INHERITANCE OF RESISTANCE TO LEAF HOPPER, *Amrasca biguttula biguttula* (Ishida) IN OKRA, *Abelmoschus esculentus* (L.) Moench.

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DECLARATION

I hereby declare that this thesis entitled "**Inheritance of resistance to leafhopper, *Amrasca biguttula biguttula* (Ishida) 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, associateship, fellowship or other similar title, of any other university or society.

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CERTIFICATE

Certified that this thesis entitled "**Inheritance of resistance to leafhopper, *Amrasca biguttula biguttula* (Ishida) in okra, *Abelmoschus esculentus* (L.) Moench.**" is a record of research work done independently by Mrs. Deepthy Sivanandan (2001-11-17) under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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Deepthy Sivanandan

Dedicated to

Roy,
Deva & Ananthan

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LIST OF ABBREVIATIONS

%	per cent
ANOVA	Analysis of variance
CD	Critical difference
cm	Centimeters (s)
DAG	Days after germination
DAS	Days after sowing
df	degrees of freedom
et al.	and others
g	Gram(s)
GCV	Genotypic coefficient of variation
i.e.	That is
L x T	Line x Tester
m	Metre
MSE	Error mean square
PCV	Phenotypic coefficient of variation
SE	Standard error
viz.	Namely

INTRODUCTION

1. INTRODUCTION

Okra [*Abelmoschus esculentus* (L.) Moench] is a prominent vegetable crop cultivated extensively in India and abroad due to its export potential, high nutritive value and amenability for year round cultivation. Okra fruits in addition to high protein content are also rich source of vitamins A, B, C and minerals iron and iodine. It is also believed to have medicinal properties against genitourinary disorders, spermatorrhoea, chronic dysentery and goitre.

India is the largest producer of okra contributing 24,50,000 tons from an area of about 3,38,000 ha (Verma, 2000). Recently due to heavy demand for export the area under okra is steadily increasing, but the productivity remains low. Low productivity and heavy loss due to insect pests and diseases constraints the full exploitation of this potential crop. Breeding of varieties/hybrids having high yield potential coupled with ability to resist various biotic and abiotic stress is needed to boost okra cultivation.

The leaf hopper, *Amrasca biguttula biguttula* is the major sucking pest of okra which reduce the yield substantially. Heavy desapping and the effect of toxic components of saliva injected into the plant for easy sap flow are manifested as hopper burn affecting leaf area, photosynthetic ability, vigour and yield of the plant. Farmers often resort to repeated application of highly toxic chemical pesticides to tackle hopper menace without regard to observing the various precautions including adherence to specified waiting period following pesticide application. High frequency of fruit picking to obtain tender marketable fruits and repeated application of chemical pesticides at short intervals to control the pests leaves toxic residues in/on the fruit much above the tolerable limits exposing the consumer, to health hazards. Moreover unscrupulous pesticide application at times cause pest flare up due to development of insecticide resistant pests, resurgence of the target pest and secondary pest out break leading to crop failure. Hence alternate pest control tactics are being explored and integrated into the IPM system of okra to reduce the pesticide load on the crop.

Utilization of host plant resistance is currently receiving more attention in IPM systems. The use of resistant crop cultivars represents one of the simplest and most convenient methods of pest control from the point of view of the farmer, horticulturist and others (Dent, 1991).

Plant resistance is available at virtually no cost to the farmers yet it helps to stabilize yields. The most attractive feature of using pest resistant varieties for crops is that virtually no skill in pest control or cash investment is required of the grower (Dyck, 1974). A promising strategy for reducing the losses due to various insect pests therefore lies in the development of agronomically better suited strains or varieties of okra which would resist the attack of major pests.

Okra varieties resistant to the leafhopper are scarce. Hence the present programme aims at identifying leafhopper resistant/tolerant okra types .It also aims to study the inheritance of leafhopper resistance, yield and yield components in okra. The lines so identified/developed can be further used for direct cultivation or breeding purposes.

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The literature pertinent to the study is organized and presented hereunder.

2.1 THE CROP

Okra is a fast growing annual herb, the young pods of this being used as a common vegetable. It is commonly grown throughout the warmer parts of temperate Asia, southern Europe, northern Africa and all parts of the tropics.

The centre of origin is Hindustani comprising of India, Pakistan and Burma (Zeven and Zhukovski 1975).

Okra *Abelmoschus esculentus* belongs to the family Malvaceae. Chromosome numbers vary greatly among the members of the genus *Abelmoschus*. The lowest chromosome number (2n=56) was observed for *A. anguloses* (Ford, 1938) whereas the highest 2n number (about 200) was reported for *A. caillei* (Singh and Bhatnagar, 1975). Though great variation was observed for the chromosome number of *A. esculentus*, the most frequently observed chromosome number was 2n=130.

Okra is basically a self pollinated crop. But crossing of upto 60 per cent has been observed in okra depending on the species, variety, season and location (Engels and Chandel, 1990). Since selfing is usually common than crossing, okra is designated as an often cross pollinated crop.

2.2 THE PEST

The leafhopper *Amrasca biguttula biguttula* (Ishida) (Syn. *Amrasca devastans* Distant) (Homoptera : Cicadellidae) is a highly damaging, pest of okra (Nair, 1976). It is also called cotton leafhopper and green leafhopper.

It is a widespread pest of okra in tropical and subtropical areas of south and south east Asia. The population as such or its increase or decrease was not correlated with any meteorological parameters, except sunshine which showed a weak negative correlation. However leafhopper population increased whenever the mean temperature was near 30°C coupled with 5-8 6h sunshine per day. Rainfall tended to reduce leaf hopper population (Singh and Sekhon, 1998).

Symptoms of infestation are manifested as yellowing of leaves, curling of leaf tips, cupping of leaves and dark brown dead spots with yellow halo called hopperburn. Severely affected leaves desiccate and fall off.

The leafhoppers have sucking mouthparts and are phloem feeders, damaging phloem tubes and causes disease like symptoms called hopperburn.

The okra leafhopper lays its egg on the midrib of leaves, the incubation period of which is 8-10 days. The life cycle consists of five nymphal instars taking 2-3 weeks for completion. Adult lives for 10-15 days. The adults can be distinguished by presence of black spots on both sides of the vertex of the head as well as on the forewing. The pest has a wide host range which includes cotton and brinjal.

2.3 HOST PLANT RESISTANCE

Host plant resistance may be defined as the collective, heritable characteristics by which a plant species, race or clone or individual may reduce the possibility of successful utilization of that plant as a host by a pest species, race, biotype or individual (Beck, 1965). It includes those characters that enable the plant to avoid or tolerate insect attack or recover from injury caused by insect attack (Snelling, 1941).

Reaction of host plant to insect pest may vary from high level of resistance to extreme susceptibility. A variety that suffers lesser attack or lesser crop loss in the event of comparable pest population can be considered partially resistant (Dent, 1991).

Categorization of plant resistance phenomena into non-preference, antibiosis and tolerance by Painter (1951) is extremely useful and still widely employed. Genetic resistance is often a combination of two or even all three of these phenomena (van Emden, 1989; Norris and Kogan, 1980). Kogan and Ortman (1978) suggested the term 'antixenosis' to replace non-preference.

2.3.1 Mechanisms of Leafhopper Resistance in Okra

Tolerance is the term used when resistant plant is capable of supporting a population of insects without loss of vigour. Uthamasamy (1985) reported that tolerance is not much pronounced in leafhopper resistance as they are sucking pests.

Non-preference and antibiosis are two important mechanisms of leafhopper resistance. Russel (1978) emphasized the role of morphological and biochemical factors in deciding the level of non-preference in plants.

Level of resistance to leafhopper in cotton depends on the thickness of leaf and width of vascular tissues (Batra and Gupta, 1970). Higher hair density in the veins and leaf lamina were seen in resistant varieties of okra (Uthamasamy, 1985). Also leafhopper populations had significant negative correlation with all facets of hairiness. Lamina hair of adequate length is important in confering leafhopper resistance in okra. Plant height and stem thickness were also found to be directly related to resistance (Uthamasamy *et al.*, 1971).

Leafhopper resistant varieties of okra contain more total chlorophyll, xanthophylls and carotene than highly susceptible and susceptible varieties (Uthamasamy, 1985). It is generally held that resistant varieties are characterised by low organic acid content (Jayaraj, 1966).

Antibiosis refers to an adverse effect of feeding on a resistant host plant on the development and / or reproduction of the insect pest. This may be due to the presence of some metabolites that are harmful to the leafhopper or absence of some nutritional factors. High nymphal mortality, prolonged nymphal period and reduction in the size and weight of the adults are some of the antibiotic effects in okra. Also it takes only fewer days to complete lifecycle in susceptible varieties which means a quicker multiplication and a greater number of generations in a given period than on the resistant variety (Uthamasamy, 1986).

2.3.2 Sources of Resistance

Okra varieties such as White Velvet, Clemson Spineless, Crimson Smooth long etc are resistant to leafhopper. van Emden (1987) suggested the screening of commercial varieties at the initial stages of search for resistance to a pest since partial resistance may be found in some varieties, eventhough this character was not purposely selected during breeding programme.

Resistance is also found in traditional varieties and unimproved germplasm (Saxena and Khan, 1991) and search within the species is an important step. Resistance in an unadapted variety or wild relative calls for their transfer to commercial cultivars. Wild sources of leafhopper resistance identified are *Abelmoschus moshatus* and *Abelmoschus tuberculatus*.

Many leafhopper resistance sources have been identified.

- IIHR 21, AE 15, AE 30, IC 7194, IC 8899, Crimson Smooth Long, *Abelmoschus manihot* ssp *manihot* – (Sharma & Arora, 1993)
- *Abelmoschus moshatus, A. tuberculatus* (Sandhu *et al.*, 1974).
- Bhindi Lorai 1 and Bhindi Lorai 3 (Sharma and Gill, 1984).
- White Velvet, Clemson Spineless, Early Long Green, Long Green, AE 71 (Teli and Daleya, 1981)

Varieties with field resistance to leafhopper include Punjab Padmini, Ludhiana Selection 2 and EMS 8-1 (Lal, 1991).

Currently, conventional plant breeding offers the surest route to generate insect resistant crop varieties, provided a suitable resistance source can be found (Gatehouse, 1991).

2.3.3 Evaluation of Resistance

Resistance is normally measured through the effect of the exposure of plants or plant parts to the insects. It can be measured in terms of insects as number of eggs oviposited, aggregation, food preference, growth rate, food intake and utilization, mortality and longevity. A detailed account of techniques for evaluating plant resistance to insects was provided by Tingey (1986).

Field screening, screen house testing and morphological characteristics of the different accessions are used for the evaluation of leafhopper resistance in okra (Uthamasamy, 1986; Bindra and Mahal, 1979).

Hopperburn studies which involve the calculation of percentage area of leaves affected by hopperburn is also used (Jayaraj, 1966).

One week old okra plants can be used for screening (Mahal *et al.*, 1991). Plants are rated on number of nymphs and adults per leaf (Brar *et al.*, 1995).

2.3.4 Genetics of Leafhopper Resistance

Reports on the genetics of leafhopper resistance are rather scanty. According to Singh and Mahal (1982a), the ability to tolerate leafhopper attack at cotyledonary stage was governed by a single dominant gene in the resistant parent.

In another study, Singh and Mahal (1982b) reported that field resistance to leafhopper were controlled by dominant as well as partially dominant genes.

According to Sharma and Gill (1984) leafhopper resistance is controlled by dominant genes.

2.3.5 Leafhopper Incidence

The effect of intercropping okra with cotton was studied and it was found that okra was 3 to 10 times preferred to cotton and about five per cent of the cicadellids were diverted from cotton (Ali and Karim, 1989).

Thirteen okra varieties were screened for *Amrasca devastans* resistance and differences in nymphal population and *Amrasca devastans* injury index were evident. IC 7194, Punjab Padmini and New Selection harboured low pest populations compared to Pusa Sawani (Mahal *et al.*, 1993).

The time required to develop characteristic symptoms of damage to cotton plants by *Amrasca biguttula* was positively correlated with age of plants. Younger plants were more susceptible (Ali, 1990).

Both sowing time and crop growth stage influenced the insect population significantly and the crop was most susceptible at 50 DAS in an experiment conducted in Varanasi (Satpathy and Rai, 1998). Leafhopper incidence was found to be maximum during last week of July to mid September (24.8 – 32.6^{0}C) and 2nd fortnight of August to first fortnight of October in cotton (Gupta *et al.*, 1997).

2.3.6 Effect of Leafhopper on Yield

Early exposure to leafhopper infestation upto 15 days after germination in the early and normally sown crop resulted seed yield losses to the extent of 37.55 and 42.18 per cent respectively (Mahal *et al.*, 1994a).

The seed yield, plant height, number of fruits per plant, fruit length and 100 seed weight had inverse relationship with the cicadellid population which reduced these parameters by an average of 28.3- 47.3 per cent (Mahal *et al.*, 1994b).

2.4 GENETIC VARIABILITY

Presence of large extent of variability has been reported for several characters in okra by several researchers (Thaker *et al.*, 1981, Chedda and Fatokun, 1982). Vashistha *et al.* (1982) observed significant differences among varieties for yield and other agronomic characters.

Length and number of fruits and yield per plant exhibited considerable variability (Murthy and Bavaji, 1980).

Jeyapandi and Balakrishnan (1992) observed significant variability for yield / plant. Bindu (1993) reported significant variation among 70 genotype for several characters.

Gondane and Lal (1994) evaluated 50 genotypes and concluded that high level of variability existed in 11 yield components.

Bindu *et al.* (1997) observed wide range of variation for most of the traits including number of branches and leaves per plant, leaf area, fruit length, days to first flower, plant height and fruit weight per plant.

Rajani and Manju (1997) reported significant variation among six parental strains and their thirty F_1's for days to first flowering, number of leaves, flowers, number of fruits per plant, length and girth of fruits, fruit weight and yield per plant. Yassin and Anbu (1997) observed wide variability for single fruit weight, number of branches, number of fruits and yield per plant but not for length and girth of fruits.

Twenty two okra genotypes exhibited wide variation for plant height, days to first flower, number of leaves and number of fruits per plant, fruit weight and yield (Hazra and Basu, 2000).

Study of 44 okra genotypes collected from NBPGR by Gandhi *et al.* (2001) revealed significant variability for all the thirteen traits under investigation including plant height, height at first fruit set, internodal length, number of fruits and number of branches per plant, length and girth of fruits and yield per plant of dry fruits and seeds.

Dhankar and Dhankhar (2002) reported broad range of variation and high mean values in rainy season for fruit per plant, days to 50 per cent flower and number of branches per plant and in spring –summer season for fruit yield and plant height.

2.4.1 Coefficient of Variation

Thaker *et al.* (1981) noticed high GCV for plant height, leaf area, fruit number, fruit weight and yield per plant. According to Balachandran (1984), number and yield of fruits had high PCV and ECV. As per the reports of Balakrishnan and Balakrishnan (1988), number of fruits and yield per plant had high GCV and PCV.

High GCV was exhibited by fruit weight per plant, leaf area, plant height, number of fruits per plant, mean fruit weight and number of branches per plant while moderate PCV and GCV were noticed for average fruit weight (Sheela, 1994). High PCV was observed for number of fruits and yield per plant (Lakshmi *et al.*, 1995).

Bindu *et al.* (1997) observed high GCV for fruit weight per plant, single fruit weight, number of branches, number of fruits per plant and fruit length while it was low for days to first flower, fruit girth and leaf axil bearing first flower. Rajani and Manju (1997) reported high PCV and GCV for fruit yield per plant but low values for fruit girth, days to first flower and fruit length.

Hazra and Basu (2000) reported high GCV for number of primary branches and moderate for plant height, number of leaves, number of fruits and yield per plant.

Dhankar and Dhankhar (2002) noticed high PCV and GCV for number of branches, number of fruits, yield and plant height in both rainy and spring summer seasons. For fruit yield and plant height values of GCV and PCV were almost equal indicating the little effect of environment but days to first flower and number of fruits and number of branches per plant were influenced by environment.

2.4.2 Heritability and Genetic Advance

Phenotypic selection was suggested to be promising for pod number and yield due to their high heritability (Rao and Ramu, 1981).

Thaker *et al.* (1981) noticed moderate heritability for plant height, fruit length and number of fruits per plant but low heritability for leaf area, fruit weight and yield. These traits except number of fruits per plant displayed high genetic advance.

Balachandran (1984) reported that heritability was high for days to 50 per cent flowering, duration and number of branches per plant while heritability and genetic advance were moderately low in the case of length and number of fruits and single fruit weight. Heritability and genetic advance were low for yield.

Reddy *et al.* (1985) reported high heritability and genetic advance for number of branches and yield per plant while high heritability was reported by Alex (1986) for days to first flower and by El-Macksoud *et al.* (1986) for earliness in flowering, number of fruits and fruit weight.

Balakrishnan and Balakrishnan (1988) suggested number of fruits per plant and fruit weight per plant as efficient and reliable indices for improving the yield in okra as they had high heritability coupled with high genetic advance. Heritability as well as genetic advance were high for fruit weight per plant (Sheela, 1994). Yield per plant had high estimates of heritability and genetic advance (Rajani and Manju, 1997).

Bindu *et al.* (1997) reported that fruit length, single fruit weight and fruit weight per plant exhibited high heritability coupled with moderately high genetic advance. Moderate heritability and low genetic advance were noticed for number of leaves and flowers per plant and fruit girth whereas leaf axil of first flower and seeds per fruit had low heritability and genetic advance.

