based on 0-5 scale proposed by Rajamony *et al.* (1990)

All the 15 crosses of okra were screened for reaction to yellow vein mosaic disease. The per cent vulnerability index (V.I) and the range of score is given in Table 19.

Table 19. Scoring for yellow vein mosaic virus resistance

	30 DAS				50 DAS				70 DAS			
Genotypes	No. of plants	V.I	Range of score	Reaction	No. of plants	V.I	Range of score	Reaction	No. of plants	V.I	Range of score	Reaction
$L_1 \times T_1$	15	20.00	1	R	15	40.00	2	MR	15	62.00	3-4	MS
$L_1 \times T_2$	15	0.00	0	HR	15	20.00	1	R	15	40.00	2	MR
$L_1 \times T_3$	15	0.00	0	HR	15	5.70	0-1	R	15	20.00	1	R
$L_2 \times T_1$	15	0.00	0	HR	15	0.00	0	HR	15	1.60	0-1	R
$L_2 \times T_2$	15	0.00	0	HR	15	0.00	0	HR	15	1.00	0-1	R
$L_2 \times T_3$	15	0.00	0	HR	15	0.00	0	HR	15	1.44	0-1	R
$L_3 \times T_1$	15	0.00	0	HR	15	40.00	2	MR	15	60.00	3	MS
$L_3 \times T_2$	15	0.00	0	HR	15	0.00	0	HR	15	38.00	1-2	MR
$L_3 \times T_3$	15	8.00	0-1	R	15	44.00	2-3	MR	15	66.00	3-4	MS
$L_4 \times T_1$	15	0.00	0	HR	15	0.00	0	HR	15	1.00	0-1	R
$L_4 \times T_2$	15	20.00	1	R	15	58.00	2-3	MS	15	67.24	3-4	MS
$L_4 \times T_3$	15	5.00	0-1	R	15	40.00	1	MR	15	60.00	3	MS
$L_5 \times T_1$	15	0.00	0	HR	15	25.40	1-2	R	15	60.00	3	MS
$L_5 \times T_2$	15	20.00	1	R	15	40.00	2	MR	15	76.00	3-4	S
$L_5 \times T_3$	15	0.00	0	HR	15	0.00	0	R	15	1.00	0-1	R

0-no symptom (Highly Resistance-HR), 1-Resistant (R), 2-Medium resistant (MR), 3-Medium susceptible (MS), 4- Susceptible (S)

5-Highly Susceptible (HS)

a. 30 DAS

At 30 DAS, among the fifteen hybrids, eleven hybrids did not produce any symptom and were classified in the category Highly Resistance (HR) while four crosses exhibited resistance (R) to the YVM disease, as evident from the Table.

b. 50 DAS

When the crop was at 50 DAS, only five hybrids were with no symptom (HR) whereas four crosses were resistant while medium resistance was expressed by five crosses. Medium susceptibility reaction to YVM was noticed for one cross (L_4 x T_2)

c. 70 DAS

Among the fifteen hybrids at later stages of crop growth, six hybrids (L_1 x T_3, L_2 x T_1, L_2 x T_2, L_2 x T_3, L_4 x T_1 and L_5 x T_3) exhibited resistant reaction while medium resistance was shown by two hybrids, medium susceptible reaction for six hybrids and one cross showed susceptible reaction.

4.3.3 Heterosis

The estimates of relative heterosis, standard heterosis and heterobeltiosis for fifteen hybrids with respect to 10 characters under study were calculated and the results are presented in Tables 20 and 21 and figure 7. Standard heterosis was calculated for each character based on the check variety Varsha Upahar.

4.3.3.1 Days to first flowering

The three hybrids L_1 x T_2 (-4.84%), L_2 x T_2 (-5.03%) and L_5 x T_3 (-5.51%) exhibited negative and significant relative heterosis among the fifteen hybrids for number of days taken to first flowering. Significant negative heterosis was recorded for the hybrid L_2 x T_1 (-3.52%).

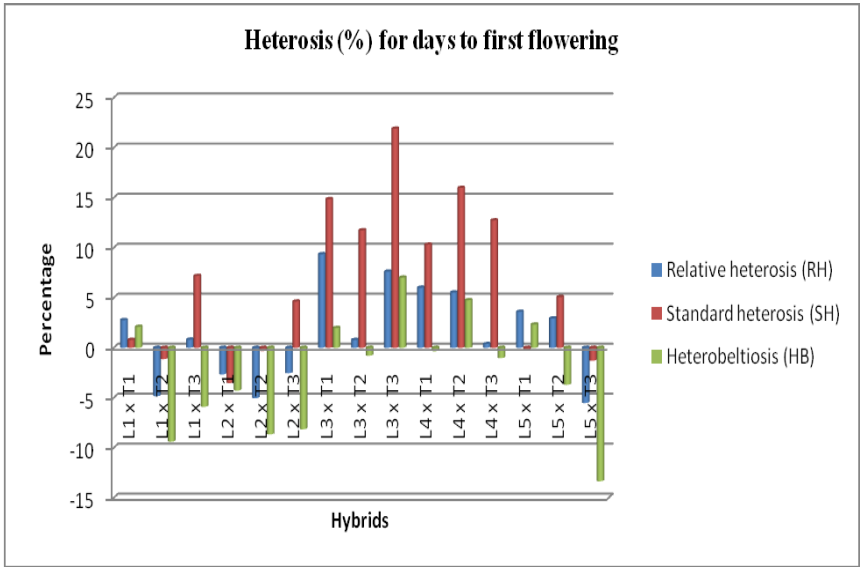
Table 20: Heterosis (%) over mid parent, standard variety and better parent for various vegetative traits in okra