Gandhi *et al.* (2001) observed medium to high heritability for all characters studied, of which fruit length (64.4 per cent) height of first fruit set (55.88 per cent) and fruit girth (43.6 per cent) had high values.

2.4.3 Correlation and Path Analysis

Genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients as reported by Murthy and Bavaji (1980). Partap *et al.* (1982) observed a direct positive contribution of fruit number and single fruit weight towards yield. Vashistha *et al.* (1982) noticed that yield in bhindi depended primarily on plant height, number of fruits per plant and fruit length. Important yield contributing characters were number and length of fruits, earliness and flowering duration (Balachandran, 1984).

Alex (1986) observed positive correlation of yield with number of flowers, length of fruiting phase as well as number of fruits per plant, length and weight of fruits per plant. Mathews (1986) identified earliness, number of flowers and number for fruits per plant as the major yield contributing traits.

Yadav (1986) noticed high positive correlation of plant height, pod length and number of fruits with yield. Alex (1986) observed positive correlation of yield with number of flowers, length of fruiting phase as well as number of fruits per plant and weight of fruits per plant.

Sheela (1986) concluded that number of flowers, number of fruits, girth and weight of fruits and length of fruiting phase were the characters contributing towards yield.

Mishra *et al.* (1990) reported positive association of yield with plant height and number, length and weight of pods and days to flowering.

Veeraraghavathatham and Irulappan (1990) reported positive association of yield with internodal length and number of fruits per plant and girth of fruits. Ariyo (1992) suggested number of fruits per plant and weight of fruits as the major yield components.

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

Lakshmi *et al.* (1995) reported the positive association of number of fruits per plant and number of branches with yield. Subhasini *et al.* (1996) reported the existence of negative association of yield with days for pod setting.

Philip (1998) reported number of branches, flowers, number of fruits per plant and average fruit weight had positive association with number of fruits per plant.

Marketable yield per plant, fruit weight, fruit length and number of fruits per plant and plant height exhibited significant positive correlation as well as high direct effect with total yield per plant (Dhall *et al.*, 2000). Philip and Manju (2002) revealed significant positive correlation of yield per plant with number of branches, flowers and number of fruits per plant, average fruit weight and plant height.

2.5 COMBINING ABILITY

Poshiya and Vashi (1995) studied combining ability in okra under three environments for fruit yield and its eight contributing characters. It was found that GCA variance was higher in magnitude than SCA variance.

Higher *sca* effects were noticed for fruit yield by Singh and Singh (1979). Thaker *et al.* (1981) observed higher *gca* effects for length and average weight of fruits.

For fruit yield per plant, *sca* effect was significant, whereas both gca and *sca* effects were significant for days to 50 per cent flower, fruit length, fruit per plant and nodes per plant (Poshiya and Shukla, 1986).

Sadashiva (1988), in a 9 x 9 partial diallel analysis, found both *gca* and *sca* effects were important for the characters *viz.*, days to 50 per cent flower and first picking, plant height number of branches per plant, node of first flower, number of fruits and yield per plant and length, girth and weight of fruits. However GCA variances were higher than SCA variances.

Significant *gca* and *sca* effect were noticed by Patel *et al.* (1994) for different yield components in okra.

2.6 HETEROSIS

Hybrids exhibiting significant heterosis for fruit yield also exhibited heterosis for most characters studied. The best heterotic hybrids were not the cross combinations that exhibited maximum *sca* effects. Highest heterosis of 27.32 per cent for fruit yield was observed over better parent (Poshiya, and Vashi, 1995).

High relative heterosis and heterobeltiosis were observed by Elangovan *et al.* (1981) for plant height, number of branches earliness, first fruiting node, yield, 100-seed weight and fruit attributes (number, length and width).

Hybrid vigour in okra was reported by Partap *et al.* (1981) and Thaker *et al.* (1981, 1982). Heterosis for plant height, number of branches and number of fruits per plant were noticed by Dhillon and Sharma (1982). Heterosis over midparental value was positive for plant height, fruit traits (number, length and weight), and yield but negative for nodes per plant (Singh, 1983).

According to Kumbhani *et al.* (1993), the high heterosis for yield per plant noticed in 28 hybrids resulted from the combined effect of heterosis for yield components such as number of pods, girth and length of pods, plant height and internodal length.

Table 1. Gene action in Okra

Character	Additive	Non additive	Dominance
Days to first flower	Partap and Dhankar (1980) Partap *et al.* (1981, 1982)	Elangovan *et al.* (1981), Rajani (1995)	Wankhade *et al.* (1995)
Leaf axil bearing first flower	Partap *et al.* (1981)	Elangovan *et al.* (1981), Vijay and Manohar, (1986).	
Branches per plant	Patel *et al.* (1994) Yadav *et al.* (2002)	Elangovan *et al.*, (1981) Rajani and Manju (1997)	Lal *et al.* (1975)
Fruits per plant	Partap and Dhankar (1980) Partap *et al.* (1981) Yadav *et al.* (2002)	Partap and Dhankhar (1980), Partap *et al.* (1981)	Lal *et al.* (1975)
Fruit length	Partap and Dhankar (1980) Veeraraghavathatham and Irulappan (1991) Yadav *et al.* (2002)	Partap and Dhankar, (1980), Elangovan *et al.* (1981) and Veeraraghavathatham and Irulappan (1990)	Rajani (1995) Rajani and Manju (1997)
Fruit girth	Partap and Dhankar (1980) Veeraraghavathatham and Irulappan (1991) Yadav *et al.* (2002)	Veeraraghavathatham and Irulappan (1990)	
Fruit weight per plant	Veeraraghavathatham and Irulappan (1991)	Veeraraghavathatham and Irulappan (1991), Wankhade *et al.* (1995)	Rajani (1995) Rajani and Manju (1997)
Yield	Partap and Dhankar (1980) Veeraraghavathatham and Irulappan (1990) Partap *et al.* (1981) Yadav *et al.* (2002)	Partap *et al.* (1981)	Wankhade *et al.* (1995) Rajani and Manju (1997)
Leafhopper resistance			Singh and Mahal (1982a) Sharma and Gill (1984)

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present study was carried out at the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during the period of 2002-2003 to study the genetic basis and inheritance pattern of important quantitative characters including yield and leafhopper resistance in okra.

3.1 MATERIALS

Forty okra varieties collected from different sources formed the materials for the study. This includes local cultivars and improved varieties and were denoted as T_1 to T_{40}. Details of the materials are given in Table 2. These genotypes were screened for leafhopper resistance and evaluated for yield and component characters.

From this accessions five resistant/tolerant and three susceptible genotypes were identified. These genotypes were laid out in a crossing block with the resistant ones as lines (female parent) and susceptible ones as testers (male parent). Crossing was done in a line x tester fashion to produce fifteen hybrids which were then evaluated for leafhopper resistance and yield in two separate field experiments.

3.2 METHODS

3.2.1 Screening for Leafhopper Resistance and Yield

The varieties were evaluated in a field experiment in RBD with two replication for leafhopper resistance as well as yield and yield attributes. Spacing of 60cm between rows and 45cm between plants in a row was adopted. Each plot consisted of a single treatment of nine plants in a single row. The experiment was conducted during September to December

Table 2 List of treatments

Treatment Number	Name	Source
1	AE 210	Vegetable and Fruit Promotion Council Keralam
2	AE 211	"
3	AE 214	"
4	AE 219	"
5	AE 260	"
6	AE 264	"
7	AE 265	"
8	AE 275	"
9	AE 279	"
10	AE 280	"
11	IC 15537	"
12	IC 45792	"
13	IC 52322	"
14	IC 90230	"
15	IC 111500	"
16	IC 117229	"
17	Kanijramkulam	Kanjiramkulam, Thiruvananthapuram
18	Venganoor	Venganoor, Thiruvananthapuram
19	Maranelloor	Maranelloor, Thiruvananthapuram
20	Palappur	Palappur, Thiruvananthapuram

Table 2 Continued

Treatment Number	Name	Source
21	Nemom	Nemom, Thiruvananthapuram
22	Balaramapuram	Balaramapuram, Thiruvananthapuram
23	Venjaramood	Venjaramood, Thiruvananthapuram
24	Kalliyoor	Kalliyoor, Thiruvananthapuram
25	Thodupuzha	Thodupuzha, Idukki
26	Kolenchery	Kolenchery, Ernakulam
27	Kariavattom	Kariavattom, Thiruvananthapuram
28	Pachalloor	Pachalloor, Thiruvananthapuram
29	Vandithadom	Vandithadam, Thiruvananthapuram
30	Kattakada	Kattakada, Thiruvananthapuram
31	Kazhakuttom	Kazhakuttom, Thiruvananthapuram
32	Pothencodu	Pothencode, Thiruvananthapuram
33	Selection 13	College of Agriculture, Vellayani
34	Selection 46	College of Agriculture, Vellayani
35	Arka Anamika	IIHR, Bangalore
36	Arka Abhay	IIHR, Bangalore
37	Aruna	College of Agriculture, Vellayani
38	Kiran	Department of Plant Breeding and Genetics. College of Agriculture, Vellayani
39	Salkirthi	Department of Plant Breeding and Genetics, College of Agriculture, Vellayani
40	Varsha Upahar	Department of Plant Breeding and Genetics. College of Agriculture, Vellayani

2001. The experimental crop was raised adopting Package of Practices Recommendation of Kerala Agricultural University (1996).

Leafhopper population counts were taken following the sampling technique suggested by Singh and Kaushik (1990). Three leaves, one each from top, middle and bottom canopy of five randomly selected plants from each treatment were used for leafhopper estimation. The population, consisting of both adults and nymphs, in the leaves were counted at 45 DAG,60 DAG and 75 DAG and the most resistant and susceptible cultivars were identified. Leafhopper population counts and/or the extent of hopper burn are the criteria usually employed for resistance evaluation. Leafhopper injury evaluation on a 1-5 scale suggested by Bindra and Mahal (1979) was used. The resistant and susceptible varieties were selected based on the population count of leaf hoppers as well as the leaf hopper injury score.

Leafhopper injury evaluation on 1-5 scale

Grade	Level of injury	Description
1	No damage	Entire leaf green
2	Low damage	25 per cent leaf showing hopper burn, yellowing at margins
3	Medium damage	50 per cent leaf area showing hopper burn, slight cupping at margins
4	High damage	75 per cent leaf area showing hopper burn, severe cupping, bronzing
5	Severe damage	Entire leaf showing hopper burn, petiole and leaf dries

Biometric observations of all the genotypes were recorded to study the variability for yield and yield attributes.

3.2.2 Crossing Programme

Five resistant / tolerant varieties and three susceptible varieties were raised in a crossing block adopting spacing of 60 x 45 cm. Crosses were effected using resistant / tolerant varieties as lines and three susceptible varieties as testers.

The technique of crossing suggested by Giriraj and Rao (1973) was adopted. On the previous evening of crossing the mature flower buds of both lines and testers which are due to open the next day were selected and the buds of testers were covered with butter paper cover to avoid contamination by foreign pollen. In case of lines, a circular cut was made around fused calyx of the bud at about 1 cm from its base. Calyx cup and corolla were retained like hood exposing staminal column and stigma. The anthers were scraped off and flower buds were protected with butter paper covers. Pollination was done the next morning between 8-10 am by rubbing the stigma of parental lines with pollen grain collected from respective testers. After pollination, the flower were again covered and labeled. The covers were removed a day after pollination. The labeled mature fruits were harvested separately and F_1 seeds were extracted.

3.2.3 Evaluation of Parents and Hybrids for Leafhopper Resistance

The experiment was laid out in RBD with three replications. Each plot consisted of a single row of nine plants of a single variety at a spacing of 60cm between rows and 45 cm between plants of a row. The experiment was conducted during January to April 2003. The fifteen F_1 hybrids along with parents were evaluated for leafhopper resistance following the screening procedure explained before taking a random sample of five plants per treatment for each replication.

3.2.4 Evaluation of Parents and Hybrids for Yield

The experiment was laid out in RBD with three replications, during January to April 2003.The spacing adopted was 60cm between rows and 45 cm between plants in a plot of size 2.4m x3.6m. Biometric observations were recorded on yield and yield attributes.

3.3 OBSERVATIONS RECORDED

3.3.1 Leafhopper Screening

a. Leafhopper population count at different stages of crop growth based on the sampling technique suggested by Singh and Kaushik (1990).

b. Leaf hopper injury evaluation on 1-5 scale (Bindra and Mahal, 1979) Grading was based on the extent of curling and cupping of leaves consequent to leafhopper infestation.

3.3.2 Biometric Observations on Yield Traits

a. Days to first flowering

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

b. Leaf axil bearing first flower

The number of the leaf axil from which the first flower was produced were recorded.

c. Number of primary branches

The number of primary branches from each observational plant was recorded.

d. Number of Fruits

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

e. Length of Fruit (cm)

The length of fruit from the base to the tip was measured from ten random fruits picked during third harvest and their mean expressed in cm.

f. Girth of Fruit (cm)

The fruits used for measuring length were used. The girth at the middle were taken and the mean expressed in cm.

g. Weight of Fruit (g)

The weight of fruits were taken from each observational plant during harvest and mean weight expressed in gram.

h. Yield per Plant (g)

The total weight of fruits obtained in different harvests from each observational plant was expressed in grams.

i. Duration

The number of days taken from sowing to final harvest was recorded.

3.4 STATISTICAL ANALYSIS

The data collected for the field experiments were subjected to statistical analysis.

3.4.1 Evaluation of Genotypes for Leafhopper Resistance and Yield

3.4.1.1 Analysis of Variance (ANOVA)

ANOVA was carried out for the leafhopper score and level of injury as well as biometrical characters.

ANOVA for each characters

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

Where r = number or replication, t = number of treatments, MSR = replication mean square, MST = Treatment mean squares, MSE = error variance.

3.4.1.2 Estimation of Genetic Parameters

a) Genetic Components of Variance

i) Genotypic variance (V_G)

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

ii) Environmental variance (V_E)

$$V_E = MSE$$

iii) Phenotypic variance (V_P)

$$V_P = V_G + V_E$$

b) Coefficient of variation

Phenotypic and genotypic coefficient of variation, PCV and GCV were estimated using estimates of V_G and V_P and expressed in per cent (Burton, 1952) for each trait.

(i) Phenotypic coefficient of variation (PCV)

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

ii) Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{V_G}}{(\bar{x})} \times 100$$

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

c) **Heritability**

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

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

Heritability was categorized as :

<30 %	-	low	
31-60 %	-	moderate	
>60 %	-	high	(Johnson *et al.*, 1955)

d) **Genetic Advance**

$$GA = K.\ H^2\sqrt{V_P}$$

Where K is the standardized selection differential, 2.06 at five per cent selection intensity.

$$\text{Genetic advance (as \% of mean)} = \frac{K.H^2\sqrt{V_P}}{\overline{x}} \times 100$$

Genetic advance was categorized as :

< 10 per cent	-	low	
11-20 per cent	-	moderate	
> 20 per cent	-	High	(Johnson *et al.*, 1955)

3.4.1.3 Association Analysis

3.4.1.3.1 Correlation Analysis

Correlation analysis was done to find the degree of association among various leaf hopper damage parameters.

Phenotypic correlation coefficient $r_{Pxy} = \dfrac{Cov_P(x,y)}{\sqrt{V_{P(x)}\ V_{P(y)}}}$

Genotypic correlation coefficient $r_{Gxy} = \dfrac{Cov_G(x,y)}{\sqrt{V_{G(x)}\ V_{G(y)}}}$

Environmental correlation coefficient $r_{Pxy} = \dfrac{Cov_E(x,y)}{\sqrt{V_{E(x)}\ V_{E(y)}}}$

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

$V_{P(x)}$, $V_{G(x)}$ and $V_{E(x)}$ are the phenotypic, genotypic and error variance for x, in that order and $V_{P(y)}$, $V_{G(y)}$ and $V_{E(y)}$ are the phenotypic, genotypic and error variance for y respectively.

3.4.1.3.2 Path Analysis

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

3.4.2 Evaluation of Parents and Hybrids for Leafhopper Resistance

3.4.2.1 ANOVA

ANOVA for RBD was carried out to test the significant difference among the leafhopper population counts of hybrids as well as parents and hybrids.

3.4.2.2 Line x Tester

For estimation of combining ability and gene action of leafhopper resistance parameters.

3.4.2.2.1 Combining ability analysis

The combining ability analysis was carried out in the L x T method described by Kempthorne (1957). The general combining ability (GCA) of parents and specific combining ability (SCA) of hybrids were estimated. The mean squares due to various sources of variation and their genetic expectation were estimated as follows.

ANOVA for line x tester analysis

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

Where, df = degree of freedom

r = number of replication

l = Number of lines

t = Number of testers

Cov. F.S. = Covariance of full sibs

Cov. H.S. = Covariance of half sibs

Mean squares due to lines M_1 and testers M_2 are tested against the mean square due to line X tester, M_3. Mean square due to L x T is tested against mean square due to error.

Using the genetic expectations of mean squares, variance due to general combining ability (σ^2 GCA) and variance due to specific combining ability (σ^2 SCA) were worked out.

a. Variance due to general combining ability

σ^2 GCA = Covariance of half sibs

$$= \frac{(M_1 - M_3) + (M_2 - M_3)}{r\,(l + t)}$$

b. Variance due to specific combining ability

σ^2 SCA = Covariance of full sibs – 2 Covariance of half sibs

$$= \frac{M_3 - M_4}{r}$$

From variance due to GCA and SCA, the additive genetic advance (σ^2A) and dominance genetic variance (σ^2D) were worked out as follows assuming F = 1.

$\sigma^2 A = 2\sigma^2 GCA$

$\sigma^2 D = \sigma^2 SCA$

c. Estimation of *gca* and *sca* 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 X_{ijk} = ijkth observation

μ = population mean

g_i = *gca* effect of ith line

g_i = *gca* effect of jth tester

s^{ij} = *sca* effect of ijth hybrid

e_{ijk} = effor associated with ijk[th] hybrid

$i = 1, 2, \ldots l$

$j = 1, 2, \ldots t$

$k = 1, 2, \ldots r$

The individual effects were estimated as follows :

$$\text{Mean} = \frac{x\ldots}{rlt}$$

1. *gca* effect of lines

$$g_i = \frac{x_i}{rt} - \frac{x\ldots}{rlt} \quad i = 1, 2, \ldots l$$

2. *gca* effect of testers

$$g_j = \frac{x_{.j.}}{rt} - \frac{x\ldots}{rlt} \quad j = 1, 2, \ldots t$$

3. *sca* effect of hybrids

$$s_{ij} = \frac{x_{ij.}}{r} - \frac{x_{i..}}{rt} - \frac{x_{.j.}}{rl} + \frac{x\ldots}{rlt}$$

where

$x\ldots$ = Sum of all hybrids combination over 'r' replication

$x_{i..}$ = Sum of all hybrids involving i^{th} line as one parent over t testers and r replications

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

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

Significance of combining ability effects was tested as follows.

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

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

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

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

Proportional Contribution

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

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

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

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

3.4.3 Evaluation of Hybrids and Parents for Yield

3.4.3.1 ANOVA

For yield and other component characters, the biometric observations were subjected to ANOVA (Panse and Sukhatme, 1985) for comparison among various treatments and to estimate variance components.

3.4.3.2 Line x Tester Analysis

Line x tester and combining ability analysis were carried out as described earlier.

3.4.3.3 Heterosis

Extent of heterosis was computed for all the 15 hybrids as relative heterosis (RH), standard heterosis (SH) and heterobeltiosis (HB) using the following formulae and expressed as percentage.

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

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

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

Where

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

$\overline{MP}$ – Midparental value

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

$\overline{BP}$ – Mean of better parent in that particular row

The significance was tested using 't' test.

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

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

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

RESULTS

4. RESULTS

Forty genotypes were collected and evaluated at the College of Agriculture, Vellayani. Data collected on eleven characters *i.e.*, nine biometric characters and two leafhopper resistance indices (leafhopper population count and leaf hopper injury score) were subjected to statistical analysis and utilized for the study of genetic variability. Five leafhopper resistant lines and three susceptible testers were identified and crossed in a L x T fashion. Five lines, three testers and their fifteen hybrids were evaluated in a field experiment and the data collected were subjected to L x T analysis for the estimation of general and specific combining ability.

4.1 GENETIC VARIABILITY

Analysis of variance for the eleven characters under study revealed significant differences among genotypes for all the characters studied, *viz.*, days to first flowering, leaf axil bearing first flower, number of primary branches, number of fruits, length of fruit, girth of fruit, weight of fruit, yield per plant, duration, leaf hopper population count as well as leaf hopper injury score. The mean performance of the genotypes are furnished in Table 3.

The mean data collected on eleven characters were subjected to analysis of variance for testing significant differences among the genotypes and the ANOVA for all the characters studied is given in Table 4.

1 Days to First Flower

The mean performance of genotypes ranged from 32.43 (T_{27}) to 67.36 (T_{39}). T_{27} was the earliest flowering type and T_{39} took the maximum time for flowering.

a. Field screening of 40 accessions for leafhopper resistance and yield

b. Line x tester experiment

Plate 1

Table 3 Mean values of 9 biometric characters and 2 leafhopper resistance indices in okra

Genotype	Days to first flowering	Leaf axil bearing first flower	No. of primary branches	No. of fruits	Length of fruit (cm)	Girth of fruit (cm)	Weight of fruit (g)	Yield per plant (g)	Duration	Leaf hopper population count	Leaf hopper injury score
T_1	41.40	4.88	1.00	4.20	23.55	7.02	24.45	111.52	88.82	13.84	2.00
T_2	56.75	5.88	2.50	6.74	14.63	6.33	24.47	143.87	84.94	14.50	2.00
T_3	40.20	3.63	0.83	5.24	19.15	7.72	17.61	106.90	90.77	12.67	2.00
T_4	42.65	5.63	0.66	4.94	22.86	7.30	23.12	116.92	96.88	11.00	1.84
T_5	42.50	4.88	2.77	5.45	21.60	7.99	21.01	119.65	99.61	11.17	1.84
T_6	41.10	5.63	2.00	4.49	15.91	9.13	23.51	109.86	103.26	19.17	2.33
T_7	40.00	4.88	0.50	5.45	18.36	6.45	24.92	139.26	87.10	9.67	1.33
T_8	49.20	5.50	0.00	2.99	22.45	6.50	24.37	76.25	94.42	10.33	1.84
T_9	40.60	4.88	2.50	4.97	18.75	7.71	29.62	154.61	107.91	6.17	1.17
T_{10}	43.21	5.50	0.33	6.01	14.93	5.65	24.00	124.14	96.02	12.17	1.67
T_{11}	40.40	4.65	0.50	6.15	17.79	6.44	25.96	167.60	87.16	10.00	1.84
T_{12}	58.16	4.25	0.66	5.06	19.74	6.75	28.18	149.67	110.64	6.33	1.17
T_{13}	43.20	3.50	0.66	6.45	17.09	5.24	19.27	114.63	87.83	13.17	2.67
T_{14}	39.31	4.63	0.00	6.80	14.20	7.03	25.84	172.29	80.73	10.67	1.84
T_{15}	45.90	5.75	0.00	9.84	22.34	4.87	27.02	266.21	78.60	9.17	1.34
T_{16}	40.40	4.38	0.00	7.13	15.49	6.56	20.70	141.35	83.04	7.84	1.34
T_{17}	34.11	6.63	0.00	4.08	19.91	6.01	19.03	85.27	89.26	10.33	1.50
T_{18}	44.76	5.63	0.33	4.54	21.89	6.85	28.36	160.76	100.87	17.17	2.17
T_{19}	44.60	5.63	0.00	6.98	21.33	7.85	32.11	215.00	80.95	11.87	2.17
T_{20}	41.90	4.50	0.50	7.19	16.99	5.94	28.91	213.60	117.08	11.00	1.17
T_{21}	40.75	5.38	2.51	8.65	19.98	6.60	32.51	251.91	109.88	4.17	1.00
T_{22}	38.10	3.88	0.50	10.01	16.98	4.15	28.27	283.74	102.68	4.17	1.00
T_{23}	41.94	4.00	2.00	13.10	18.97	6.05	19.52	236.97	110.01	5.33	1.00
T_{24}	43.40	5.75	1.00	5.43	21.15	4.76	20.92	112.32	98.68	38.00	3.00
T_{25}	51.37	5.88	1.00	4.59	21.40	7.82	26.69	126.56	90.15	18.67	2.17
T_{26}	43.61	4.88	0.66	4.09	21.68	6.68	27.38	120.98	92.71	13.33	1.84
T_{27}	32.43	3.75	1.00	5.92	25.82	8.31	34.36	212.74	98.38	14.00	2.68
T_{28}	47.22	4.13	2.51	7.05	17.99	7.75	27.07	208.80	100.43	9.67	1.50
T_{29}	43.41	4.13	2.51	6.07	24.25	7.42	33.94	231.31	111.99	9.00	1.50
T_{30}	56.51	4.50	0.50	4.78	20.31	6.36	25.99	115.10	104.34	11.84	2.17
T_{31}	41.40	4.75	2.50	10.05	16.60	5.05	26.04	266.63	78.58	10.67	1.67
T_{32}	37.07	3.75	0.33	6.18	25.23	5.60	27.82	161.39	77.97	11.34	1.83
T_{33}	34.42	5.13	1.00	6.68	20.62	6.07	28.21	192.71	92.38	9.00	1.50
T_{34}	53.48	5.17	0.50	6.19	20.20	5.38	30.75	175.90	103.98	8.83	1.50
T_{35}	53.95	4.65	1.17	8.28	17.60	6.66	24.25	192.51	102.57	9.33	1.67
T_{36}	51.66	5.80	0.50	5.15	16.46	5.54	22.58	129.58	86.74	11.33	1.67
T_{37}	59.24	5.85	1.51	6.87	18.67	4.59	24.95	149.64	97.03	26.50	2.68
T_{38}	56.60	4.93	0.33	6.02	16.76	5.41	24.99	146.46	87.88	11.00	2.00
T_{39}	67.36	6.50	0.50	5.70	20.40	5.55	24.12	124.76	92.41	19.00	2.17
T_{40}	42.38	4.08	0.00	13.11	18.99	5.83	28.35	350.82	113.90	7.33	1.00
CD	3.110	0.597	0.387	1.282	2.673	0.871	1.587	6.193	2.360	6.347	0.628

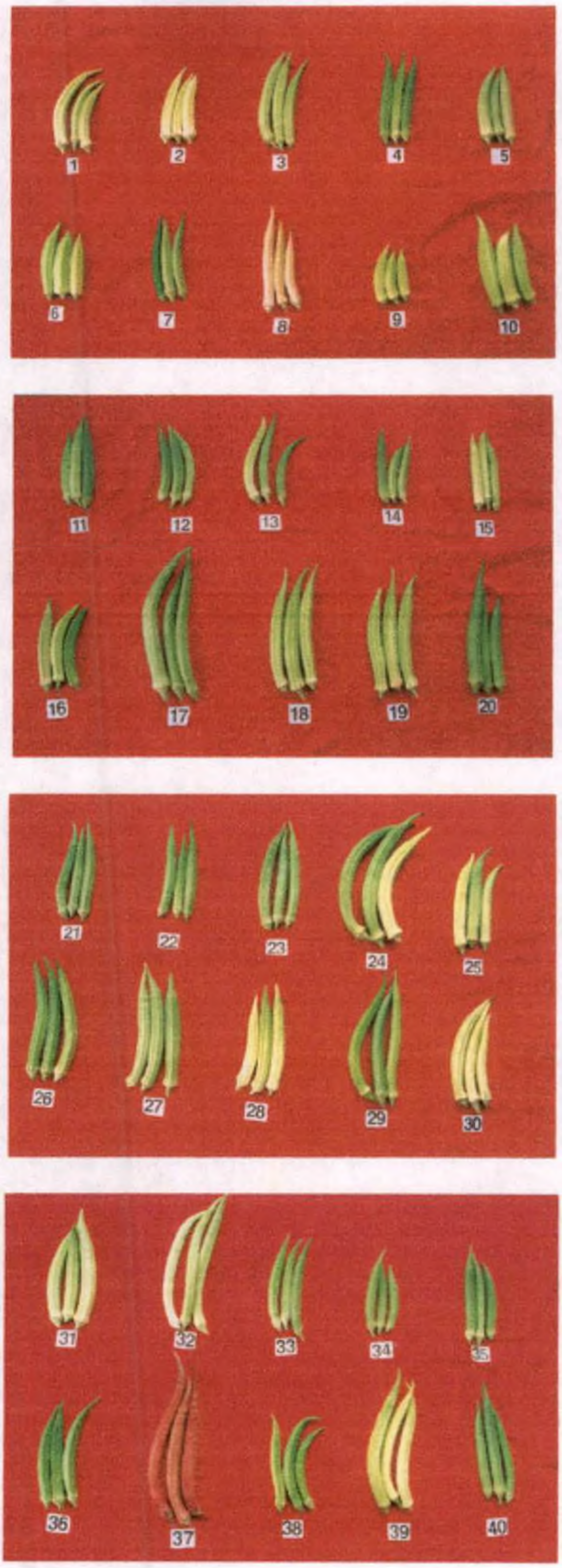


Plate II Variability in fruits of *Abelmoschus esculentus* (L.) Moench

a. Leafhopper – *Amrasca biguttula biguttula* (Ishida)

b. Leaf showing curling and crinkling due to leafhopper infestation

Plate III

Table 4 ANOVA for 11 characters in okra

Sl. No.	Characters	Mean square	
		Treatment df = 39	Error df = 39
1	Days to first flowering	117.51**	2.37
2	Leaf axil bearing first flower	1.28**	0.08
3	Number of primary branches	1.55**	0.04
4	Number of fruits	9.87**	0.40
5	Length of fruit (cm)	16.68**	1.75
6	Girth of fruit (cm)	2.47**	0.19
7	Weight of fruit (g)	31.85**	0.62
8	Yield per plant (g)	344.51**	9.37
9	Duration	223.28**	1.36
10	Leaf hopper population count	72.78**	9.84
11	Leaf hopper injury score	0.50**	0.09

**1 % level of significance, *5 % level of significance

2 Leaf Axil Bearing First Flower

Six genotypes T_3, T_{22}, T_{23}, T_{27}, T_{32} and T_{40} were on par, with T_{13} which had the lowest value 3.5 for leaf axil bearing first flower. The highest value was for T_{17} (6.63) and this was on par with T_{39}.

3 Number of Primary Branches

The number of primary branches were nil for seven genotypes, *i.e.* T_8, T_{14}, T_{15}, T_{16}, T_{17}, T_{19} and T_{40}. The next lowest value 0.33 were obtained for four genotype T_{10}, T_{18}, T_{32} and T_{38} and 12 genotypes were on par with it. The highest value was obtained for T_5 (2.77) and six genotypes on par with it.

4 Number of Fruits

The number of fruits ranged from 2.99 (T_8) to 13.11 (T_{40}). The lowest number of fruits were obtained for T_8.

5 Length of Fruit (cm)

The mean values ranged from 14.20 (T_{14}) to 25.82 (T_{27}). Three genotypes T_1, T_{29} and T_{32} were on par with the longest fruit bearing genotype T_{27} while nine genotypes were on par with T_{14}.

6 Girth of the Fruit (cm)

The highest mean value for girth was recorded by T_6 (9.13) and T_{27} was on par with it. Lowest mean value 4.15 was for T_{22} and three genotypes T_{15}, T_{24} and T_{37} were on par with it.

7 Weight of Fruit (g)

There was a wide range of variation among genotypes 17.61 (T_3) to 34.36 (T_{27}). T_{29} was on par with T_{27} and T_{17} was on par with T_3.

8. Yield per Plant (g)

The best yielder was T_{40} with 350.82 g where the lowest yielder was T_8 with 76.25 g. There was wide range of variation in yield between genotypes.

9 Duration

There was wide variation in duration for the different genotypes studied. The lowest (77.97) and highest (117.08) values were for T_{32} and T_{20} respectively. Genotypes T_{15} and T_{31} were on par with T_{32}.

10 Leaf hopper population count

The highest population was observed for T_{24} (38.00) and lowest for T_{21} and T_{22} (4.17). Sixteen other genotypes were on par with T_{22}. Higher population counts were exhibited by T_{37} (26.50) and T_6 (19.17) also, and eight other genotypes were on par with T_6.

11 Leaf hopper injury score

The highest score obtained was 3.00 (T_{24}) and the least susceptible were four genotypes (T_{21}, T_{22}, T_{23} and T_{40}) with a score of 1.00. Eleven genotypes were on par with T_{40}. Three genotypes T_{13}, T_{27} and T_{37} were on par with T_{24}, the most susceptible one among the genotypes studied.

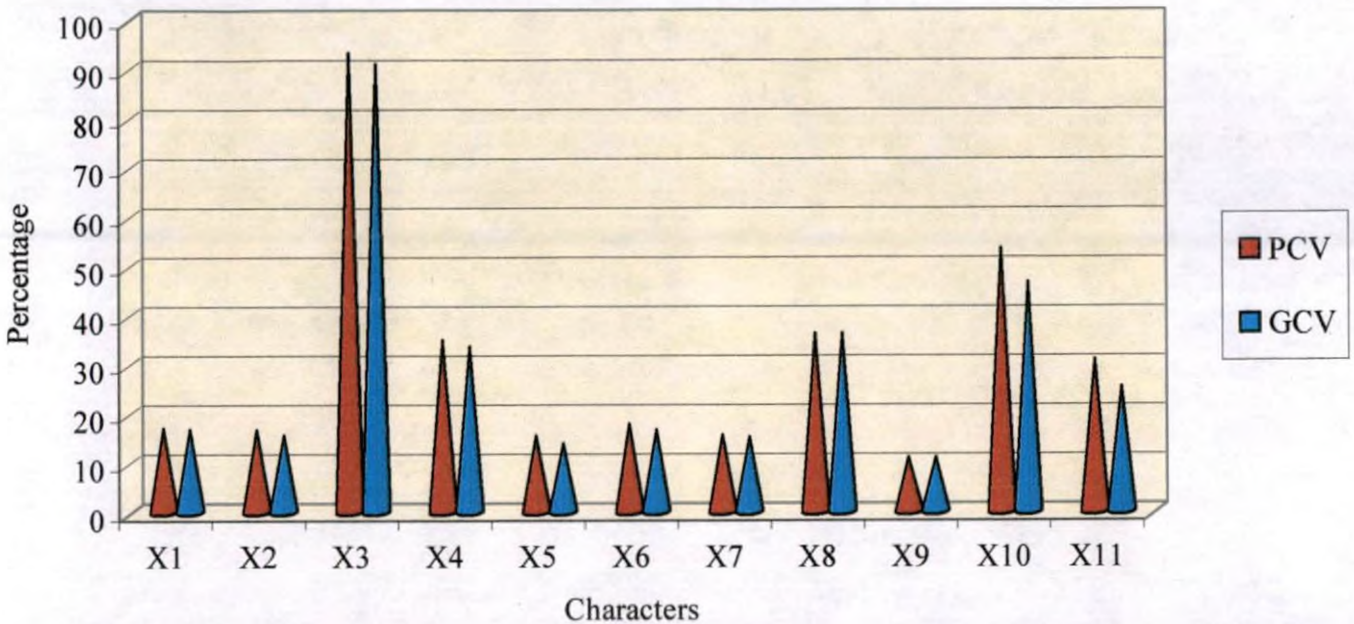
4.2 GENETIC PARAMETERS

The genetic parameters *viz.*, phenotypic and genotypic coefficients of variation, heritability and genetic advance for each character under study are presented in Table 5. The GCV and PCV for the 11 characters are graphically represented in figure 1.