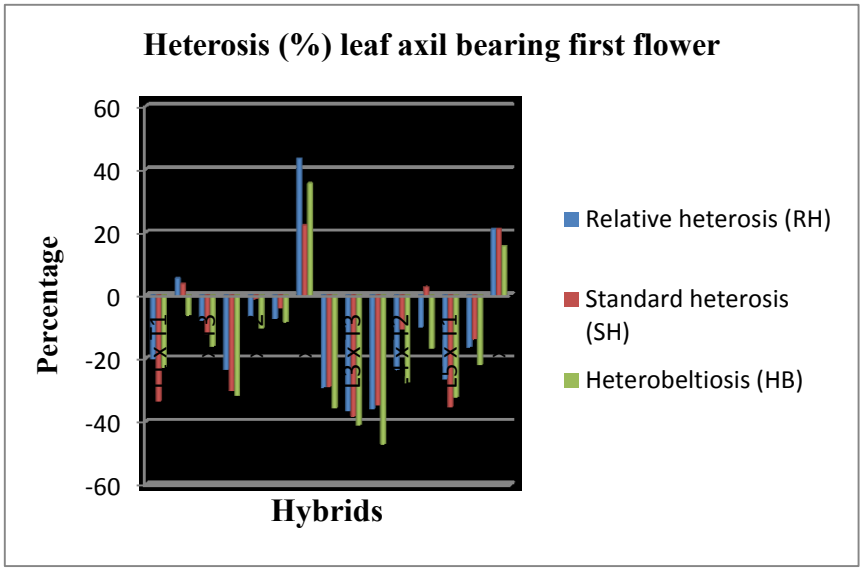
Hybrids	Days to first flowering			Leaf axil bearing first fruit			Number of primary branches			Plant height			Duration		
	RH	SH	HB	RH	SH	HB	RH	SH	HB	RH	SH	HB	RH	SH	HB
L_1 x T_1	2.77	0.79	2.1	-20.13*	-33.56**	-22.83*	-6.48	35.07	-6.9	0.34	-18.26**	-2.22	-16.33**	-27.54**	-17.14**
L_1 x T_2	-4.84**	-1.12	-9.38**	5.32	3.54	-6.31	-6.36	69.93**	-22.00*	-15.26**	-20.62**	-26.53**	-9.83**	-24.68**	-13.87**
L_1 x T_3	0.82	7.19**	-5.89**	-7.92	-12.15	-16.11*	-51.39**	-12.85	-59.18**	-2	-15.17**	-9.57**	-2.03	-18.01**	-6.23**
L_2 x T_1	-2.66	-3.52*	-4.28**	-23.56**	-30.19**	-31.81**	-18.91	30.71	-26.82*	-16.20**	-18.02**	-26.85**	-7.39**	-17.88**	-10.33**
L_2 x T_2	-5.03**	-0.32	-8.65**	-7.1	-1.1	-10.52	-29.67**	39.43	-36.00**	-20.67**	-12.69**	-22.09**	-4.33*	-18.11**	-10.58**
L_2 x T_3	-2.53	4.63*	-8.14**	-7.41	-4.13	-8.44	-42.22**	13.28	-46.93**	-13.62**	-11.08**	-20.66**	-5.11**	-18.62**	-11.15**
L_3 x T_1	9.36**	14.87**	1.98	43.34**	22.16**	35.48**	-20	-12.85	-39.39**	-12.02**	-20.74**	-17.94**	-14.17**	-21.03**	-19.63**
L_3 x T_2	0.79	11.75**	-0.78	-29.15**	-28.91**	-35.68**	8.8	58.82*	-27.1*	-19.81**	-17.95**	-24.06**	-8.87**	-18.96**	-17.52**
L_3 x T_3	7.62**	21.91**	7.02**	-36.71**	-38.33**	-41.11**	-39.39**	-12.85	-59.18**	-3.46	-8.09**	-4.85	-14.42**	-23.75**	-22.39**
L_4 x T_1	6.01**	10.32**	-0.34	-36.00**	-34.84**	-47.16**	-1.4	52.50*	-7.89	-12.28**	-12.01**	-24.81**	-7.66**	-16.62**	-12.07**
L_4 x T_2	5.53**	15.99**	4.76**	-23.68**	-10.76	-27.64**	0	91.72**	-12	-21.76**	-11.95**	-24.76**	-8.94**	-20.58**	-16.24**
L_4 x T_3	0.38	12.74**	-1.02	-10.1	2.5	-16.88*	-40.22**	13.28	-46.93**	-24.11**	-20.00**	-31.64**	-11.70**	-22.84**	-18.63**
L_5 x T_1	3.60*	-0.29	2.33	-26.49**	-35.42**	-32.31**	5.26	30.71	-9.09	-15.35**	-19.81**	-24.26**	-19.71**	-21.14**	-28.75**
L_5 x T_2	2.94	5.07**	-3.69*	-16.38*	-13.9	-22.10**	-8.1	48.14*	-32.00**	-27.64**	-22.60**	-28.36**	-24.48**	-28.15**	-35.08**
L_5 x T_3	-5.51**	-1.28	-13.34**	20.93**	21.00*	15.55*	27.39*	102.61**	-5.1	5.36*	5.19*	-0.64	-12.69**	-16.79**	-24.82**

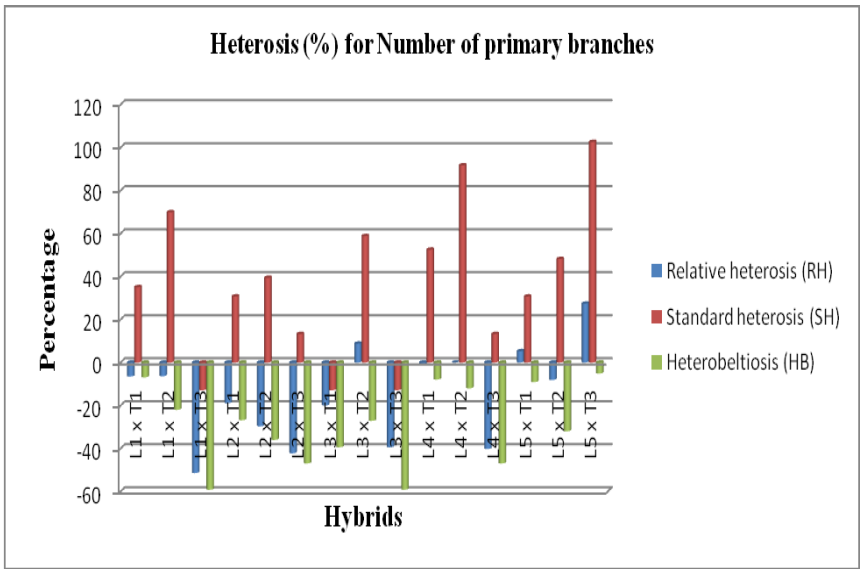
Table21: Heterosis (%) over mid parent, standard variety and better parent for various yield traits in okra

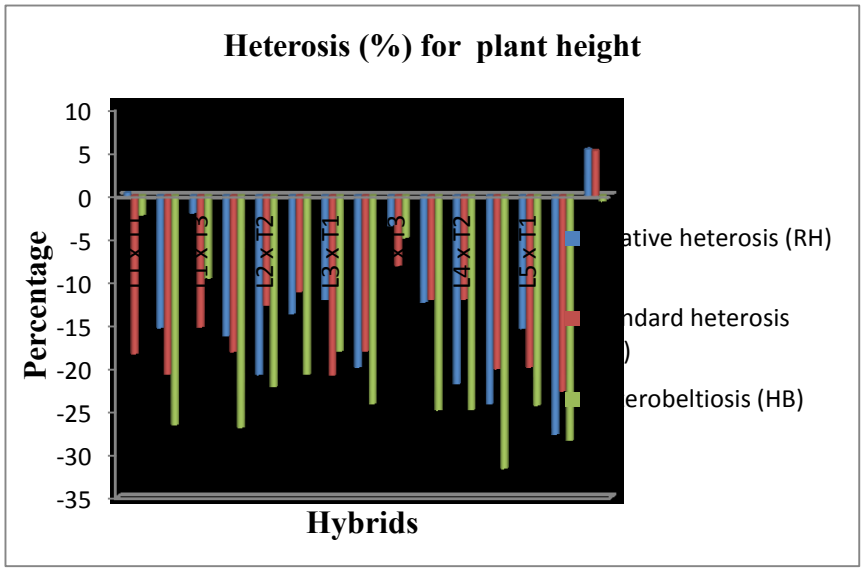
Hybrids	Number of fruits per plant			Fruit weight			Fruit length			Fruit girth			Yield plant -1		
	RH	SH	HB	RH	SH	HB	RH	SH	HB	RH	SH	HB	RH	SH	HB
$L_1 \times T_1$	-31.31**	-19.39**	-37.72**	-12.91**	2.93	-27.27**	3.32	16.98**	-3.25	-24.93**	-19.78**	-26.85**	-41.51**	-7.17	-54.87**
$L_1 \times T_2$	-31.54**	-15.12**	-40.53**	0.26	9.88**	-11.60**	15.05**	35.01**	11.65*	-21.38**	-13.78**	-25.23**	-33.03**	3.75	-47.63**
$L_1 \times T_3$	-40.87**	-17.02**	-52.70**	-7.18**	14.10**	-24.43**	19.24**	40.07**	15.83**	-21.48**	-16.26**	-23.34**	-47.39**	5.87	-63.58**
$L_2 \times T_1$	9.54**	15.31**	-10.91**	1.19	29.35**	-8.61**	33.83**	60.06**	19.74**	-1.63	5.49	-3.80	8.00*	67.15**	-18.74**
$L_2 \times T_2$	28.00**	43.24**	0.36	27.08**	51.49**	21.87**	36.17**	68.49**	26.05**	6.88**	17.69**	1.99	59.16**	140.32**	21.27**
$L_2 \times T_3$	-21.25**	0.99	-42.43**	4.02*	37.89**	-8.68**	20.18**	48.83**	11.34*	7.80**	15.38**	5.63	-22.00**	53.87**	-47.07**
$L_3 \times T_1$	-36.8**	-25.08**	-42.12**	-8.15**	16.72**	-17.53**	35.71**	48.32**	31.19**	-13.32**	-10.98**	-18.83**	-42.65**	-2.18	-52.44**
$L_3 \times T_2$	-30.26**	-12.70**	-38.83**	-0.40	17.98**	-5.07*	16.36**	31.98**	15.99**	-13.37**	-8.57*	-20.76**	-31.13**	14.87*	-42.03**
$L_3 \times T_3$	-26.29**	4.31	-40.54**	-41.43**	-22.79**	-48.87**	15.26**	30.86**	14.77**	12.92**	15.71**	5.93*	-57.74**	-9.95	-69.02**
$L_4 \times T_1$	12.86**	28.97**	-0.36	12.83**	46.15**	3.25	27.12**	34.90**	26.42**	-1.58	2.63	-6.41*	24.82**	109.84**	2.00
$L_4 \times T_2$	-13.25**	4.88	-26.51**	2.40	23.81**	-0.39	24.19**	36.92**	20.33**	-20.00**	-14.28**	-25.71**	-11.51**	45.40**	-26.62**
$L_4 \times T_3$	-50.77**	-32.43**	-61.48**	-17.90**	10.22**	-27.00**	2.79	13.45*	-0.49	-5.59*	-1.75	-10.06**	-61.17**	-18.22**	-71.87**
$L_5 \times T_1$	-43.80**	-27.78**	-44.21**	-13.01**	11.19**	-21.44**	-3.60	23.16**	-17.89**	5.09	8.90**	-0.70	-51.25**	-10.18	-56.33**
$L_5 \times T_2$	-40.66**	-19.81**	-43.82**	-1.01	17.98**	-5.07*	-4.19	26.36**	-15.76**	-7.38**	6.48*	-7.71**	-41.48**	5.60	-46.70**
$L_5 \times T_3$	21.87**	84.63**	5.24*	31.86**	74.79**	15.75**	25.50**	65.68**	10.44*	4.35	7.91*	-1.20	58.75**	260.03**	23.82**