Among the different characters studied, the magnitude of PCV was high for number of primary branches (93.23) followed by leafhopper

Table 5 Genetic parameters in okra

Sl. No.	Characters	PCV	GCV	GA (% mean)	H^2 (%)
1	Days to first flowering	17.14	16.80	33.91	96.05
2	Leaf axil bearing first flower	16.73	15.62	30.07	87.25
3	Number of primary branches	93.23	91.06	180.53	95.39
4	Number of fruits	35.05	33.65	65.58	92.17
5	Length of fruit (cm)	15.59	14.03	25.65	81.05
6	Girth of fruit (cm)	17.97	16.67	31.37	85.99
7	Weight of fruit (g)	15.63	15.33	30.53	96.21
8	Yield per plant (g)	36.31	36.26	73.53	99.76
9	Duration	11.10	11.03	22.26	98.79
10	Leaf hopper population count	53.49	46.68	82.71	76.17
11	Leaf hopper injury score	30.91	25.43	42.42	67.68

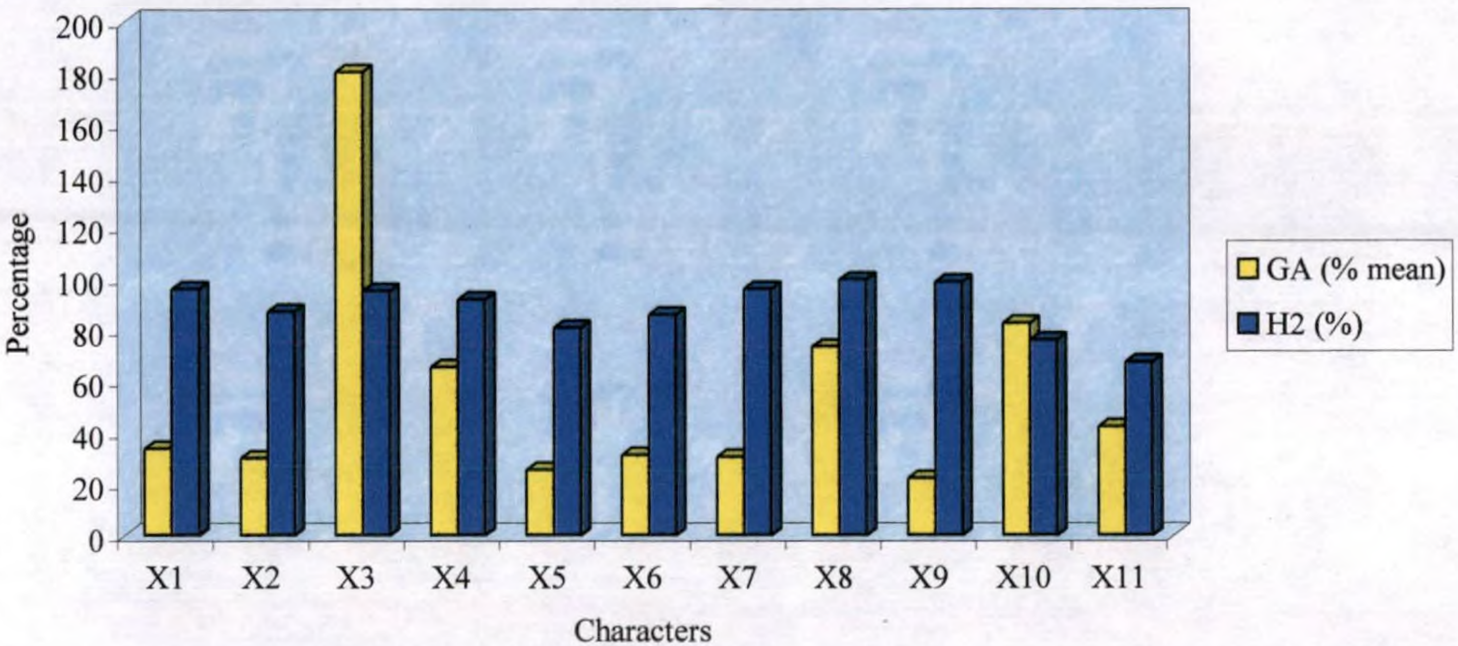


X1 - Days to first flowering
X2 - Leaf axil bearing first flower
X3 - Number of primary branches
X4 - Number of fruits per plant
X5 - Length of fruit

X5 - Length of fruit
X6 - Girth of fruit
X7 - Weight of fruit
X8 - Yield per plant

X9 - Duration
X10 - Leafhopper population count
X11 - Leafhopper injury index

Fig. 1 PCV and GCV for nine biometric characters and two leafhopper resistance indices in okra



X1 - Days to first flower
X2 - Leaf axil bearing first flower
X3 - Number of primary branches
X4 - Number of fruits per plant
X5 - Length of fruit
X5 - Length of fruit
X6 - Girth of fruit
X7 - Weight of fruit
X8 - Yield per plant
X9 - Duration
X10 - Leafhopper population count
X11 - Leafhopper injury index

Fig. 2 Heritability and genetic advance for nine biometric characters and two leafhopper resistance indices in okra

population count (53.49), number of fruits (35.01), leafhopper injury score (30.91). The other characters showed moderate values of PCV.

High values of GCV were recorded for the characters, number of primary branches (91.06), leafhopper population count (46.68), yield per plant (36.26), number of fruits per plant (33.65) and leafhopper injury score (25.43). All the other characters recorded moderate values for GCV.

Estimates of broad sense heritability and genetic advance are graphically represented in Fig. 2. Very high heritability was exhibited by yield per plant (99.76) followed by duration (98.79). Lowest heritability among the characters was observed for leafhopper injury score.

Maximum genetic advance was observed for number of primary branches (180.53) followed by yield per plant (73.53). All characters showed high genetic advance.

4.3 ASSOCIATION ANALYSIS

4.3.1 Correlations

(1) Phenotypic Correlation

Phenotypic correlation coefficients estimated for 11 characters are furnished in Table 6.

Days to first flowering had positive correlation with leaf axil bearing first flower (0.3416).

Leaf axil bearing first flower has significant positive correlation with leafhopper population count (0.3818) but it was negatively associated with number of fruits (-0.3198) and yield (-0.3410).

Number of primary branches did not have any significant correlation with any of the other parameters.

Table 6 Phenotypic correlation among 11 characters

Characters	Days to first flower	Leaf axil bearing first flower	Number of primary branches	Number of fruits	Length of fruit (cm)	Girth of fruit (cm)	Weight of fruit (g)	Yield per plant (g)	Duration	Leaf hopper population count
Leaf axil bearing first flower	0.3416*									
Number of primary branches	-0.0082	-0.0802								
Number of fruits	-0.1236	-0.3198*	0.1197							
Length of fruit (cm)	-0.1331	-0.0093	-0.0562	-0.2364						
Girth of fruit (cm)	-0.2330	-0.0916	0.2866	-0.3746*	0.2395					
Weight of fruit (g)	-0.0550	-0.1073	0.0952	0.0945	0.3395*	0.1641				
Yield per plant (g)	-0.2065	-0.3410*	0.1336	0.8402**	-0.0205	-0.2180	0.5369**			
Duration	0.0698	-0.1981	0.3046	0.1668	0.0786	0.1213	0.2813	0.2633		
Leaf hopper population count	0.2166	0.3818*	-0.0176	-0.3187	0.1083	-0.0807	-0.2312	-0.3925*	-0.1201	
Leaf hopper Injury score	0.1717	0.2280	-0.0615	-0.4264**	0.1615	0.0807	-0.1891	-0.4712**	-0.2859	0.7700**

**1 % level of significance, *5 % level of significance

Table 7 Genotypic correlation among 11 characters in okra

Characters	Days to first flower	Leaf axil bearing first flower	Number of primary branches	Number of fruits	Length of fruit (cm)	Girth of fruit (cm)	Weight of fruit (g)	Yield per plant (g)	Duration	Leaf hopper population count
Leaf axil bearing first flower	0.3598*									
Number of primary branches	0.0025	-0.0795								
Number of fruits	-0.1153	-0.3531*	0.1308							
Length of fruit (cm)	-0.1682	-0.0289	-0.0212	-0.2568						
Girth of fruit (cm)	-0.2693	-0.0886	0.3181	-0.4310**	0.2581					
Weight of fruit (g)	-0.0516	-0.1241	0.0960	0.1058	0.3761*	0.1848				
Yield per plant (g)	-0.2093	-0.3662*	0.1359	0.8789**	-0.0205	-0.2341	0.5487**			
Duration	0.0759	-0.2173	0.3196*	0.1728	0.0728	0.1268	0.2892	0.2642		
Leaf hopper population count	0.2673	0.4589**	0.0150	-0.3829*	0.1139	-0.0988	-0.2733	-0.4533**	-0.1523	
Leaf hopper Injury score	0.2260	0.1972	-0.0376	-0.5431**	0.2262	0.1352	-0.2188	-0.5765**	-0.3671	0.8879**

**1 % level of significance, *5 % level of significance

Number of fruits was closely associated positively with yield (0.8402) whereas it was negatively correlated with girth of fruit (-0.3746), and leafhopper injury score (-0.4264).

Length of fruit was positively correlated with weight of fruit (0.3395). Yield per plant had a very significant and negative correlation with leafhopper population count (-0.3925) and leafhopper injury score (-0.4712) but a significant positive correlation with weight of fruit (0.5369).

Leafhopper population count was positively associated with leaf axil bearing first flower and leafhopper injury score whereas it had negative correlation with yield.

Leafhopper injury score had a positive association with leafhopper population (0.7700) but a negative association was observed for yield and number of fruits.

(2) Genotypic Correlation

Genotypic correlation coefficients among the eleven characters were estimated and are presented in Table 7.

Days to first flowering was significantly and positively associated with leaf axil bearing first flower (0.3598).

Leaf axil bearing first flower and leafhopper population count had a positive correlation (0.4589) whereas number of fruits (-0.3531) per plant and yield (-0.3662) were negatively associated with it.

Number of primary branches and duration (0.3196) had a positive association.

Number of fruits had a positive correlation with yield (0.8789), but it was negatively correlated with girth of fruit (-0.4310), leafhopper population count (-0.3829).

Length of fruit was positively associated with weight of fruit (0.3761). Girth of fruit had negative correlation with number of fruits.

Weight of fruit was positively associated with length of fruit (0.3761) as well as yield (0.5487).

Positive significant association was observed for number of fruits and weight of fruit with yield whereas negative correlation was observed for leaf axil bearing first flower, leafhopper population count (-0.4533) and leafhopper injury score.

Duration of plant showed significant correlation with number of primary branches (0.3196).

Positive association was observed between leafhopper population count with leaf axil bearing first flower (0.4589) and leafhopper injury score (0.8879). Negative correlation existed between leafhopper population and yield as well as number of fruits (-0.3829).

Leaf hopper injury score had a negative correlation with number of fruits (-0.5431) and yield (-0.5765).

(3) Environmental Correlation

Environment correlation coefficients were estimated for 11 characters are presented in Table 8.

Significant positive correlation was observed between leaf axil bearing first flower and leafhopper injury score (0.3768).

Table 8 Environmental correlation among 11 characters in okra

Characters	Days to first flower	Leaf axil bearing first flower	Number of primary branches	Number of fruits	Length of fruit (cm)	Girth of fruit (cm)	Weight of fruit (g)	Yield per plant (g)	Duration	Leaf hopper population count
Leaf axil bearing first flower	-0.1715									
Number of primary branches	-0.2479	-0.1003								
Number of fruits	-0.2723	-0.0314	-0.0503							
Length of fruit (cm)	0.1776	0.0967	-0.4016**	-0.1185						
Girth of fruit (cm)	0.1584	-0.1110	-0.0181	0.0873	0.1473					
Weight of fruit (g)	-0.1398	0.0918	0.0760	-0.0944	0.0868	-0.0542				
Yield per plant (g)	-0.1610	0.0317	0.0948	-0.1740	-0.0918	-0.0607	-0.0597			
Duration	-0.1894	0.0934	-0.2380	0.0616	0.2808	0.1062	-0.0320	0.1831		
Leaf hopper population count	-0.1240	0.0444	-0.2900	0.0158	0.0885	-0.0041	0.0296	0.1063	0.2245	
Leaf hopper Injury score	-0.0931	0.3768*	-0.2560	0.0156	-0.0242	-0.1054	-0.1173	0.0873	0.2275	0.4774**

**1 % level of significance, *5 % level of significance

Table 9 Path analysis

Characters	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	Total Correlation
X_1	**-0.0442**	0.0255	-0.0001	-0.1087	-0.0323	-0.0269	0.0072	-0.0358	0.0061	-0.2092
X_2	-0.0159	**0.0708**	0.0029	-0.3330	-0.0055	-0.0089	-0.0205	-0.0614	0.0053	-0.3662
X_3	-0.0001	-0.0056	**-0.0366**	0.1233	-0.0041	0.0318	0.0302	-0.0020	-0.0010	0.1359
X_4	0.0051	-0.0250	-0.0048	**0.9430**	-0.0493	-0.0431	0.0163	0.0512	-0.0146	0.8788
X_5	0.0074	-0.0020	0.0008	-0.2422	**0.1920**	0.0258	0.0069	-0.0152	0.0061	-0.0204
X_6	0.0119	-0.0063	-0.0117	-0.4054	0.0495	**0.1000**	0.0120	0.0132	0.0036	-0.2332
X_7	-0.0034	-0.0154	-0.1170	0.1630	0.0140	0.0217	**0.0946**	0.0204	-0.0099	0.1680
X_8	-0.0118	0.0325	-0.0005	-0.3611	0.0219	-0.0099	-0.0144	**-0.1338**	0.0239	-0.4532
X_9	-0.0100	0.0140	0.0014	-0.5121	0.0434	0.0135	-0.0347	-0.1188	**0.0269**	-0.5764

$R^2 = 0.15$ Values on principal diagonal are direct effects

X_1 Days to first flower
X_2 Leaf axil bearing first flower
X_3 Number of primary branches
X_4 Number of fruit
X_5 Length of fruit
X_6 Girth of fruit
X_7 Plant duration
X_8 Leafhopper population
X_9 Leafhopper injury score

Negative association was observed between number of primary branches (-0.4016) and length of fruit.

Leafhopper population and leafhopper injury score had a significant positive association (0.4774).

Significant environmental correlation was not observed among other characters.

4.3.2 Path Analysis

The characters which exhibited high correlation with fruit weight per plant (yield) were selected for path coefficient analysis. The direct and indirect effects of the selected nine component characters on fruit yield were estimated and presented in Table 9.

Leafhopper population count had the highest direct negative effect on yield (-0.1338).

Days to first flowering had direct negative effect with yield (-0.0442). The highest positive indirect effect was exerted through leaf axil bearing first flower (0.0255) whereas the lowest was through leafhopper injury score (0.0061). The negative indirect effect was highest through number of fruits per plant (-0.1087) and least through number of primary branches (-0.0001).

Leaf axil bearing first flower had positive direct effect (0.0708). Indirect negative effect through number of fruits (-0.3330) was the highest and length of fruit (-0.0055) was the lowest. Positive indirect effect through leafhopper injury score were highest (0.0053) while through number of primary branches was the lowest (0.0029).

Number of primary branches had negative direct effect (-0.0366). Minimum positive indirect effect was exerted through plant duration

(0.0302) and minimum through number of fruit (0.1233). Highest negative indirect effect was exerted through the leaf axil bearing first flower (-0.0056) and lowest through days to first flowering (-0.0001).

Number of fruits had a positive direct effect with yield (0.9430). The highest positive indirect effects were through leafhopper population (0.0512) and days to first flower (0.0051) whereas the highest and lowest negative indirect effects were manifested through plant duration (-0.0431) and number of primary branches (-0.0048) respectively.

Length of fruit had a positive direct effect (0.1920). The highest positive indirect effect was manifested through girth of fruit (0.0258) followed by days to first flower (0.0074) whereas the maximum and minimum negative indirect effects were through number of fruit (-0.2422) and leaf axil bearing first flower (-0.0020).

The direct effect on yield by girth of fruit was positive (0.1000). Positive indirect effect was exerted through days to first flower (0.0119), length of fruit (0.0495), leafhopper count (0.0132) etc. while negative indirect effects was exerted mainly through number of fruit (-0.4054).

Plant duration exerted a positive direct effect on yield (0.0946). Negative indirect effect was exerted mostly through number of primary branches (-0. 1170) and leaf axil bearing first flower (-0.0154) and positive indirect yield was manifested mainly through number of fruit (0.1630).

Leafhopper population count had a negative direct effect on yield (-0.1338) but leafhopper injury score had a slight positive direct effect (0.0269).

The highest positive indirect effect of leafhopper population was exerted through leaf axil having first flower (0.0325) followed by length (0.0219) and leafhopper injury score (0.0239). Negative indirect effect was manifested through leaf axil bearing first flower (-0.0118) and plant duration (-0.0144) mainly.

Highest negative indirect effect of leafhopper injury score was exerted through number of fruits (-0.5121) whereas highest positive indirect effect was manifested through length (0.0434).

4.4 LINE x TESTER ANALYSIS

Five resistant/tolerant lines and three susceptible testers were crossed in a line x tester fashion. The data collected from field were subjected to statistical analysis.

The genotypes with the lowest leafhopper population count and leafhopper injury score were selected as the lines whereas the genotypes with the highest leafhopper population count and leafhopper injury score were selected as testers.

The five lines chosen were T_{21}, T_{12}, T_{23}, T_9, T_{20} which were designated as L_1, L_2, L_3, L_4 and L_5.The testers chosen were T_{18}, T_{37} and T_{34} which were designated as T_1, T_2 and T_3 respectively.

Results of line x tester analysis are presented in Table 10. Significant variation was observed among treatments for all the characters studied.

Parents varied significantly with respect to all traits except length of fruits while crosses had significant variation except leaf axil bearing first flower. Interaction effect of parents and hybrids were not significant for number of fruits, fruit length and plant duration.

Line x tester mean square was significant for all the characters under study. Lines varied significantly for leaf axil bearing first flower, number of fruits, weight of fruits, yield and duration while the testers exhibited variation for none of the characters.

Table 10 ANOVA for line x tester analysis in okra

Source	df	Days to first flowering	Leaf axil bearing first flower	Number of primary branches	Number of fruits	Length of fruit (cm)	Girth of fruit (cm)	Weight of fruit (g)	Yield per plant (g)	Plant duration	Leafhopper population	Leafhopper Injury score
Replication	2	2.25	0.22**	0.24**	0.04	5.74**	0.21	0.49	15.75	19.81	0.484	0.056**
Treatments	22	129.97**	0.96**	2.58**	10.87**	4.16**	2.70**	36.21**	7984.97**	172.63**	129.56**	0.82**
Parents	7	184.21**	1.70**	2.51**	15.80**	2.98	3.30**	31.35**	15795.30**	21.47**	322.99**	1.58**
Crosses	14	109.09**	0.50	2.51**	9.18**	4.79**	2.53**	33.53**	4056.76**	164.15**	41.08**	0.38**
Parents Vs crosses	1	42.66**	2.22**	4.03**	0.006	3.58	0.91**	107.89**	8307.50**	19.41	14.22**	1.40**
Lines	4	78.62	1.01**	3.41	26.21**	3.60	0.61	81.21**	10755.78**	209.46**	29.82	0.26
Testers	2	215.04	0.07	3.58	1.61	5.46	2.79	15.37	950.94	334.02	4.36	0.28
Line x Tester	8	97.82**	0.34**	1.79**	2.56**	5.21**	3.43**	14.22**	1483.70**	99.02**	55.88**	0.46**
Error	44	0.83	2.54	0.07	0.12	1.69	0.09	0.42	114.19	9.67	0.92	0.01

**1 % level of significance, *5 % level of significance

4.4.1 *Per se* Performance of Parents and Hybrids

Per se performance of five lines, three testers and their fifteen hybrids with respect to eleven characters is presented in Tables 11 and 12.

1. Days to First Flower

L_1 (40.80) among lines and T_3 (41.73) among testers were the earliest flowering while L_5 (58.16) and T_2 (58.57) were the last flowering types among the lines and testers respectively. The earliest flowering hybrids were L_1 x T_1 (41.60), L_2 x T_1 (41.43), L_2 x T_3 (41.37) and L_3 x T_3 (41.43). L_1 x T_2 (56.27) took the longest time to flower.

2. Leaf Axil Bearing First Flower

L_4 (4.03) had the lowest value among lines and T_1 (5.33) had the lowest value among testers. The highest value among lines and testers were obtained for L_2 (5.40) and T_2 (5.98) respectively. Minimum value of this trait among hybrids was observed for L_4 x T_2 (4.43). Maximum value (5.80) obtained for L_1 x T_2 and L_5 x T_1 and seven hybrids were on par with it.

3. Number of Primary Branches

Minimum number of primary branches were obtained for L_3 (0.22) among lines and T_1 (0.33) among testers while the maximum value were obtained for L_1 (2.56) and T_2 (1.44) among lines and testers respectively. Among hybrids L_1 x T_1, L_2 x T_1, L_3 x T_3 and L_5 x T_1 had no primary branches while L_2 x T_2 (2.56) had the highest.

4. Number of Fruits

Among lines highest number of fruits were obtained for L_4 (12.32) while the lowest number of fruits were obtained for L_5 (5.33). Among testers T_2 (6.40) produced maximum number of fruits. Maximum number of fruits were obtained from L_2 x T_3 (11.33) and lowest from L_4 x T1 (5.07), L_4 x T_3 (5.06), L_5 x T_1 and L_5 x T_3 were on par with L_4 x T_1.

Table 11 Mean performance of parents for 11 characters

Parents	Days to first flowering	Leaf axil bearing first flower	Number of primary branches	Number of fruits	Length of fruit (cm)	Girth of fruit (cm)	Weight of fruit (g)	Yield per plant (g)	Duration	Leaf hopper population count	Leaf hopper Injury score
Lines											
L_1	40.80	5.30	2.56	7.97	20.74	7.07	30.93	246.44	115.90	4.00	1.00
L_2	41.33	5.40	2.44	5.45	19.86	7.47	29.77	162.12	114.31	6.22	1.00
L_3	41.17	4.27	0.22	7.05	18.42	6.11	28.13	198.52	120.43	4.22	1.00
L_4	41.43	4.03	2.00	12.32	17.66	6.73	28.23	348.04	108.83	5.66	1.00
L_5	58.16	4.35	0.66	5.33	19.89	7.21	28.03	149.52	110.50	4.78	1.00
CD	0.866	0.228	0.251	0.332	1.240	0.299	0.615	10.150	2.950	0.909	-
Testers											
T_1	42.33	5.33	0.33	6.10	19.16	8.16	27.67	168.75	100.13	17.00	2.00
T_2	58.57	5.98	1.44	6.40	18.66	5.60	23.60	151.31	99.16	33.44	2.89
T_3	41.73	5.95	1.33	5.87	19.86	4.96	21.13	123.99	98.45	16.56	2.00
CD	0.670	0.177	0.195	0.257	0.956	0.231	0.476	7.862	-	0.705	0.052

Table 12 Mean performance of hybrids for 11 characters

Hybrids	Days to first flowering	Leaf axil bearing first flower	Number of primary branches	Number of fruits	Length of fruit (cm)	Girth of fruit (cm)	Weight of fruit (g)	Yield per plant (g)	Duration	Leaf hopper population count	Leaf hopper Injury score
L_1 x T_1	41.60	5.33	0.00	6.82	21.26	8.13	28.11	191.79	99.22	13.33	2.00
L_1 x T_2	56.27	5.80	2.22	8.20	19.32	6.77	29.46	241.57	107.33	14.56	2.00
L_1 x T_3	43.30	5.63	1.55	7.46	21.56	5.93	28.13	209.90	105.30	5.57	1.00
L_2 x T_1	41.43	5.51	0.00	9.00	19.64	7.64	22.87	205.68	106.53	16.66	2.11
L_2 x T_2	54.37	5.35	2.56	8.63	19.33	7.12	20.93	180.29	96.90	16.78	2.20
L_2 x T_3	41.37	5.98	1.88	11.33	18.52	6.36	18.40	208.79	110.59	11.55	1.78
L_3 x T_1	43.60	5.75	0.55	7.80	21.13	8.05	29.93	151.70	110.60	9.77	1.00
L_3 x T_2	55.53	5.70	0.11	7.07	19.39	6.13	26.20	155.34	111.97	11.66	1.89
L_3 x T_3	41.43	5.13	0.00	6.10	18.84	5.77	22.87	115.86	124.61	14.44	1.89
L_4 x T_1	41.97	5.23	1.00	5.07	17.79	8.15	25.00	194.99	112.97	11.11	1.78
L_4 x T_2	48.83	4.43	1.88	5.94	18.38	5.97	21.83	154.32	109.17	11.67	1.67
L_4 x T_3	43.37	4.81	0.66	5.06	21.44	5.81	22.63	137.99	99.13	16.66	2.00
L_5 x T_1	50.47	5.83	0.00	5.53	19.63	8.16	25.73	142.48	114.02	16.16	2.00
L_5 x T_2	56.17	5.44	0.33	6.37	18.81	6.80	22.13	141.06	103.98	10.78	1.67
L_5 x T_3	50.43	5.43	0.22	5.23	21.37	6.77	24.20	126.50	97.99	10.78	1.78
CD	1.499	0.395	0.153	0.575	2.138	0.517	1.065	17.581	5.117	1.575	0.205

5. Length of Fruit

L_1 (20.74), L_5 (19.89) and L_2 (19.86) produced longest fruits among lines while T_3 (19.86) produced the longest fruits among the testers. Among hybrids the longest fruits were obtained from L_1 x T_3 (21.56) and L_1 x T_1 (21.26), L_3 x T_1 (21.13), L_4 x T_3 (21.44) and L_5 x T_3 (21.37) were on par. The hybrid with shortest fruits L_4 x T_1 (17.79) and nine other hybrids were on par with it.

6. Girth

Girth of fruit was maximum for L_2 (7.47) followed by L_5 (7.21) among lines and T_1 (8.16) among testers. Three hybrids L_1 x T_1 (8.13), L_3 x T_1 (8.05), L_4 x T_1 (8.15), L_5 x T_1 (8.16) had the highest homogenous values while L_2 x T_1 (7.64) and L_2 x T_2 (7.12) were on par the lowest values were obtained for L_3 x T_3 (5.77).

7. Weight of Fruit

Among the lines and testers the maximum values for weight of fruit was obtained for L_1 (30.93) and T_1 (27.67) respectively while the minimum values were obtained for L_5 (28.03) and T_3 (21.13) respectively. L_3 x T_1 (29.93) recorded the highest while L_2 x T_3 (18.40) recorded the lowest.

8. Yield per Plant

L_4 (348.04) and T_1 (168.75) recorded highest yield among their respective groups while L_5 (149.52) and T_3 (123.99) recorded the lowest. Highest and lowest yields among hybrids were L_1 x T_2 (241.57) and L_3 x T_3 (115.86) respectively.

9. Duration

Among lines the longest and shortest duration were obtained for L_3 (120.43) and L_4 (108.83) respectively. Among testers the longest duration was obtained for T_1 (100.13). L_3 x T_3 (124.61) and L_2 x T_2 (96.90) recorded the highest and lowest duration among hybrids.

10. Leafhopper population count

All the lines harboured very less leafhopper population with L_1 (4.00) having the least. Among testers T_2 (33.44) was the most susceptible followed by T_1 (17.00). Hybrid where least number of leafhopper were found were L_1 x T_3 (5.57) and highest number was found in L_2 x T_2 (16.78), L_2 x T_1 and L_4 x T_3 (16.66) were on par with it.

11. Leaf hopper Injury Score

Leafhopper injury score was minimum (1.00) for all the lines. Among testers T_2 (2.89) had the highest score. Highest score among hybrids were obtained for L_2 x T_2 (2.20) while the lowest was recorded for L_1 x T_3 (1.00) and L_3 x T_1 (1.00).

4.4.2 Heterosis (%)

Relative heterosis, Standard heterosis and heterobeltiosis were estimated for fifteen hybrids with respect to nine biometric characters under study and the results are furnished in Tables 13 to 21. Standard heterosis was calculated for each character based on the check variety Aruna.

1.Days to first flowering

Significant negative relative heterosis was exhibited by L_5 x T_2 (-3.77). All the hybrids exhibited standard heterosis, of this all were negative except L_2 x T_2 and L_3 x T_1. Hybrids L_2 x T_1 (-29.26), L_2 x T_3 (-29.37) and L_3 x T_3 (-29.26) had the highest significant negative standard heterosis while negative significant heterobeltiosis was found in L_1 x T_3 (-6.13), L_5 x T_1 (-4.39), L_5 x T_2 (-3.42).

Table 13 Heterosis (%) for days to first flowering

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)
$L_1 \times T_1$	0.07	-28.97**	1.96
$L_1 \times T_2$	13.25**	-3.93**	37.97**
$L_1 \times T_3$	4.92**	-26.07**	-6.13**
$L_2 \times T_1$	-0.96	-29.26**	0.24
$L_2 \times T_2$	8.85**	7.17**	31.55**
$L_2 \times T_3$	-2.41	-29.37**	0.10
$L_3 \times T_1$	4.43**	25.56**	5.90**
$L_3 \times T_2$	11.17**	-5.19**	34.88**
$L_3 \times T_3$	0.77	-29.26**	0.63
$L_4 \times T_1$	0.21	-28.34**	-1.30
$L_4 \times T_2$	-0.02	-16.63**	17.86**
$L_4 \times T_3$	4.30**	-25.95**	4.68**
$L_5 \times T_1$	0.44	-13.83**	-4.39**
$L_5 \times T_2$	-3.77**	-4.09**	-3.42**
$L_5 \times T_3$	0.96	-13.89**	20.85**

Table 14 Heterosis (%) for leaf axil bearing first flower

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)
$L_1 \times T_1$	18.79	-10.87**	0.57
$L_1 \times T_2$	2.84	-3.01	9.43**
$L_1 \times T_3$	0.00	-5.85	6.22
$L_2 \times T_1$	2.60	-7.86**	3.37
$L_2 \times T_2$	-5.97	-10.54**	-0.93
$L_2 \times T_3$	5.28	0.00	10.74**
$L_3 \times T_1$	19.79**	-3.85	34.66**
$L_3 \times T_2$	11.11**	-4.68	33.49**
$L_3 \times T_3$	0.39	-14.21**	20.14**
$L_4 \times T_1$	11.75**	-12.54**	29.78**
$L_4 \times T_2$	-11.58**	-25.92**	9.93**
$L_4 \times T_3$	-3.60	-19.57**	19.35**
$L_5 \times T_1$	20.45**	-2.50	34.02**
$L_5 \times T_2$	5.22	-9.03**	25.06**
$L_5 \times T_3$	5.44	-9.19**	24.83**

**1 % level of significance, *5 % level of significance

Table 15 Heterosis (%) for number of primary branches

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)
$L_1 \times T_1$	-100.00**	-100.00**	-100.00**
$L_1 \times T_2$	11.00	54.16**	-13.28
$L_1 \times T_3$	-20.51**	-63.17**	-39.45**
$L_2 \times T_1$	100.00**	-100.00**	-100.00**
$L_2 \times T_2$	31.96**	77.77**	4.92
$L_2 \times T_3$	52.91	30.56**	-22.95**
$L_3 \times T_1$	96.43	-61.81**	66.66
$L_3 \times T_2$	86.75**	-92.36**	-92.36**
$L_3 \times T_3$	100.00**	-100.00**	-100.00**
$L_4 \times T_1$	14.53	30.56**	-50.00**
$L_4 \times T_2$	9.30	30.56**	-0.06**
$L_4 \times T_3$	-60.48**	-54.17**	-0.67**
$L_5 \times T_1$	-100.00**	-100.00**	-100.00**
$L_5 \times T_2$	-68.57**	-77.08**	-77.08**
$L_5 \times T_3$	-78.00**	-84.72**	-83.46**

Table 16 Heterosis (%) for number of fruits

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)
$L_1 \times T_1$	-3.13	6.56	14.43**
$L_1 \times T_2$	14.04**	28.13**	2.88
$L_1 \times T_3$	7.80**	16.56**	-6.39
$L_2 \times T_1$	55.71**	40.63**	47.54**
$L_2 \times T_2$	45.55**	34.84**	34.84**
$L_2 \times T_3$	100.18**	77.03**	93.02**
$L_3 \times T_1$	18.54**	21.88**	10.95**
$L_3 \times T_2$	5.05	10.47**	0.57
$L_3 \times T_3$	-5.57	-4.69	-13.23**
$L_4 \times T_1$	-44.95**	-20.78**	-58.85**
$L_4 \times T_2$	-36.54**	-7.19	-51.79**
$L_4 \times T_3$	-44.40**	-20.94**	-58.93**
$L_5 \times T_1$	-3.32	-13.59**	-9.34
$L_5 \times T_2$	8.52**	-0.47	-46.88
$L_5 \times T_3$	6.61	-18.28**	-10.40**

**1 % level of significance, *5 % level of significance

Table 17 Heterosis (%) for length of fruits

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)
$L_1 \times T_1$	6.57	13.93**	2.50
$L_1 \times T_2$	-1.92	3.54	6.84
$L_1 \times T_3$	6.21	15.54**	3.95
$L_2 \times T_1$	0.66	5.25	-1.10
$L_2 \times T_2$	0.36	3.59	-2.66
$L_2 \times T_3$	-6.75	-0.75	-6.74
$L_3 \times T_1$	12.45**	13.24**	10.28
$L_3 \times T_2$	4.58	3.91	3.91
$L_3 \times T_3$	-1.57	0.96	5.14
$L_4 \times T_1$	-3.37	-4.66	-7.15
$L_4 \times T_2$	1.21	-1.50	-1.50
$L_4 \times T_3$	14.29**	14.88**	7.95
$L_5 \times T_1$	0.01	5.19	-1.31
$L_5 \times T_2$	-0.02	0.80	-5.43
$L_5 \times T_3$	0.07	14.52**	7.44

Table 18 Heterosis (%) for girth of fruits

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)
$L_1 \times T_1$	6.69**	45.18**	-0.37
$L_1 \times T_2$	6.78	20.89**	-4.27
$L_1 \times T_3$	-1.33	5.89	-16.12**
$L_2 \times T_1$	2.30	36.43**	-6.37**
$L_2 \times T_2$	8.86**	27.14**	-4.68
$L_2 \times T_3$	2.25	13.57**	-14.85**
$L_3 \times T_1$	12.75**	43.75**	-1.34
$L_3 \times T_2$	4.61	9.46**	32.73
$L_3 \times T_3$	4.15	3.04	-5.56
$L_4 \times T_1$	9.39**	45.54**	12.25
$L_4 \times T_2$	-3.24	6.60	-11.29**
$L_4 \times T_3$	-0.68	3.75	-13.67**
$L_5 \times T_1$	6.11	45.71**	100.00
$L_5 \times T_2$	10.21**	21.43**	-5.68
$L_5 \times T_3$	15.73**	20.89**	-6.10

**1 % level of significance, *5 % level of significance

2.Leaf axil bearing first flower

A single hybrid L_4 x T_2 (-11.58) exhibited the desired negative relative heterosis. The highest negative standard heterosis was recorded by L_4 x T_2 (-25.92) followed by L_4 x T_3 (-19.57) while none of the hybrids exhibited desirable heterobeltiosis.