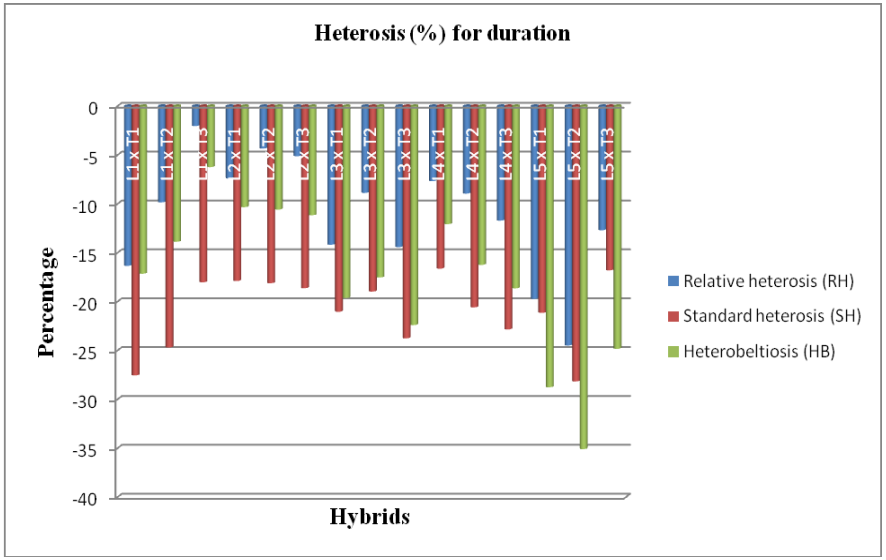
Fig.7. Heterosis for various characters in fifteen hybrids