3.Number of primary branches.

The hybrid L_2 x T_1 exhibited the highest relative heterosis of 100 followed by L_3 x T_2 (86.75). The highest standard heterosis was obtained for L_2 x T_2 (77.77) followed by L_1 x T_2 (54.16). Significant positive heterobeltiosis was not exhibited by any of the hybrids.

4. Number of fruits

Significant positive relative heterosis was recorded for seven hybrids while significant negative relative heterosis was recorded for three hybrids. Among this the maximum positive relative heterosis was obtained for L_2 x T_3 (100.18) which also recorded the highest positive significant values for standard heterosis (77.03) and heterobeltiosis (93.02). Significant positive standard heterosis obtained for seven hybrids.

5. Length of fruits

The highest positive significant values for relative heterosis was obtained L_4 x T_3 (14.29) followed by L_3 x T_1 (12.45). Standard heterosis was highest for L_1 x T_3 (15.54) followed by L_4 x T_3 (14.88) and heterobeltiosis was not significant.

6.Girth of fruits

The highest positive significant value of 15.73 was recorded by L_5 x T_3 for relative heterosis while eleven hybrids recorded significant positive standard heterosis. Heterobeltiosis was negative for most of the hybrids.

Table 19 Heterosis (%) for weight of fruits

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)
$L_1 \times T_1$	-4.06**	19.11**	9.12**
$L_1 \times T_2$	8.03**	24.83**	-4.75**
$L_1 \times T_3$	8.06**	19.92**	-9.05**
$L_2 \times T_1$	-20.37**	-3.09**	-23.18**
$L_2 \times T_2$	-21.58**	-11.39**	-29.69**
$L_2 \times T_3$	-27.70**	-22.03**	-38.19**
$L_3 \times T_1$	7.28**	26.82**	6.39**
$L_3 \times T_2$	1.31	11.02**	-6.86**
$L_3 \times T_3$	-7.15**	-3.09	-18.69**
$L_4 \times T_1$	-10.55**	5.93**	-11.44**
$L_4 \times T_2$	-15.78**	-7.50**	-22.67**
$L_4 \times T_3$	-8.25**	-4.11	-19.84**
$L_5 \times T_1$	-7.61**	9.03**	-8.21**
$L_5 \times T_2$	-14.29**	-6.23	-21.05**
$L_5 \times T_3$	-1.54	2.54	-13.66**

Table 20 Heterosis (%) for yield

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)
$L_1 \times T_1$	-7.61**	26.76**	-22.18**
$L_1 \times T_2$	0.50**	59.65**	-1.98
$L_1 \times T_3$	13.32**	38.72**	-14.83**
$L_2 \times T_1$	24.32**	35.93**	21.88**
$L_2 \times T_2$	15.03**	19.15**	11.21**
$L_2 \times T_3$	45.95**	37.99**	28.79**
$L_3 \times T_1$	-17.39**	0.26	-23.58**
$L_3 \times T_2$	-11.11**	2.66	-21.75**
$L_3 \times T_3$	-28.15**	-23.42**	-41.64**
$L_4 \times T_1$	-24.54**	28.87**	-43.97**
$L_4 \times T_2$	-11.78**	1.98	-55.66**
$L_4 \times T_3$	-44.73**	-8.80	-60.35**
$L_5 \times T_1$	-23.40**	-5.84	-15.57**
$L_5 \times T_2$	-11.36**	-6.77	-6.77
$L_5 \times T_3$	-7.50	-16.39**	-15.40**

**1 % level of significance, *5 % level of significance

Table 21 Heterosis (%) for duration

Hybrids	Relative heterosis (RH)	Standard heterosis (SH)	Heterobeltiosis (HB)
$L_1 \times T_1$	-8.15**	0.06	-14.39**
$L_1 \times T_2$	-0.19	8.24**	-7.39**
$L_1 \times T_3$	-1.73	6.19**	-9.15**
$L_2 \times T_1$	-0.64	7.43**	-6.81**
$L_2 \times T_2$	-9.22**	-2.28	-15.23**
$L_2 \times T_3$	3.96	11.53**	-3.25
$L_3 \times T_1$	0.29	11.54**	-8.16**
$L_3 \times T_2$	1.98	12.92**	-7.02**
$L_3 \times T_3$	13.86**	25.66**	3.47
$L_4 \times T_1$	8.13**	13.93**	3.80
$L_4 \times T_2$	4.98**	10.09	0.31
$L_4 \times T_3$	-4.33	-0.03	-8.91**
$L_5 \times T_1$	8.26**	14.98**	3.19
$L_5 \times T_2$	-0.81	-4.86	-5.90**
$L_5 \times T_3$	-6.21**	-1.18	-11.32**

**1 % level of significance, *5 % level of significance

7. Weight of fruits

The positive significant value was obtained for three hybrids of which L_1 x T_3 (8.06) and L_1 x T_2 (8.03) were the highest. Highest standard heterosis was obtained for L_3 x T_1 (26.82) while two hybrids exhibited heterobeltiosis, L_3 x T_1 (6.39) and L_1 x T_1 (9.12).

8. Yield

Only five hybrids showed positive significant relative heterosis of which L_2 x T_3 (45.95) recorded the highest value and also exhibited positive significant standard heterosis (37.99) and the highest heterobeltiosis (28.79). Highest significant standard heterosis was exhibited by L_1 x T_2 (59.65).

9. Duration

Four hybrids recorded significant positive relative heterosis. L_3 x T_3 recorded the highest relative heterosis (13.86) and standard heterosis (25.66). Nine hybrids recorded positive standard heterosis while none of the hybrids exhibited heterobeltiosis in the positive direction.

4.4.3 Combining Ability

General combining ability (*gca*) effects of lines and testers are presented in Table 22 and specific combining ability (*sca*) effects of hybrids are presented in Table 23.

1. Days to First Flower

Among lines significant *gca* effects were found for L_2, L_3 and L_4 and all testers. All the hybrids except L_2 x T_1 (0.37), L_3 x T_3 (0.75) and L_5 x T_3 (-1.45) showed significant *sca* effects. Highest positive *sca* effects were obtained for L_3 x T_1 (6.37) while the lowest positive *sca* effect was

Table 22 General combining ability effects of parents for 11 characters

Parents	Days to first flowering	Leaf axil bearing first flower	Number of primary branches	Number of fruits	Length of fruit (cm)	Girth of fruit (cm)	Weight of fruit (g)	Yield per plant (g)	Duration	Leaf hopper population count	Leaf hopper injury score
Lines											
L_1	-0.29	0.17**	0.39**	0.45**	0.95**	0.42**	4.00**	43.87**	-3.40**	-1.25*	-0.12**
L_2	5.01**	0.14	-0.68**	-1.33**	0.18	0.34**	-0.54**	-33.87**	-2.02	0.13	0.03
L_3	-2.62**	-0.60**	0.32**	-0.05	-0.56	-0.26**	-1.40**	-8.12**	-0.26	0.71**	0.03
L_4	-1.62**	0.19**	0.62**	2.61**	-0.60	0.14	-3.83**	27.70**	-2.69**	2.56**	0.25**
L_5	-0.49	0.11	-0.64**	-0.17**	0.03	-0.25**	1.77**	-29.58**	8.37**	-2.15**	-0.19**
SE	0.303	0.080	0.088	0.117	0.433	0.105	0.216	3.562	1.037	0.319	0.041
Testers											
T_1	-2.26**	-2.69**	0.21**	0.25**	-0.38	-0.47**	-1.17**	-4.28	5.38**	-0.54**	-0.18**
T_2	4.37**	-0.08	0.36**	0.12	-0.32	0.08	0.60**	9.19**	-1.92**	0.53**	0.15**
T_3	-2.11**	-0.05	-0.56**	-0.37**	0.69**	0.38**	0.57**	-4.90	-3.46**	0.002	-0.03
SE	0.235	0.621	0.068	0.090	0.335	0.081	0.167	2.759	0.803	0.247	0.032

**1 % level of significance, *5 % level of significance

for L_4 x T_2 (4.27). The highest and lowest negative *sca* effects were recorded for L_3 x T_2 (-7.13) and L_1 x T_1 (-1.49) respectively.

2. Leaf Axil Bearing First Flower

Line L_3 (-0.6) and tester T_1 (-2.69) showed significant *gca* effects. Among hybrids, 10 hybrids showed significant *sca* effects. Positive significant *sca* effects were highest for L_4 x T_1(0.39) and negative significant *sca* effects were highest for L_2 x T_3 (-6.20).

3. Number of Primary Branches

All the lines showed significant positive (L_1, L_3 and L_4) or negative (L_2 and L_5) *gca* effects. All testers showed significant *gca* effects. All the hybrids except L_1 x T_1 and L_3 x T_3 exhibited significant *sca* effects.

4. Number of Fruits

All lines except L_3 showed significant *gca* effects. Among this L_1 (0.45) and L_4 (2.61) had positive values while L_2 (-1.33) and L_5 (-0.17) had negative values. In the tester category T_3 (-0.37) was significant negative and T_1 (0.21) significant positive. Among hybrids, L_4 x T_1 (1.43), L_2 x T_3 (1.03), L_3 x T_2 (0.69), L_1 x T_2 (0.58) and L_5 x T_2 (0.46) had significant positive *sca* effects while L_4 x T_2 (-1.14), L_2 x T_2 (-0.60), L_3 x T_3 (-0.52) and L_5 x T_1 (-0.54) had significant negative *sca* effects.

5. Length of Fruit

A single line L_1 (0.95) and a single tester T_3 (0.69) showed significant *gca* effects. In the case of hybrids L_2 x T_2 (1.75) and L_3 x T_3 (1.54) exhibited positive *sca* effect.

6. Girth of Fruits

L_1 (0.42) and L_2 (0.34) among lines and T_3 (0.38) showed significant *gca* effects. Among hybrids L_3 x T_3 (-1.22) showed significant negative

Table 23 Specific combining ability of hybrids for 11 characters

Hybrids	Days to first flowering	Leaf axil bearing first flower	Number of primary branches	Number of fruits	Length of fruit (cm)	Girth of fruit (cm)	Weight of fruit (g)	Yield per plant (g)	Duration	Leaf hopper population count	Leaf hopper Injury score
$L_1 \times T_1$	-1.49**	0.07	0.09	-0.28	1.22	-0.55**	0.74	-0.24	-4.03	-4.98**	-0.55**
$L_1 \times T_2$	4.84**	0.13	0.61**	0.58**	-1.07	-0.26	0.30	17.96	5.30**	2.83**	0.19**
$L_1 \times T_3$	-3.35**	-0.20**	-0.70**	-0.30	-0.15	0.80	-1.03**	-17.72	-1.27	2.15**	0.36**
$L_2 \times T_1$	0.37	0.27**	-0.38**	-0.43**	0.07	1.39**	2.88**	10.08	3.31	4.13**	0.30**
$L_2 \times T_2$	-6.29**	-0.21**	-0.32**	-0.60**	1.75**	-0.56	-0.42	-19.37**	-5.42**	-2.33**	-0.18**
$L_2 \times T_3$	5.92**	-6.20**	0.70**	1.03**	-1.82**	-0.83	-2.46**	9.29	2.11	-1.80**	-0.12
$L_3 \times T_1$	6.37**	-0.37*	0.50**	-0.17	-0.45	-0.21	-0.15	-3.83	-3.30	-0.94	-0.03
$L_3 \times T_2$	-7.13**	0.33**	-0.54**	0.69**	-1.09	1.42**	1.25**	32.37**	7.80**	-2.57**	-0.18**
$L_3 \times T_3$	0.75	0.03	0.03	-0.52**	1.54**	-1.22**	-1.09**	-19.54**	-4.50	3.51**	0.21*
$L_4 \times T_1$	-2.09**	0.39**	0.20**	1.43**	-0.27	-0.22	-1.16**	14.81	0.51	-2.90**	-0.14
$L_4 \times T_2$	4.27**	-0.34**	0.72**	-1.14**	0.49	-0.03	-0.40	-27.15**	-5.84**	1.24**	0.04
$L_4 \times T_3$	-2.18**	-0.04	-0.93**	-0.29	-0.22	-0.22	1.56**	12.33	5.33	1.66**	0.10
$L_5 \times T_1$	-3.16**	-0.37**	-0.42**	-0.54**	-0.57	-0.42	-2.30	-20.83**	3.50	4.69**	0.41**
$L_5 \times T_2$	4.31**	0.09	-0.47**	0.46**	-7.08**	-0.60	-0.73	5.18	-1.84	0.83	0.15
$L_5 \times T_3$	-1.45	0.28**	0.89**	0.08	0.64	1.01**	3.02**	15.64	-1.67	-5.53**	-0.56
SE	0.526	0.139	0.153	0.202	0.750	0.181	0.374	6.169	1.795	0.553	0.071

**1 % level of significance, *5 % level of significance

sca effects while L_2 x T_1 (1.39), L_3 x T_2 (1.42), L_5 x T_3 (1.01) showed significant positive *sca* effect.

7. Weight of Fruit

All lines and all testers showed significant positive *gca* effects. Among hybrids L_2 x T_1 (2.88), L_3 x T_2 (1.25), L_1 x T_3 (-1.03) and L_4 x T_3 (1.56) showed significant positive *sca* effects.

8. Yield per Plant

All the lines showed significant *gca* effects. Among testers only T_2 (9.19) exhibited positive *gca* effect. In the hybrid category significant positive *sca* effects were record for L_3 x T_2 (32.37) while L_4 x T_2 (-27.15), L_5 x T_1 (-20.83), L_3 x T_3 (-19.54) and L_2 x T_2 (-19.37) exhibited negative *gca* effects.

9. Duration

L_1 (-3.4), L_4 (-2.69) and L_5 (8.37) among lines showed significant *gca* effect, so were testers T_1 (5.38), T_2 (-1.92) and T_3 (-3.46). None of the other lines showed any significant *gca* effect. Considering hybrids, L_3 x T_2 (7.8) and L_1 x T_2 (5.3) had positive *sca* effect while L_4 x T_2 (-5.84) and L_2 x T_2 (-5.42) recorded negative *sca* effects.

10. Leafhopper Population count

The lines L_1 (-1.25) and L_5 (-2.15) showed significant negative *gca* effect while T_1 (-0.54) among the testers showed significant negative *gca* effect. Considering hybrids, L_5 x T_3 (-5.53), L_1 x T_1 (-4.98), L_4 x T_1 (-2.9), L_3 x T_2 (-2.57), L_2 x T_2 (-2.33), L_2 x T_3 (-1.8) showed negative *sca* effect while L_5 x T_1 (4.69), L_2 x T_1 (4.13), L_3 x T_3 (3.51), L_1 x T_2 (2.83), L_1 x T_3 (2.15), L_4 x T_3 (1.66) showed significant positive *sca* effects.

11. Leafhopper injury score

Lines, L_1 (-0.12) and L_5 (-0.11) and testers T_1 (-0.18) showed significant negative *gca* effects. Among hybrids, positive *sca* effects were recorded for L_5 x T_1 (0.41), L_1 x T_3 (0.36), L_2 x T_1 (0.30) while L_1 x T_1 (-0.55), L_2 x T_2 and L_3 x T_3 (-0.18) recorded negative *sca* effect.

4.4.4 Proportional Contribution of Parents and Hybrids

Proportional contribution of lines, testers and hybrids to the total variation in each of the eleven characters under study are presented in Table 24 and Fig.3

Proportional contribution of hybrids (51.24) was maximum towards total variability in the case of days to first flowering, while lines and testers contributed 20.59 per cent and 28.16 per cent respectively.

In the case of leaf axil bearing first flower lines (58.17 per cent) contributed the highest followed by hybrids (39.66 per cent) and testers (2.17 per cent). Testers contributed least (20.41) towards total variability in the case of number of primary branches and proportional contribution of lines (38.86) and hybrids (40.73) were almost equal.

Total proportional contribution by lines (81.59 per cent) towards number of fruits was very high, but the contribution of testers was very low (2.50) while the rest was contributed by hybrids.

Regarding length and girth, maximum proportional contribution was by hybrids 62.30 per cent and 77.44 per cent respectively. The lines accounted to 21.49 per cent and 6.84 per cent and testers 16.30 per cent and 15.72 per cent respectively.