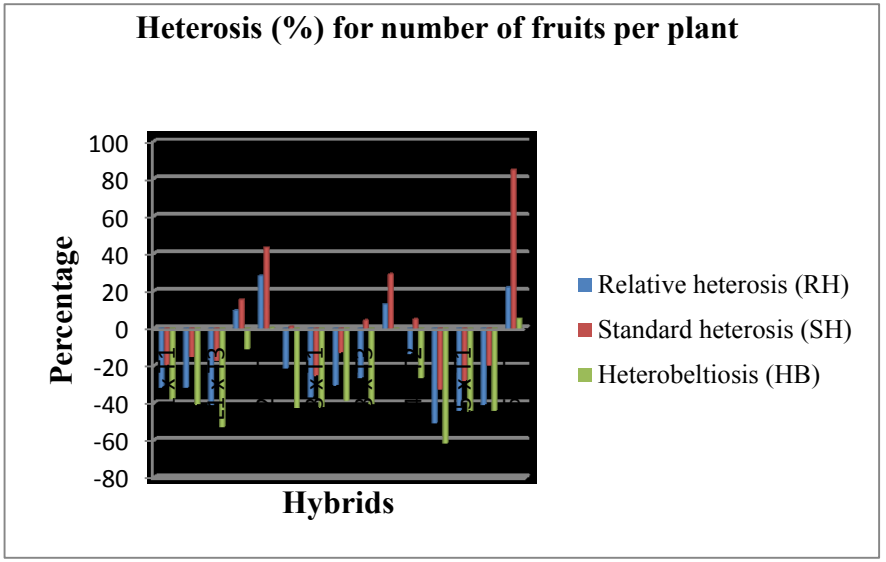


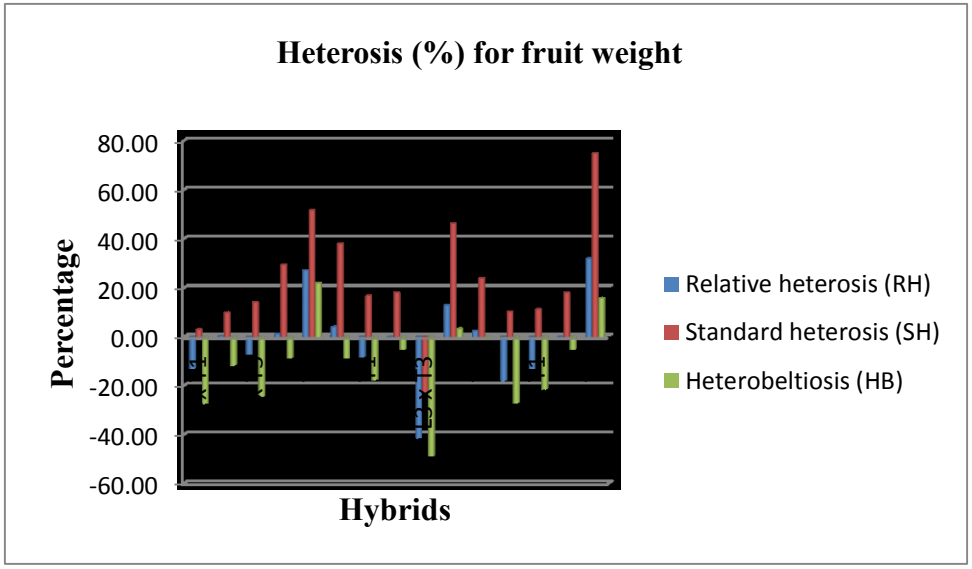


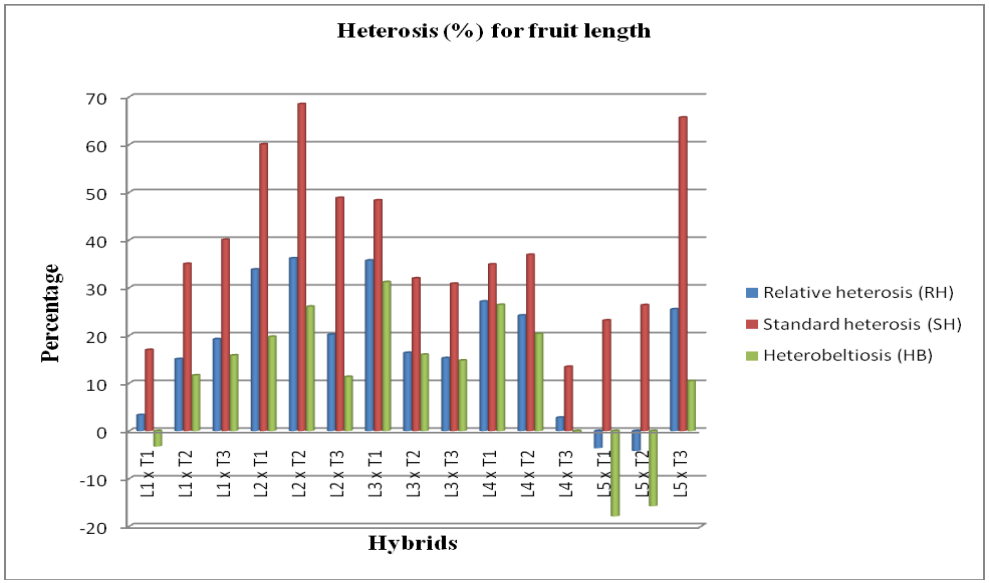


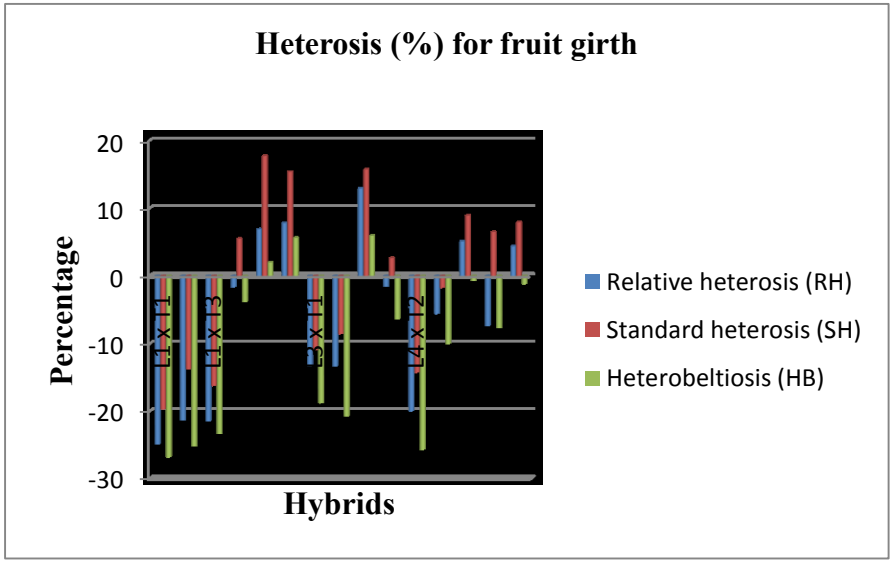


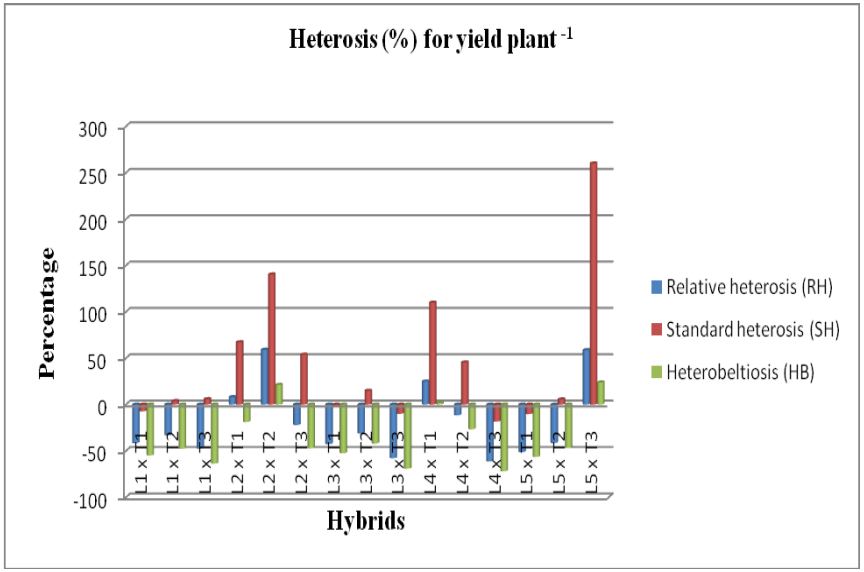

Heterosis (%) for duration
Percentage
0
-5
-10
-15
-20
-25
-30
-35
-40
L1 x T1
L1 x T2
L1 x T3
L2 x T1
L2 x T2
L2 x T3
L3 x T1
L3 x T2
L3 x T3
L4 x T1
L4 x T2
L4 x T3
L5 x T1
L5 x T2
L5 x T3
Hybrids
Relative heterosis (RH)
Standard heterosis (SH)
Heterobeltiosis (HB)


Heterosis (%) for number of fruits per plant
Percentage
100
80
60
40
20
0
-20
-40
-60
-80
Hybrids
Relative heterosis (RH)
Standard heterosis (SH)
Heterobeltiosis (HB)


Heterosis (%) for fruit weight
Percentage
80.00
60.00
40.00
20.00
0.00
-20.00
-40.00
-60.00
Hybrids
Relative heterosis (RH)
Standard heterosis (SH)
Heterobeltiosis (HB)


Heterosis (%) for fruit length
Percentage
70
60
50
40
30
20
10
0
-10
-20
L1 x T1
L1 x T2
L1 x T3
L2 x T1
L2 x T2
L2 x T3
L3 x T1
L3 x T2
L3 x T3
L4 x T1
L4 x T2
L4 x T3
L5 x T1
L5 x T2
L5 x T3
Hybrids
Relative heterosis (RH)
Standard heterosis (SH)
Heterobeltiosis (HB)


Heterosis (%) for fruit girth
Percentage
20
10
0
-10
-20
-30
L1 x T1
L1 x T3
L3 x T1
L4 x T2
Hybrids
Relative heterosis (RH)
Standard heterosis (SH)
Heterobeltiosis (HB)


Heterosis (%) for yield plant -1
Percentage
300
250
200
150
100
50
0
-50
-100
L1 x T1
L1 x T2
L1 x T3
L2 x T1
L2 x T2
L2 x T3
L3 x T1
L3 x T2
L3 x T3
L4 x T1
L4 x T2
L4 x T3
L5 x T1
L5 x T2
L5 x T3
Hybrids
Relative heterosis (RH)
Standard heterosis (SH)
Heterobeltiosis (HB)

Seven hybrids namely, L_5 x T_3 (-13.34%), L_1 x T_2 (-9.38%), L_2 x T_2 (-8.65%), L_2 x T_3 (-8.14%), L_1 x T_3 (-5.89%), L_2 x T_1 (-4.28%), and L_5 x T_2 (-3.69%) recorded significant negative values for heterobeltiosis.

Most of the hybrids showed significant negative heterosis over the better parent for days to first flower. The hybrid, L_5 x T_3 exhibited significant negative relative heterosis and heterobeltiosis for number of days taken for first flowering.

4.3.3.2 Leaf axil bearing first fruit

Two hybrids exhibited desirable significant heterosis over mid parent for leaf axils bearing first fruit and the highest percentage of significant positive relative , standard and better parent heterosis was noticed for L_3 x T_1 (43.34% , 22.16% and 35.48%) closely followed by L_5 x T_3 (20.93% , 21.00% and 15.55%).

4.3.3.4 Plant height

Relative and standard heterosis was significant and positive for hybrid L_5 x T_3 (5.36% and 5.19%) for plant height respectively.

4.3.3.5 Duration

Significant negative heterosis over mid parent, standard variety and better parent for duration was observed for hybrids. Maximum and minimum negative relative heterosis was possessed by L_5 x T_2 (-24.48 %) and L_2 x T_2 (-4.33%) respectively. The highest and lowest standard heterosis was noticed for L_5 x T_2 (-28.15%) and L_4 x T_1 (-16.62 %) and heterobeltiosis by L_5 x T_2 (-35.08 %) and

L_1 x T_3 (-6.23 %). The hybrid, L_5 x T_3, expressed negative significant heterosis over mid parent, standard variety and better parent for duration of crop.

4.3.3.6 Number of fruits per plant

Relative and standard heterosis for number of fruits was positive and significant for four hybrids namely L_2 x T_2 (28.00 % and 43.24 %), L_5 x T_3 (21.87 % and 84.63 %), L_4 x T_1 (12.86 % and 28.97 %) and L_2 x T_1 (9.54% and 15.31 %). Heterobeltiosis was positive and significant for only one hybrid L_5 x T_3 (5.24 %). The hybrid, L_5 x T_3, expressed positive significant heterosis over mid parent, standard variety and better parent for this character.

4.3.3.7 Fruit weight

The fruit weight had a positive and significant heterosis over the mid parent for four hybrids. Among these, L_5 x T_3 (31.86 %) had the maximum value followed by L_2 x T_2 (27.08 %), L_4 x T_1 (12.83 %) and L_2 x T_3 (4.02 %). Among fifteen hybrids evaluated, thirteen hybrids exhibited positively significant standard heterosis for fruit weight. The maximum value was observed for L_5 x T_3 (74.79%) followed by L_2 x T_2 (51.49 %).

A significant positive heterobeltiosis was exhibited for L_2 x T_2 (21.87 %) and L_5 x T_3 (15.75 %).The crosses L_2 x T_2 and L_5 x T_3 had positive significance for fruit weight over mid parent, standard variety and better parent.

4.3.3.8 Fruit length

Eleven hybrids showed positively significant heterosis for fruit length over mid parent. Among these, L_2 x T_2 (36.17 %) exhibited maximum heterosis followed by L_3 x T_1(35.71 %) ,L_2 x T_1 (33.83 %), L_4 x T_1 (27.12 %) and L_5 x T_3 (25.50 %).

Positively significant heterosis over check variety was exhibited by all the fifteen hybrids. The maximum and minimum values were recorded for L_2 x T_2 (68.49 %) closely followed by L_5 x T_3 (65.68%) and L_4 x T_3 (13.45 %), respectively

Out of the thirteen hybrids which exhibited significant heterobeltiosis, the cross with highest positive heterosis was noticed for L_3 x T_1 (31.19 %) and the cross L_5 x T_3 (10.44 %) had lowest positive heterosis over better. The hybrids L_2 x T_2, L_4 x T_1, L_4 x T_2, L_5 x T_3, L_3x T_1, L_3x T_2, L_3x T_3, L_2 x T_1 and L_2 x T_3 showed positive heterosis for all estimates.

4.3.3.9 Fruit girth

The three hybrids *viz.,* L_3 x T_3 (12.92 %), L_2 x T_3 (7.80 %) and L_2 x T_2 (6.88 %) had positive significant heterosis for fruit girth over mid parent Positively significant standard heterosis over standard variety for fruit girth was observed for six hybrids namely L_2 x T_2 (17.69 %), L_3 x T_3 (15.71 %) , L_2 x T_3 (15.38 %), L_5 x T_1 (8.90 %), L_5 x T_3 (7.91 %) and L_5 x T_2 (6.48 %). Heterobeltiosis was positively significant for only L_3 x T_3 (5.93 %) with regard to fruit girth.

4.3.3.10 Yield per plant

Significant relative heterosis was exhibited by all the fifteen hybrids. The highest positively significant value was noticed for L_2 x T_2 (59.16%) closely followed by L_5 x T_3 (58.75%).

The seven hybrids displayed significant positive standard heterosis for yield plant^{-1}. The cross L_5 x T_3 had the maximum significant positive value (260.03 %) followed by L_2 x T_2 (140.32 %), L_4 x T_1 (109.84 %), L_2 x T_1 (67.15 %), L_2 x T_3 (53.87 %), L_4 x T_2 (45.40 %) and L_3 x T_2 (14.87 %). Heterobeltiosis was significant and positive for L_5 x T_3 (23.82 %) and L_2 x T_2 (21.27 %). The hybrids which showed positive and significant estimates for all three types of heterosis were L_5 x T_3 and L_2 x T_2.

L5 x T3 **L2 x T1**

L2 x T2 **L4 x T1**

Plate 10: High yielding and YVM resistant hybrids

DISCUSSION

5. DISCUSSION

Okra improvement for yield and resistance to yellow vein mosaic virus disease needs a sound knowledge on the genetic architecture of the crop and inheritance of characters of interest to breeder.

An ideal okra variety/hybrid should be vigorous, have a good branching habit, short internodes, earliness in flowering, bear deep green fruits which are medium long (12-15 cm) with medium diameter (1.5-2.00) and high fruit weight and should be resistant to stresses. Assembly of all these desirable characters in a single genotype is a difficult task, since many genes govern each of these characters. The successful okra improvement programme depends on the nature and magnitude of genetic variability, the degree of transmission of traits and their interaction with yield. The variability available in okra is to be assessed by evaluation of germplasm collected from diverse geographical sources.

In recent years, F_1 hybrids are gaining greater importance owing to their high yields with resistance to biotic stresses and uniformity. Line x Tester analysis is one of the techniques where large number of genotypes could be tested for their combining ability. Heterosis breeding and recombination breeding needs selection of suitable parents with wide genetic diversity which when combined are expected to display greater vigour in the progenies.

In the present investigation, greater attention has been given

1. To assess genetic variability, correlation for yield and resistance to YVM virus disease in 36 genotypes of okra.
2. To estimate the combining ability effects of selected parents and their hybrids.
3. To find out the magnitude of heterosis in cross combinations for yield and YVM resistance.

The findings of experiments conducted are discussed under the following headings.

5.1. EVALUATION OF GERMPLASM

1. Genetic variability
2. Correlation studies
3. Scoring of genotypes for YVM resistance
4. Confirmation of disease resistance

5.2. DEVELOPMENT AND EVALUATION OF F_1 HYBRIDS

1. Combining ability
2. Scoring of hybrids for YVM virus resistance
3. Heterosis

5.1. EVALUATION OF GERMPLASM

5.1.1 Genetic variability

The phenotypic variability in a population is the sum total of the variation arising due to genotypic and environmental effects. Knowledge of the nature and magnitude of genetic variation contributing to gain under selection is of utmost importance (Allard, 1960). The breeding procedure, efficiency of selection and final success are dependent on the germplasm chosen (Zelleke, 2000).The results of the present investigation on genetic variability indicated the presence of adequate variability among the thirty six genotypes studied for all the characters. Bendale *et al*. (2008), Sindhumole *et al.* (2006), Vishal kumar *et al*. (2006), Gandhi *et al.* (2001), Gondane and Lal (1994), Patel and Dalal (1992) and Vijaya and Manohar (1990) have reported similar results in okra.

Appreciable variation in days to first flowering was noticed for all the genotypes and it ranged between 36 and 46 days. Similar results were reported by Rajani and Manju (1997) and Sindhumole (2003). Leaf axil bearing first fruit ranged from 4.13 to 6.73. Number of primary branches produced by the plant varied from 1 to 4.26. The duration also exhibited commendable variation, the range being 80.26 to 128.06 days. Several research findings are

available in accordance with the above results. (Rajani and Manju, 1997; Sindhumole, 2003; Singh *et al.,* 2006; Singh and Singh, 2006; Singh *et al.,* 2007; Saifullah and Rabbani, 2009).

Plant height, one of the important yield attributing character in okra also showed wide variability among the 36 genotypes studied. The results are in agreement with Mohamed and Anbu (1997), Panda and Singh (1997), Singh and Singh (2006), Singh *et al.* 2007, Saifullah and Rabbani (2009) and Akotkar *et al.* (2010).

Considerable amount of variation was noticed for fruit characters such as number of fruits per plant, fruit weight, fruit length, fruit girth and fruit yield per plant. Corroborative findings were reported by Mohamed and Anbu (1997), Sindhumole (2003), Alam and Hossain (2006), Singh and Singh (2006), Singh *et al.* (2006), Singh *et al.* (2007), Saifullah and Rabbani, (2009) and Akotkar *et al.* (2010).