In the case of weight of fruit, lines (69.21) contributed maximum followed by hybrids (24.24) and testers (6.55 per cent). Proportional

Table 24 Proportional contribution of parents and hybrids

Sl. No.	Characters	Proportional contribution		
		Lines	Testers	Hybrids
1	Days to first flowering	20.59	28.16	51.24
2	Leaf axil bearing first flower	58.17	2.17	39.66
3	Number of primary branches	38.86	20.41	40.73
4	Number of fruits per plant	81.59	2.50	15.91
5	Length of fruit (cm)	21.49	16.30	62.30
6	Girth of fruit (cm)	6.84	15.72	77.44
7	Weight of fruit (g)	69.21	6.55	24.24
8	Yield per plant (g)	75.75	3.35	20.89
9	Duration	36.46	29.07	34.47
10	Leaf hopper population count	20.74	1.52	77.74
11	Leaf hopper injury score	19.78	10.43	69.79

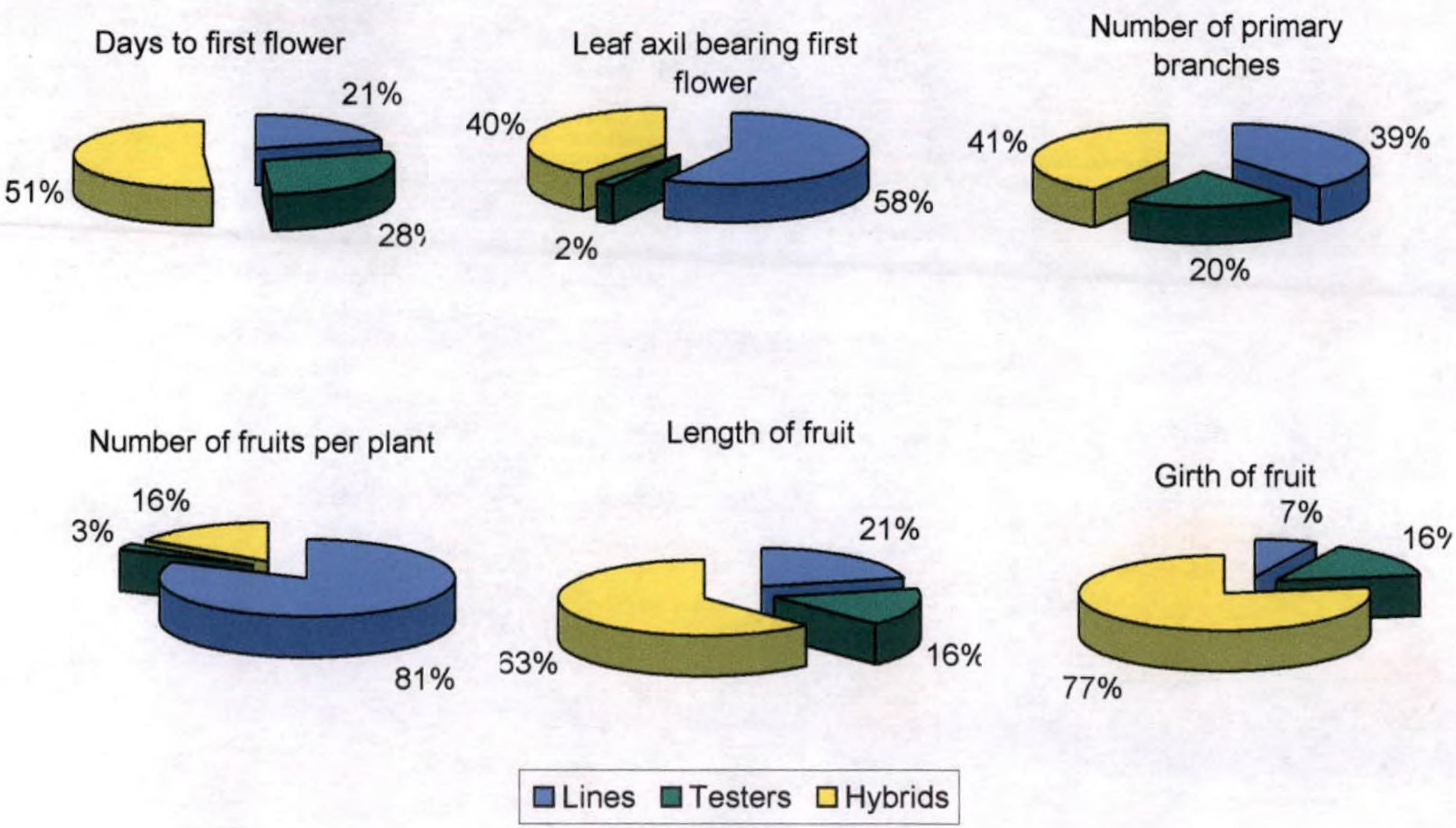


Fig. 3 Proportional contribution of lines, testers and hybrids

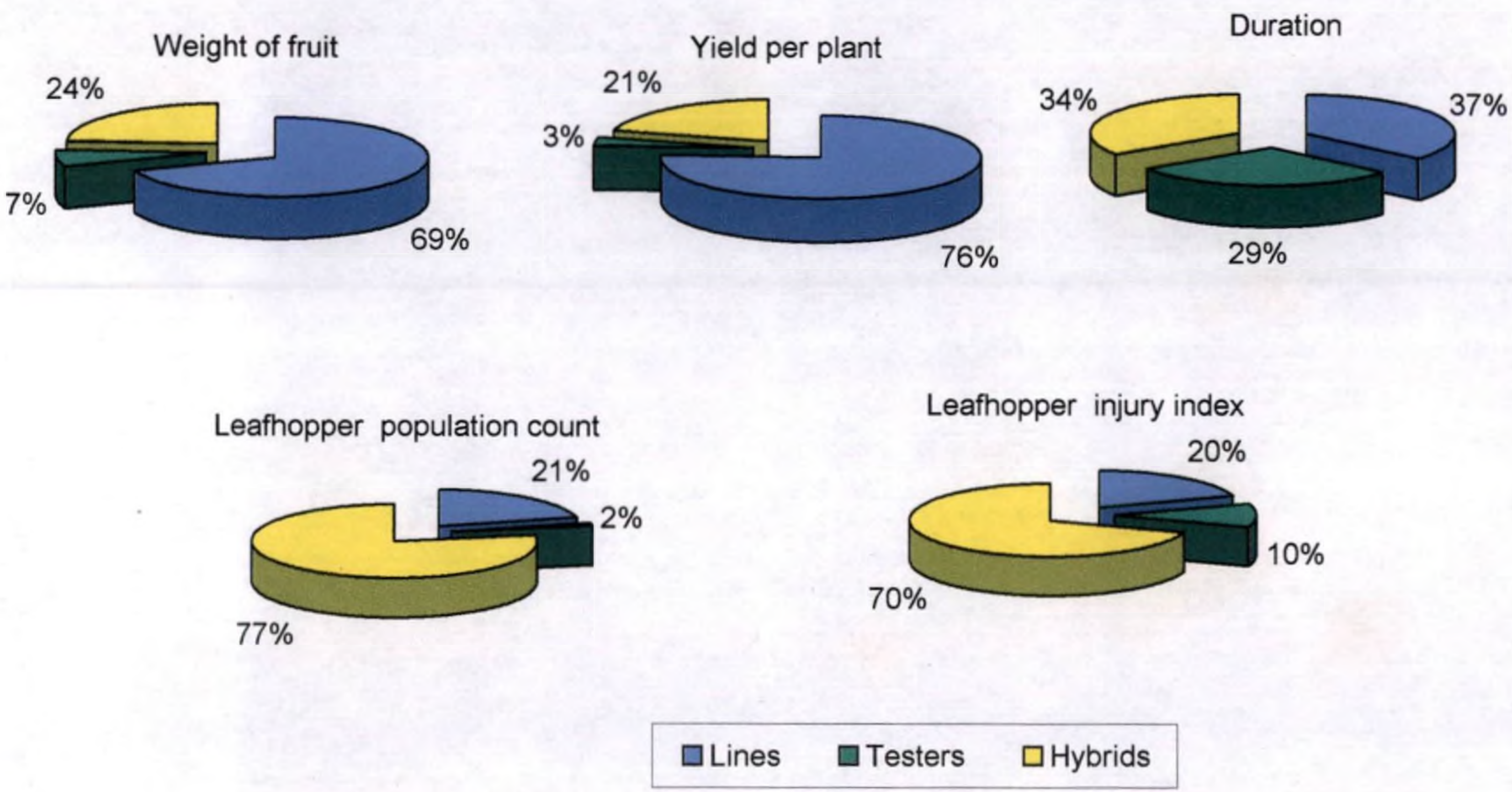


Fig. 3 Continued

Table 25 Additive and dominance variance

Sl. No.	Characters	$\sigma^2 a$	$\sigma^2 d$	$\sigma^2 a/\sigma^2 d$
1	Days to first flowering	0.80	32.33	0.02
2	Leaf axil bearing first flower	0.01	0.09	0.11
3	Number of primary branches	0.05	0.57	0.09
4	Number of fruits per plant	0.47	0.81	0.58
5	Length of fruit (cm)	0.03	1.18	0.03
6	Girth of fruit (cm)	-0.06	1.11	-
7	Weight of fruit (g)	1.36	4.60	0.30
8	Yield per plant (g)	181.93	456.50	0.40
9	Plant duration	4.60	29.78	0.15
10	Leaf hopper population count	-1.05	18.32	-
11	Leaf hopper injury score	0.01	0.15	0.04

contribution of lines (75.75 per cent) towards yield was maximum while that of tester (3.35 per cent) was minimum. Proportional contribution of hybrids were 20.89 per cent.

For duration lines (36.46 per cent) and hybrids (34.47 per cent) contributed almost equal proportion while the rest 29.07 per cent was contributed by tester.

Considering leafhopper resistance maximum proportional contribution was made by hybrids (77.74 per cent) while the lines (20.74 per cent) contributed more than tester (1.52).

Regarding leafhopper injury score, highest proportional contribution made by hybrids (69.79 per cent) followed by lines (19.75 per cent) and (10.43 per cent).

4.4.5 Additive and Dominance Variance

Dominance variance was high for all characters studied like days to first flower (32.33), number of fruits (0.81), length (1.18), girth (1.11), weight of fruits (4.60), yield (456.50), plant duration (29.78), leafhopper population (18.32) and leafhopper injury score (0.15) (Table 25).

The ratio σ^2a / σ^2d was highest for number of fruits (0.58) followed by yield (0.40). It was least for days to first flowering (0.02) followed by length of fruit (0.03) and leafhopper injury score (0.04).

DISCUSSION

5. DISCUSSION

Okra is one of the most important vegetable crops grown throughout the world for fresh consumption as well as for processing purpose. Repeated application of chemicals to tackle pests and harvesting at alternate days to meet consumer preference of tender fruits enhances the chance of leaving residues above the tolerable limits in the pods.

Market surveys conducted at many parts of the country have revealed the presence of pesticide residue much above the maximum residue limits on the fruits. This poses a serious impediment in the export of the produce to developed countries, having stringent quality control criteria. Alternate pest control tactics including breeding for pest resistance are given emphasis to reduce the over reliance on chemical pesticides. The leafhopper *Amrasca biguttula biguttula* is one the serious sucking pest of okra causing severe yield reduction.

The present investigation was undertaken to evaluate variability for yield and other important characters including leafhopper resistance indices in a collection of okra genotypes, to estimate combining ability and heterosis as well as gene effects involved in the inheritance of these characters using line x tester analysis with five lines and three testers. The results of the study are discussed under different headings.

5.1 VARIABILITY STUDIES

The breeding procedure, efficiency of selection and final success are dependent on the germplasm chosen (Zelleke, 2000). The observed variability in a population is the sum total of the variation arising due to genotypic and environmental effects. Knowledge on the nature and magnitude of genetic variation contributing to gain under selection is of utmost importance (Allard, 1960). Analysis of variance helps in partitioning the total phenotypic variation into components attributable to genotype and environment thereby providing information regarding the nature and magnitude of variability of a trait.

There were significant differences among 40 genotypes of okra for all the biometric characters studied *viz.,* days to first flowering, leaf axil bearing first flower, number of primary branches, number of fruits, length and girth of fruits, weight of fruits, yield per plant and duration. Also the genotypes showed wide variability for the two pest resistance indices *viz.*, leafhopper population count and leafhopper injury score.

There are several research reports on the existence of large varietal variation in okra with respect to different characters. This includes the works of Murthy and Bavaji (1980) for number, length and yield of fruits, Vashistha *et al.* (1982) for yield, Rajani and Manju (1997) for days to first flowering, branches, number of fruits, length, girth, weight and yield of fruits, Hazra and Basu (2000) for days to flower, seeds/ fruit and number, weight and yield of fruits and Gandhi *et al.* (2001) for number, length, girth and seeds of fruits.

Yield per plant showed wide variation ranging from 76.25 g (T_8) to 350.82 g (T_{40}). T_{40} was superior in yield to all other varieties and recorded the highest mean value of 13.11 for number of fruits per plant. Varietal variation for fruit characters, *viz.*, length, girth and weight of fruits observed in the present study is remarkable. This is in agreement with the wide varietal variation in fruit characters reported earlier by Rajani and Manju (1997).

The variation in leafhopper population count among the genotypes was considerable ranging from 4.17 (T_{21} and T_{22}) to 38.00 (T_{24}). The leafhopper injury score of 1.00 recorded for T_{21} and T_{22} suggested that these varieties were free from any apparent leaf damage. Apart from this T_{23} and T_{40} were the genotypes without any leaf damage. The insect population count recorded for them were also comparable to T_{21} and T_{22}.

5.2. GENETIC PARAMETERS

The genetic parameters *viz.*, coefficients of variation, heritability and genetic advance were estimated for all the characters considered in the present study. Genotypic coefficient of variation is a better tool to understand useful variability as it is free from environmental component contributing to the total variability. Moreover, coefficient of variation, being unit free, provides for the comparison for the variability for different characters measured in diverse units.

5.2.1 Coefficients of Variation

In the present study, number of primary branches showed the highest magnitude of PCV and GCV, the values being 93.23 and 91.06 respectively. Number of fruits per plant also expressed high PCV and GCV in this study. High PCV and GCV reported for number of branches and fruits per plant by Sheela (1994) supported the above conclusions.

Another character showing high PCV and GCV in the present study was yield per plant. This is similar to the findings of Rajani and Manju (1997). Hazra and Basu (2000) reported high GCV for number of primary branches and moderate GCV for number of fruits and yield per plant.

Bindu *et al.* (1997) reported low GCV for girth of fruits, days to first flowering and leaf axil bearing first flower. In the present study GCV was moderate for these characters.

High values of GCV and PCV for leafhopper population count and injury score observed in this study suggested the effectiveness of selection for these characters.

5.2.2 Heritability and Genetic Advance

Burton (1952) suggested that GCV along with heritability would provide a precise idea regarding the amount of genetic gain that can be expected by selection. The estimates of heritability help the plant breeder in the selection of elite genotypes from diverse populations. High heritability coupled with high genetic advance would be a more reliable criterion than simple heritability value alone (Johnson *et al.*, 1955).

In the present study all characters including yield and leafhopper population count showed high heritability and high genetic advance. High magnitude of heritability along with high estimates of genetic advance is indicative of additive gene action. This suggests the scope for improvement of the characters considered in the study through selection. High heritability for yield observed in the present study is worthy of special mention.

There are several reports of high heritability and genetic advance for various characters in okra. These include the high heritability and genetic advance reported by Balachandran (1984) for fruit set, number of branches, flowering duration, Reddy *et al.* (1985) for branches and yield, Alex (1986) for days to first flower and El-Macksoud *et al.* (1986) for earliness in flowering, fruits and fruit weight Bindu *et al.* (1997) for fruit length, single fruit weight, fruit weight per plant and Rajani and Manju (1997) for yield, Yassin and Anbu (1997) for branches, single fruit weight and yield per plant.

Moderate values for both heritability and genetic advances were reported for length and weight of fruits and number of fruits by Balachandran (1984). Bindu *et al.* (1997) moderate heritability with low genetic advance for girth of fruit. Further they noticed high heritability along with moderate genetic advance for fruit length, fruit weight and yield.

5.3 ASSOCIATION ANALYSIS

5.3.1. Correlation

Correlation analysis provides reliable estimates on the nature, extent and direction of selection. Selection based on yield and its components would be more efficient than that on the basis of yield alone (Evans, 1978). Yield is a complex character and is associated with a number of component characters. The relationship of yield with other characters is of great importance while formulating selection programme for improvement of yield.

In the present study genotypic correlation of yield with number of fruits (0.8789) and weight of fruits (0.5487) was positive and significant. This implies that selection for yield based on these characters would lead to improvement in yield.

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

In the present study, an interesting trend observed was that the genotypic correlation coefficients (r_{Gxy}) were of highest magnitude followed by the respective phenotypic correlation coefficients (r_{Pxy}). This corroborates with the findings of Murthy and Bavaji (1980) who observed higher magnitude of r_{Gxy} and r_{Pxy}.

It was noticed that leafhopper population count and leafhopper injury score had significant negative association with yield. It was reported by Mahal *et al.* (1994b) that the leafhopper population had an inverse relation with number of fruits and yield.

Positive association of yield with number of fruits was observed by Mahajan and Sharma (1979) and Yadav (1986). High association of number of fruits with yield in okra was reported by Mathew (1986), Sheela (1986) and Veeraraghavathatham and Irulappan (1990). Other reports in support of the present findings include that of Ariyo (1992) Gondane *et al.* (1995), Subhasini *et al.* (1996) and Philip and Manju (2002).

In the present study yield recorded a negative association with leaf axil bearing first flower. This is supported by the findings of Philip (1998). Also leaf axil bearing first flower had a negative association with number of fruits but positive association with days to first flowering which agrees with the report of Philip (1998). The positive association recorded for fruit weight with fruit length in the present study corroborates the reports of Philip (1998) and John (1997).