White fly (*Bemisia tabaci*) is the major vector transmitting the virus causing the dreaded yellow vein mosaic disease. The population of the vector was studied at three stages of crop growth namely, 30DAS, 50 DAS and 70 DAS respectively and mean was worked out. The mean population of white fly was highest at 50 DAS. This result is in agreement with the reports of Mazumder *et al.* (1996), Bhagat *et al*. (2001) and Sindhumole (2003). The number of leaves with disease symptoms (incidence) was highest during 70 DAS in the present study whereas Sindhumole (2003) reported YVM incidence the highest at 30-45 days.

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

In the present study, PCV was higher than GCV for all the characters with close correspondence between them. This indicated the fact that environmental influence is very low and hence selection for these characters

would be made based on their phenotypic performance. Moderate and high GCV values for most of the characters except days to first flowering, fruit length and fruit girth revealed the presence of high magnitude of genetic variability in the population studied.

Greater magnitude of PCV and GCV was observed for yield per plant and its component characters like number of primary branches and plant height. These findings are in agreement with Hazra and Basu (2000) and Reddy *et al.* (2012) for yield per plant; Mohamed and Anbu (1997), Gandhi *et al.* (2001), Jaiprakashnarayan *et al.* (2006), Singh *et al.* (2006), Vishalkumar *et al.* (2006), Singh *et al.* (2007), Saifullah and Rabbani (2009) and Jindal *et al.* (2010) for number of primary branches and for plant height by Prakash and Pitchaimuthu (2010).

Moderate PCV and GCV were observed for number of fruits per plant, leaf axil bearing first fruit, fruit weight and duration. Corroborative findings of moderate PCV and GCV for these characters were given by Rajani and Manju, (1997) and Mulge *et al.* (2004).

The characters like days to first flowering, fruit length and fruit girth recorded low PCV and GCV values. It indicates presence of narrow genetic base for these traits. This is in conformity with the findings of Balakrishnan and Balakrishnan (1988), Dhankar and Dhankar (2002a) and Akotkar *et al.* (2010).

Existence of mere variability in the population may not serve the whole objective of breeding programme. To exercise an effective selection, it is important to know about the extent of variation that is heritable. Therefore, it is essential to partition the overall variability into its heritable and non heritable components for predicting the genetic advance, which will enhance the precision of selection.

The results of present study revealed that all the characters have high heritability and all characters except days to first flowering , fruit length and

fruit girth have high genetic advance over mean. Heritability was highest for duration followed by plant height.

High heritability for days to first flowering in the present investigation is in accordance with the reports by Jaiprakashnarayan *et al.* (2006), Prakash and Pitchaimuthu (2010), Adiger *et al.* (2011) and Reddy *et al.* (2012).

The number of primary branches also recorded high heritability. Similar results were obtained by Nair and Sheela (1985), Reddy *et al.* (1985), Kale *et al.* (1989), Mohamed and Anbu (1997), Hazra and Basu (2000), Singh *et al.* (2006), Singh and Singh (2006), Vishalkumar *et al.* (2006), Saifullah and Rabbani (2009), Jindal *et al.* (2010) and Reddy *et al.* (2012).

High heritability estimated for plant height and fruit length in the present study is well in agreement with the reports by several workers such as Murthy and Bavaji (1980), Dhall *et al.* (2000), Mehta *et al.* (2006) and Reddy *et al.* (2012).

High heritability for fruit weight seen in the present investigation is in accordance with the reports of Mohamed and Anbu (1997), Hazra and Basu (2000), Mehta *et al.* (2006), Saifullah and Rabbani (2009), Prakash and Pitchaimuthu (2010), Adiger *et al.* (2011) and Reddy *et al.* (2012).

The fruit yield and its contributing character like number of fruits per plant, fruit weight, fruit length and fruit girth also exhibited high estimates of heritability. Corroborative reports of high heritability for the above characters by Balakrishnan and Balakrishnan (1988), Jeyapandi and Balakrishnan (1992), Mohamed and Anbu (1997), Mulge *et al.* (2004), Singh *et al.* (2006), Singh and Singh (2006), Sindhumole *et al.* (2006), Vishalkumar *et al.* (2006), Saifullah and Rabbani (2009) and Reddy *et al.* (2012) support the findings in the present study.

High estimates of genetic advance as percentage of mean were recorded for number of primary branches, number of fruits per plant, plant height, duration, leaf axil bearing first fruit, fruit weight and yield per plant.

Several research findings are in line with this result such as Dhall *et al.* (2000), Hazra and Basu (2000), Gandhi *et al.* (2001), Mulge *et al.*(2004), Mehta *et al.* (2006), Singh *et al.* (2006), Singh and Singh (2006), Vishalkumar *et al.* (2006), Akotkar *et al.* (2010) and Reddy *et al.* (2012).

Among the ten characters studied, seven characters displayed high heritability coupled with high genetic advance as percent over mean. This emphasizes the predominance of additive gene effects for these characters and crop improvement through selection based on these characters is rewarding. Three characters showed high heritability accompanied with moderate genetic advance over mean implying the role of non-additive effects and hence selection based on these traits may not be rewarding.

5.1.2 Correlation studies

Correlation between different characters could arise due to linkage, pleiotropy or developmentally influenced relationships. Correlation between two characters gives the idea about the extent of variation that could be expected in one trait by altering the other character. Therefore, analysis of yield in terms of genotypic and phenotypic correlation coefficients of component characters leads to the understanding of characters that can form the basis of selection. The genotypic correlation between characters provides a reliable measure of the genetic association between characters and helps to differentiate the vital association useful in breeding from non-vital ones (Falconer, 1981).If the difference between genotypic correlation and phenotypic correlation is narrow, it indicates that the association between pairs of characters is less influenced by environmental factors.

In the present study on character association, correlations were estimated for twelve characters including fruit yield. Fruit yield per plant showed strong positive and significant genotypic and phenotypic correlation with number of fruits per plant, fruit weight, fruit girth and number of primary branches. The positive association of yield per plant with number of fruits per plant in this

study is in accordance with the reports by several workers such as Dhall *et al.* (2000), Dhankhar and Dhankhar (2002b), Jaiprakashnarayan and Mulge (2004), Sindhumole *et al.* (2006), Singh *et al.* (2006), Ramya and Senthilkumar (2009), Guddadamath *et al.* (2011), Adiger *et al.* (2011).Many early workers also reported high positive correlation of yield per plant with fruit weight and fruit girth namely Nair and Sheela (1985), Jeyapandi and Balakrishnan (1990), Patel and Dalal (1994), Dash and Mishra (1995), Sindhumole *et al.*(2006) and Singh *et al.* (2006) which supports the present findings.

The significant positive correlation of fruit yield per plant with number of fruits per plant, fruit weight, fruit girth and number of primary branches indicates that selection for these characters would lead to simultaneous improvement for yield per plant in okra.

Days to first flowering had positive significant inter correlation with leaf axil bearing first fruit and fruit length. Similar results were obtained by Sindhumole (2003). The inter association between duration and plant height was positive and significant which is in agreement with the findings of Reddy *et al.* (1985) while it was negative and significant with leaf axil bearing first fruit and days to first flowering.

Positive and highly significant correlation between fruit weight, fruit length and fruit girth observed in the present investigation is in confirmation with the findings of Balkrishnan and Balkrishnan (1990), Sureshkumar (2000) and Vijayakumar (2009).

Number of fruits per plant had positive correlation with fruit girth. Maksoud *et al.* (1984), Reddy *et al.* (1985), and Patel and Dalal (1994) support the above finding. Fruit weight and fruit length also had significant correlation between them and this finding is supported by the reports of Maksoud *et al.* (1984). It is to be noted that number of fruits per plant, fruit weight and fruit girth besides being positively associated with yield, showed positive correlation to one another and these two or three characters had high

heritability. These characters can be given importance while doing selection procedures which are aimed at yield improvement.

The number of white flies was significantly and negatively correlated with plant height, duration of the crop and fruit length. A significant and negative correlation was noticed for number of leaves with disease symptoms with duration and fruit length. A strong positive correlation existed between number of white flies and number of leaves with disease symptoms. These results were in agreement with Bhagat *et al.* (2001) and Sindhumole (2003).

5.1.3 Scoring of genotypes for YVM resistance

The thirty six genotypes were scored for symptoms of yellow vein mosaic disease based on the scale developed by Rajamony *et al.* (1990) and vulnerability index was worked out. Among the thirty six genotypes, only five genotypes were resistant to the dreaded disease at all the three stages of crop growth. Several researchers worked on YVM disease scoring with different germplasm collections and reported only few lines to be resistant to the disease. Some worth mentioning researchers in this field are Mazumder *et al*. (1996), Ramesh *et al*. (1999), Bhagat (2000), Rajamony *et al.* (2002), Ahmed and Patil (2004), Sindhumole *et al*. (2006) and Prashanth *et al*. (2008).

5.1.4 Confirmation of disease resistance

For confirmation of disease resistance, vector and graft transmission studies were undertaken in glasshouse for the five resistant genotypes identified in experiment I.

In the vector transmission studies, disease resistance was confirmed by artificial inoculation on the five resistant genotypes using viruliferous white flies carrying YVM virus. The vulnerability index of treated plants was calculated and categorized as highly resistant and resistant, thereby confirming the disease resistance of the selected genotypes. Similar findings were reported by Sindhumole (2003).

Grafting trials were also conducted for five resistant genotypes selected from the first experiment. The resistant genotypes were used as the root stock and highly susceptible genotype, Kiran, as scion. The vulnerability index of grafted plants were calculated and categorized as highly resistant and resistant. Similar grafting trials for disease resistance confirmation were done by Salehuzzaman (1985), Ali *et al*. (2000) and Sindhumole (2003).

5.2. DEVELOPMENT AND EVALUATION OF F_1 HYBRIDS

Simple selection techniques were successful in breeding crop plants for a long time. But many generations of deliberate selection have resulted in more uniformity. Hence for a systematic breeding programme, it is essential to identify parents, as well as crosses which could be exploited in order to bring out further genetic improvement in economic characters. In a crop like okra where there are increasing evidences for polygenic action determining yield and yield components, the choice of the parents must be based on refined biometrical techniques. The Line x Tester analysis is one of the techniques where a large number of genotypes could be tested for their combing ability.

The present study is an attempt to make use of Line x Tester analysis to estimate the combining ability and to find out magnitude of heterosis in new cross combinations. Results obtained in the present study are discussed in the ensuing paragraphs.

5.2.1 *Per se* performance

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 hybridization programme. The parents with high mean performance would be useful in producing better offspring in any breeding programme (Singh *et al.*, 1993).

Best hybrids and good segregants can be obtained from parents with superior *per se* performance. The potential of the variety or commercial hybrid

could be adjudged by comparing mean performance and combining ability effects of parents. From the *per se* performance of parents, L_5 excelled in yield per plant, number of fruits and fruit length and resistance to YVM disease whereas T_3 was the highest yielder among testers with maximum number of fruits per plant and high fruit weight but susceptible to the disease followed by T_1. The lines L_2 and L_4 were also good performers with regard to fruit weight and girth. These results were in accordance with the findings of many researchers such as Vijay and Manohar (1986), Suresh kumar (2000), Thippeswamy (2001) and Sindhumole (2003).

5.2.2 GCA: SCA variance

Baker (1978) suggested that the relative importance of general and specific combining ability should be assessed by estimating the components of genetic variance and expressed as a ratio between GCA and SCA. In the present study, the SCA variance was found to be higher than GCA variance for all characters except for days to first flowering and fruit girth which was in accordance with the findings of Patel *et al*. (1994) and Ahmed *et al*. (1997). The GCA: SCA ratio was observed to be more than one for days to first flowering and fruit girth indicating the influence of additive gene action. A similar result where GCA variance was high was reported by Chavadhal and Malkhandale (1994). When additive genes are more important, the choice of parents based on *per se* performance may be effective (Sharma and Chauhan, 1985). However Bastian (1999) and Gayathri (2011) opined that the nature of gene action varies with the material, the analytical procedure used and the environment under which the test is carried out.

5.2.3 *gca* effects of parents

The *gca* effects of parents were estimated by several breeders for different crops to evaluate the ability of parents to transmit desirable characters to their offspring. Within the group of lines, L_5 and L_2 were good

general combiners for days to first flowering, number of fruits per plant, fruit weight, fruit girth and yield per plant. Several findings are in agreement with the above result [Thaker *et al.,* (1981); Vijay and Manohar (1986); Laxmiprasanna (1996); Ahmed *et al.,* (1999); Chavadhal and Malkhandale (1994); Nichal *et al.* (2001b); Thippeswamy (2001) and Mamta and Arora (2003)]. Among testers, T_3 had the best general combining ability for major share of the traits under consideration including fruit yield, fruit weight and fruit girth.

5.2.4 *Per se* performance and *gca* effects

The association between *gca* effects and mean performance of the parents suggested that the performance *per se* could be a good indicator of its ability to transmit the desirable attributes to its progenies. When the per se performance and *gca* effects of both lines and testers are combined, it is noteworthy that the mean values of parents totally reflected the *gca* effects in respect of majority of the characters. Corroborative reports of such findings were given by Sureshkumar (2000), Thippeswamy (2001) and Sindhumole (2003). Based on the overall performance, $L_5$and L_2 deserves the positions of superior lines and T_3 and T_1 as the best testers owing to the excellent mean performance and remarkable combining power.

5.2.5 *Per se* performance, *sca* effects and heterosis

The basic idea of hybridization is to combine favourable genes present in different parents into a single genotype. To exploit hybrid vigour, the parameters like *per se* performance of hybrids, *sca* effects and standard heterosis of hybrids have to be taken into account (Gayathri, 2011)

The present study revealed better performance of hybrids reflecting from parents with high *per se* performance. The most superior hybrid which gave the highest yield with maximum number of fruits per plant, heavy and long fruits with good fruit diameter and more number of primary branches was

the hybrid L_5 x T_3. It is a tall plant taking only lesser days to produce first flower. The disease scoring reactions rated this hybrid combination as resistant to YVM virus disease. The second best hybrid based on *per se* performance was L_2 x T_2 for yield and fruit girth which was also resistant to the disease. However there were many hybrids with high *per se* performance involving parents with average performance.

The *sca* effects are due to non additive gene action (Sprague and Tatum, 1942). High *gca* values of the parents contribute much for the expression of heterotic vigour. The *sca* effects of the hybrids have also been attributed to the combination of positive favorable genes from different parents or might be due to the presence of linkage in repulsion phase. In the present study hybrid L_5 x T_3 had significant *sca* effects for all characters except fruit girth. The parents reflected high *gca*. The hybrid L_2 x T1 possessed high *sca* effects for yield and its contributing characters.

The term heterosis coined by Shull (1948) refers to the superiority of F_1 hybrid over its parents. In the present study heterosis was estimated in three ways viz. relative heterosis (over midparent value), heterobeltiosis (over superior parent) and standard heterosis (over standard variety). But for practical purposes it is better to compare heterobeltiosis and standard heterosis. In the present study L_5 x T_3 recorded positive heterosis for all characters except fruit girth.

In the present investigation, an attempt was also made to choose hybrid combinations for high order of expression for all the three genetic parameters *viz. per se* performance, *sca* effects and standard heterosis to give more validity for selection.

Based on the three parameters, the hybrid L_5 x T_3 excelled all other hybrids followed by L_2 x T_1. However, this is not uniform for all the characters and all the crosses. There are crosses at low and high levels for *per se* performance, *sca* effects and standard heterosis in different combinations. Therefore, the study had clearly indicated that the *sca* effects may not always

lead to correct choice of hybrid combinations. Hence selection of hybrids based on high *per se* performance and heterotic expression would be more useful than based on *sca* effects alone as reported by Bastian (1999) and Gayathri (2011)

Future Line of studies:

Hybrid breeding is one of the best methods to increase productivity. Commercial exploitation of hybrid vigour could be achieved through hybrids with high *per se* performance along with *sca* for yield and yield contributing characters. The present study highlighted cross combinations where parents with good *gca* effects produce hybrids with good *per sca* and heterosis (heterobeltiosis and standard heterosis).

However the results from this experiment are based on single plant basis. The yield increase obtained should be verified on per plot basis. The hybrids were produced and evaluated in one location but its performance should be tested at different locations to verify whether the yield and resistance go well in different areas. Such studies could throw more light on the heterotic expression, uniform yield and resistance to biotic stresses which is not possible in the time frame permitted for this study. Hence in future such studies have to be undertaken so that the crosses made could be promoted as hybrids and released for commercial cultivation. Hybrids are the hope of the farming community in the near future.

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SUMMARY

6. SUMMARY

Evaluation of germplasm for genetic variability, character association and resistance to yellow vein mosaic disease, confirmation of disease resistance in selected genotypes through vector and graft transmission studies, development and evaluation of F_1's for combining ability, heterosis and disease resistance were conducted on okra (*Abelmoschus esculentus* (L.) Moench) at the Department of Plant Breeding and Genetics and Department of Plant Pathology, College of Agriculture, Vellayani during 2011-2012. The okra germplasm consisting of thirty six accessions collected from different parts of Kerala and Karnataka was assessed for the extent of variability, heritability and genetic advance. The relationship among the yield and associated traits was also worked out from this population and scoring for disease resistance. Based on the results of variability experiment, five genotypes which were resistant to yellow vein mosaic virus disease were selected and resistance was confirmed by artificial transmission methods such as vector transmission and graft transmission in glass house. After confirmation of resistance these five genotypes were crossed with three high yielding susceptible genotypes to develop F_1s in a Line x Tester fashion and combining ability effects and heterosis was calculated. The salient results of investigation are summarised below:

- Analysis of variance showed significant difference among the thirty six genotypes for all characters studied.
- The assessed germplasm contained ample variability and offered scope for selection based on characters like plant height, number of primary branches, leaf axil bearing first fruit, duration, number of fruits per plant, fruit weight, fruit length and yield per plant.
- Among the thirty six genotypes AE-8 (Thirumala local), AE-32 (Kunnapuzha local), AE-33(Holavanalli local), AE-2 (IC 1012-1) and AE-28 (Halu Bhendi) were resistant to yellow vein mosaic as confirmed by scoring and transmission studies while the genotype, AE-34 (Mallapalli local) recorded the highest

yield in spite of high disease symptoms followed by AE-4 (Punjab Phalgani) and AE-13 (Kattakada local).

- Genotypic and phenotypic coefficient of variation was high for yield per plant, number of primary branches and plant height whereas moderate values were recorded for leaf axil bearing first fruit, duration, number of fruits per plant and fruit weight. Narrow difference between GCV and PCV suggest that environment influence is minimal for the traits studied.
- High estimates of heritability coupled with high to moderate genetic advance as percent over mean was recorded for all the characters studied and hence simple and early selection will be effective for these characters.
- In the character association studies, yield had positive and significant association with number of fruits per plant, fruit weight, fruit girth and number of primary branches indicating that selection for these characters may improve yield.
- Number of leaves with disease symptom exhibited significant positive association with number of white flies on leaves and leaf axil bearing first fruit.
- Five genotypes *viz.,* AE-2, AE-8, AE-28, AE-32 and AE-33 exhibited resistance to YVMV during all the crop stages.
- The confirmation studies for disease resistance in glass house by vector and graft transmission methods revealed that five genotypes namely AE-8 (Thirumala local), AE-32 (Kunnapuzha local), AE-33 (Holavanalli local), AE-2 (IC 1012-1) and AE-28 (Halu Bhendi) were resistant to the disease.
- In the line x tester analysis, the mean sums of squares due to genotypes were significant for all the characters studied.
- Combining ability analysis revealed higher magnitude of SCA variance for all the characters studied except days to first flowering and fruit girth indicating preponderance of non additive gene action.
- Among the lines, AE-33 (Holavanalli local) and AE-8 (Thirumala local) were identified as good parents for days to first flowering, number of fruits per

plant, fruit weight, fruit girth and yield per plant based on *per se* performance.

- Tester AE-34 (Mallapalli local) was adjudged as best for yield, fruit girth, fruit weight, number of fruits per plant, plant height, leaf axil bearing first fruit and days to first flowering based on *per se* performance.
- Among the hybrids cross combination Holavanalli local x Mallapalli local had high *per se* and *sca* effects for yield per plant, fruit length, fruit weight, number of fruits per plant, duration, plant height, number of primary branches, leaf axil bearing first fruit and days to first flowering followed by the cross combination Thirumala local x Punjab Phalgani which had high *sca* effects and standard heterosis for yield and yield contributing characters.
- The screening of the hybrids revealed that the crosses Holavanalli local x Mallapalli local, Kunnapuzha local x Punjab Phalgani, Thirumala local x Kattakada local, Thirumala local x Punjab Phalgani and Thirumala local x Mallapalli local were resistant to yellow vein mosaic virus disease.
- Based on *per se* performance for yield and disease resistance the hybrids Thirumala local x Kattakada local and Kunnapuzha local x Punjab Phalgani are also considered as good hybrids.
- The cross combination Holavanalli local x Mallapalli local (L_5 x T_3) showed significant standard heterosis for all the characters and hence recommended for heterosis breeding i.e. release as hybrid for commercial cultivation after detailed studies at different locations.

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ABSTRACT

8. ABSTRACT

The present investigation on "Variability for yield and resistance to yellow vein mosaic virus disease in okra (*Abelmoschus esculentus* (L.) Moench)" was conducted at the Department of Plant Breeding and Genetics and Department of Plant Pathology, College of Agriculture, Vellayani during 2011-2012 and evaluation of germplasm for genetic variability, character association and resistance to yellow vein mosaic disease, confirmation of disease resistance in selected genotypes through vector and graft transmission studies, development and evaluation of F_1's for combining ability, heterosis and disease resistance were done.

The okra germplasm consisting of thirty six accessions collected from different parts of Kerala and Karnataka was assessed for the extent of variability, heritability and genetic advance, the relationship among the yield and associated traits and disease scoring. Analysis of variance showed significant difference among the thirty six genotypes for all the characters studied. The germplasm possessed sufficient variability and offered scope for selection based on characters like plant height, number of primary branches, leaf axil bearing first fruit, duration, number of fruits per plant, fruit weight, fruit length and yield per plant. Five genotypes *viz.,* AE-2 (IC 1012-1), AE-8 (Thirumala local), AE-28 (Halu Bhendi), AE-32 (Kunnapuzha local)and AE-33 (Holavanalli local) exhibited resistance to YVMV during all the crop stages after scoring studies and resistance was confirmed to these selected ones by artificial transmission methods such as vector transmission and graft transmission in glass house. High genotypic and phenotypic coefficient of variation was noticed for almost all characters and narrow difference between GCV and PCV suggest that environmental influence is minimal for the traits studied. High estimates of heritability coupled with high to moderate genetic advance as percent over mean was recorded for all the characters considered. Yield had positive and significant association with number of fruits per plant, fruit weight, fruit girth and number of

primary branches indicating that selection based on these characters may improve yield. In the line x tester analysis, the mean sum of squares due to genotypes was significant for all the characters studied. Combining ability analysis revealed higher magnitude of SCA variance for all the characters except days to first flowering and fruit girth indicating preponderance of non additive gene action. Among the hybrids cross combination Holavanalli local x Mallapalli local had high *per se* and *sca* effects for yield per plant, fruit length, fruit weight, number of fruits per plant, duration, plant height, number of primary branches, leaf axil bearing first fruit and days to first flowering and was considered as the superior hybrid followed by the cross combination Thirumala local x Punjab Phalgani which had high *sca* effects and standard heterosis for yield and yield contributing characters. These hybrids were also resistant to yellow vein mosaic virus disease. Based on *per se* performance for yield and disease resistance scores the hybrids Thirumala local x Kattakada local and Kunnapuzha local x Punjab Phalgani can also be considered as good hybrids. The cross combination Holavanalli local x Mallapalli local showed significant standard heterosis for all the characters and hence recommended for heterosis breeding.