The positive association of length of fruit with average fruit weight observed in the study agrees with the reports of John (1997).

The two leafhopper resistance indices leafhopper population count and leafhopper injury score were positively correlated (0.4774). This implies that the injury inflicted by the pest is proportional to the leafhopper population. So either of the damage parameters can be used for leafhopper resistance evaluation. T_{24} recorded the highest leafhopper population count as well as injury score which is considered as the most susceptible among genotypes.

5.3.2 Path Analysis

The path analysis reveals whether the association of a character with yield is due to a direct effect on yield or is a consequence of their indirect effects *via* other component characters. Rate of improvement is expected to be rapid if differential emphasis is laid on the component character during selection, based on the influence of component characters on yield.

Path coefficient analysis in the present study revealed the direct and indirect effects exerted on yield by nine characters which had high genetic correlation.

Highest positive direct effect on yield was exhibited by number of fruits. This is in agreement with the findings of Balakrishnan and Balakrishnan (1988) and Kale *et al.* (1989). The highest negative effect on yield was recorded by leafhopper population count agrees with the findings of Mahal *et al.* (1994b).

Higher positive direct effects were also exhibited by length of fruit and girth of fruit. This is supported by the findings of Kale *et al.* (1989) for fruit length.

Correlation coefficients were positive for number of fruits (0.8788), duration (0.1680) and number of primary branches. Except number of primary branches, the other two also had positive direct effects. So selection based on both of these characters will definitely improve yield. Direct effect and total correlation were negative for days to first flowering which is desirable.

The total correlation as well as direct effect for leafhopper population score as well as leafhopper injury score were negative. The residual value obtained was low (R^2 = 0.15) indicating that the component characters selected for path analysis well explained the cause and effect system.

5.4 LINE x TESTER ANALYSIS

Numerous biometrical methods are routinely employed to detect precisely the genetic make up of genotypes under consideration as well as to evaluate effectively their combining ability for developing a suitable breeding methodology. Line x tester being unique among them, envisages the screening of a large number of genotypes at a time and is highly dependable in determining the relative ability of the males and females for synthesizing desirable hybrid combinations.

During the current research programme, line x tester analysis was undertaken in order to sort out the good parents as well as crosses by examining their mean performance, general combining ability of parents, specific combining ability of hybrids along with their heterosis estimates.

Significant variation existed for all the characters for line x tester interaction, as revealed by the ANOVA, which justifies the adequacy of genotypes chosen for hybridization programme.

5.4.1 *Heterosis*

Exploitation of hybrid vigour is one of the most important tools which could be used to increase yield. Commercial utilization of hybrid vigour is further facilitated in okra as its floral biology enables easy emasculation and pollination besides being able to produce large number of seeds in a single pollination. Heterosis breeding is an alternative method for obtaining quantum leaps in the production and productivity in okra. Magnitude of heterosis particularly for yield is of paramount importance. However, expression even to a small magnitude for individual component character also is desirable factor (Hatchcock and McDaniel, 1973).

Heterosis is the result of certain types of gene effects *viz.*, additive dominance and epistatic. Heterosis expression for various characters with regard to the respective mid, standard and better parents of fifteen hybrids were analysed. High estimates of relative heterosis was recorded for number of primary branches, number of fruits and yield.

Standard heterosis recorded high values for days to first flower, number and girth of fruit, leaf axil bearing first flower and yield. Regarding heterobeltiosis significant values were obtained for number of fruits, leaf axil bearing first flower.

Elangovan *et al.* (1981) agrees with the result for number of primary branches, yield and number of fruits regarding relative heterosis and heterobeltiosis.

Dhillon and Sharma (1982) agrees with the findings for number of branches and number of fruits and Balachandran (1984) noticed desirable heterosis over mid, better and standard parents for number, length and weight of fruits which corroborated with the present study.

5.4.2 Evaluation and Selection of Parents and Hybrids

5.4.2.1 Parents

The performance of crosses developed in a hybridization programme largely depend on the parental attributes .The basis of the choice of parents should be their *per se* performance along with their *gca* estimates (Yadav and Murthy, 1966).

Considering the mean performance, the best line was L_1 due to its best all round performance with respect to yield and its components and least leafhopper population it harboured. Also L_1 took lesser number of days to flower and it excelled in number of primary branches, weight of fruits and duration. Next to L_1 was L_4 which took less days to first flowering, more number of fruits, better length and girth of fruits and comparable weight of fruit and yield/plant. It also harboured the lesser leafhopper population.

The best performing tester was T_2 with respect to all the characters studied, though it was susceptible. T_1 was also good while considering yield and other contributing characters.

The best general combiner among lines was L_1. It was a good general combiner with respect to days to first flowering, number of primary branches, length, girth, weight and yield per plant. L_1 recorded the least *gca* effect for leafhopper population count and leafhopper score.

The *gca* effects of L_4 with respect to days to first flowering, number of primary branches, fruits and yield and *gca* effects of L_5 with respect to leafhopper population were good. Overall best performer was L_1. T_1 among testers exhibited excellent combining ability for days to first flower, leaf axil bearing first flower, number of primary branches, duration, leafhopper population count and leafhopper injury score. T_2 exhibited good combining ability for yield, while overall good performer was susceptible T_2 (Aruna) with more number of primary branches and significant *gca* effects for weight of fruit and yield.

5.4.2.1.1 Choice of superior Parents

Combined appraisal of the *per se* performance and *gca* effects of both lines and testers, the general trend seen was that the mean value of parents totally reflected the *gca* effects in most of traits.

Considering overall performance, L_1 and T_2 were the best line and tester. T_1 was medium good. L_1 has excellent combining ability for number of primary branches, leaf axil bearing first flower, number of fruits, length, girth and weight of fruits, yield and least leafhopper population.

5.4.2. 2 Hybrids

The factors that should be considered for hybrid vigour exploitation are *per se* performance, heterosis values and *sca* effects of the crosses.

The mean values for various traits reflects the field performance and as such, they should be considered with utmost importance. The *sca* effect alone may not be the criterion for assessing hybrid vigour because hybrids with high *sca* effects may sometimes possess low heterosis estimates and *vice versa*. Hence mean performance, standard heterosis and *sca* effects should be utilized together for choosing and beneficial cross combinations.

5.4.3 Combining Ability

Sprague and Tatum (1942) introduced the concept of combining ability, who defined it as the relative ability to transmit the desirable performance of a genotype to its crosses. General combining ability, the average performance of ratio in a series of crosses, reflects the additive gene effects of parents. Specific combining ability, on the other hand indicates those situation in which certain crosses do relatively better or worse than would be expected on the basis of average performance of their respective parents and it is a measure of non additive gene action (Rojar and Sprague, 1942).

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

Highly significant *sca* effects were also observed for fruit yield which were in consonance with the observation of Poshiya and Shukla (1986) and Sadashiva (1988).

All the character under study with respect to mean value, combining ability and standard heterosis are discussed hereunder.

1. **Days to first flower**

The variance for lines or testers were not significant. But line x tester variance was significant. Hence non-additive gene action is indicated. This is in conformity with the findings of Elangovan *et al.* (1981) and Rajani (1995). Heterosis breeding seems to be a suitable proposition for the improvement of the character.

The *gca* effects of the lines L_3 (-2.62) and L_4 (-1.62) recorded the desirable negative *gca* effects. Two testers showed significant and negative *gca* effects, *viz.*, T_1 (-2.26) and T_3 (-2.11).

The hybrids *viz.*, L_1 x T_1 (-1.49), L_1 x T_3 (3.35), L_2 x T_2 (-6.29), L_3 x T_2 (-7.13), L_4 x T_1 (-2.09), L_4 x T_3 (-2.18), L_5 x T_1 (-3.16) had the desirable negative *sca* effects of which L_3 x T_2 was the best followed by L_2 x T_2. Several hybrids recorded the negative standard heterosis of which L_2 x T_3 (-29.37) was the best.

2. **Leaf axil bearing first flower**

Lines recorded significant GCA variance which indicated additive gene action. Significant SCA variance indicates the importance of non-additive genetic component for the expression of the character. This results corroborate the findings of Elangovan *et al.* (1981) and Vijay and Manohar (1986) for non-additive gene action and Partap *et al.* (1981) for additive gene action. So hybrid vigour can be exploited for the improvement of the character together with combination breeding.

Negative *gca* effects, which is preferred was recorded by L_3 (-0.60) and among testers T_1 (-2.69) recorded significant negative *gca* effects. So both of these can be used to breed better varieties for the particular character.

The *sca* effect was significant and negative for L_1 x T_3 (-0.20), L_2 x T_2 (-0.21), L_2 x T_3 (-6.2), L_3 x T_1 (-0.37), L_4 x T_2 (-0.34), L_5 x T_1 (-0.37). Among these hybrids L_2 x T_3 was the best hybrid.

3. Number of primary branches

The GCA variance was not significant for lines or testers, but the SCA variance was positive and significant, indicating the role of non-additive genetic component for the expression of the character. Similar results were reported by Elangovan *et al.* (1981).

The *gca* effect was significant and positive for L_1 (0.39), L_3 (0.32), L_4 (0.62), T_1 (0.21) and T_2 (0.36). So these genotypes can be used as parents in breeding programmes for improvement of this character.

Among hybrids, the *sca* effects were positive and significant for six hybrids, of which L_5 x T_3 (0.89) and L_4 x T_2 (0.72) were adjudged as the better ones. L_4 x T_2 (30.56) also recorded significant standard heterosis and mean values.

4. Number of fruits

Analysis variance revealed significant GCA variance for lines and significant SCA variance for hybrids. This indicates additive and non-additive gene action in the expression of a character.

This result is supported by the reports of Partap and Dhankar (1980) and Partap *et al.* (1981) for additive gene action. Significant positive *gca* effects were obtained for L_1 (0.45) and L_4 (2.61). The *gca* effects were significant for the tester T_1 (0.25) and for the improvement of this character recombination breeding and heterosis breeding can be resorted to.

Positive and significant *sca* effects were obtained for five hybrids, *viz.*, L_1 x T_2 (0.58), L_2 x T_3 (1.03), L_3 x T_2 (0.69) and L_4 x T_2 (1.43) and

L_5 x T_2 (0.46). L_2 x T_3 is the best hybrid for this character, considering the three selection criteria, heterosis, mean performance and *sca* effects.

5. Length of fruit

Positive and significant SCA variance was recorded for length of fruit but GCA variance was not siginificant indicating predominance of non-additive gene action for the character. This is in conformity with the works of Partap and Dhankar (1980), Elangovan *et al.* (1981) and Veeraraghava thatham and Irulappan (1990).

L_1 (0.05) among lines and T_3 (0.69) among testers recorded significant *gca* effects. The *sca* effect was significant for two hybrids. Since L_1 x T_1 had high mean value together with high standard heterosis it can be considered as a good hybrid. As the character is largely controlled by non-additive gene action, hybrid vigour exploitation seems to be feasible.

6. Girth of fruit

Positive and significant SCA variance was recorded for the character indicating the predominance of non-additive gene action.

Among the lines, L_1 (0.42) and L_2 (0.34) possessed high and significant *gca* effects as well as mean values and among testers T_3 (0.38) was the best general combiner with respect to the character. The hybrids L_2 x T_1, L_3 x T_2 and L_5 x T_3 had significant positive *sca* effects, but lesser mean values. However all these hybrids expressed high standard heterosis.

The best hybrid, considering the *sca* effects and heterosis was L_2 x T_1 and this is a combination of positive and negative general combiners.

7. **Weight of fruit**

There was significant GCA variance and SCA variance indicating the involvement of both additive and non-additive gene action. Veeraraghavathatham and Irulappan (1991) and Wankhade *et al.* (1995) agrees with the results for non additive gene action, while Veeraraghavathatham and Irulappan (1991) confirms the non additive gene action in the expression of the character. So heterosis breeding or combination breeding can be used for the improvement of the character.

Significant and positive *gca* effects were obtained for L_1 (4.00) and L_5 (1.77), T_2 (0.60) and T_3 (0.57). So these genotypes are the best general combiners and can be used for breeding for weight of fruits.

Positive and significant *sca* effect was obtained for L_2 x T_1, L_3 x T_2, L_4 x T_3 and L_5 x T_3. Among this L_3 x T_2 is the best hybrid, considering the average performance, standard heterosis and *sca* effects.

8. **Yield**

Significant GCA variance was recorded by lines and SCA variance was significant and positive for hybrids. This indicates the presence of additive as well as non-additive gene action. Partap and Dhankar (1980), Partap *et al.* (1981), Yadav *et al.* (2002) reported additive gene action in the expression of the character. Partap *et al.* (1981) reported the role of non additive gene action in the expression of the character.

Positive and significant *gca* effects for L_1 (43.87), L_4 (27.70) and T_2 (9.19) were recorded. So these are good general combiners, which can be used to breed high yielding okra varieties.

Positive and significant *sca* effects were recorded for L_3 x T_2 (32.37). Though the *sca* effects was positive but not significant for L_2 x T_3

it possessed high mean value as well as standard heterosis. So it can be identified as a hybrid with high yielding potential.

Sadashiva (1988) and Wankhade *et al.* (1995) had previously reported high *sca* effects for fuit yield in okra. Due to predominance of non-additive as well as additive gene action for this trait, recombination breeding or exploitation of hybrid vigour can be resorted to for the improvement of this trait.

9. Duration

Analysis of variance revealed that there was significant variation among lines and line x tester. This indicates the involvement of both additive and non-additive components of gene action in expressing the character.

Positive and significant *gca* effects were recorded by L_5 (8.37), among lines and T_1 (5.38), among testers. So these are good general combiners. The *sca* effect was positive and significant for only two hybrids, *viz.*, L_1 x T_2 (5.30) and L_3 x T_2 (7.80), whose standard heterosis was also significant and positive.

10. Leafhopper population count

Analysis of variance showed that GCA variance was not significant, but SCA variance was found to be significant. This confirms the presence of non-additive gene action in the expression of the character. However, Sharma and Gill (1984) reported that resistance to leafhopper is governed by additive gene effects.

Negative and significant *gca* effects, which is desirable, were recorded for L_1. T_1 had negative significant *gca*.

Negative and significant *sca* effects were recorded for L_1 x T_1 (-4.98), L_2 x T_2 (-2.33), L_2 x T_3 (-1.8), L_3 x T_2 (-2.57), L_4 x T_1 (-2.9) and L_5 x T_3 (-5.53). Considering leafhopper resistance, L_5 x T_3 is the best hybrid, but the mean performance was not good enough and it was a low yielder. So L_3 x T_2 is the best hybrid with regard to leafhopper resistance as well as yield.

11. Leafhopper injury score

Significant SCA variance suggests the predominance of non-additive gene action. This indicates the possibility for developing hybrid varieties that suffer lesser leaf hopper injury.

Among the lines, the *gca* effect was negative and significant for L_1 and L_5, while it was negative and significant for T_1 among testers.

The hybrids that recorded negative and significant *sca* effect were L_1 x T_1 (-0.55), L_2 x T_2 and L_3 x T_2 (-0.18).

5.4.4 Proportional contribution of parents and hybrids

In the present study hybrids contributed maximum for most of the traits, namely, days to first flowering, number of primary branches, length of fruit, girth of fruit, leafhopper population count as well as leafhopper injury index. Similar observations with respect to days to first flowering was reported by Sheela (1994).

The contribution of lines were the highest for leaf axil bearing first flower, weight of fruit, number of fruits, yield per plant and duration.

5.4.5 Gene Action

It was observed that dominance variance was higher for most of the characters which indicates non additive gene action. For all the other characters, *viz.*, days to first flowering, leaf axil bearing first flower, number of fruits per plant, length, girth and weight of fruit, yield and

a. Best line L_1 (Nemom local)

b. Best tester T_2 (Aruna)

c. Leafhopper resistant hybrid L_3 x T_2

Plate IV

duration, dominance gene action was predominant. It was observed that leafhopper population and leafhopper injury were governed by dominance gene action.

The ratio of additive to dominance variance was less than one for all the characters mentioned above. This indicates the predominance of non additive gene action in the inheritance of these characters.

Since there is preponderance of non additive gene effects for characters such as yield and its components as well as leafhopper resistance indices, exploitation of hybrid vigour is an appropriate breeding approach when yield and leafhopper resistance are considered.

Based on the present study L_3 x T_2 is identified as a desirable hybrid in terms of leafhopper resistance as well as yield. It is an early flowering genotype with higher weight of fruit and yield per plant. It has longer duration with resistance/tolerance to leafhopper.

SUMMARY

6. SUMMARY

Okra [*Abelmoschus esculentus* (L.) Moench] is a prominent vegetable crop cultivated extensively in India due to its amenability for year round cultivation. The leafhopper, *Amrasca biguttula biguttula* is the major sucking pest of okra which reduce the yield substantially. Okra varieties resistant to the leafhopper are scarce. So it is essential to develop varieties resistant to the pest. The present study was undertaken in the Department of Plant Breeding and Genetics, College of Agriculture, Vellayani during 2002-2003 to study the genetic basis of yield, yield attributes and leafhopper resistance through a line x tester experiment.

Forty okra varieties collected from different sources formed the materials for the study. This includes local cultivars and improved varieties which were evaluated for leafhopper resistance and yield. Jassid population counts as well as leafhopper injury scores were taken.

Screening for leafhopper resistance was carried out using leafhopper population count and leafhopper injury score. ANOVA revealed wide variability among the genotypes for all characters.

Evaluation for yield (40 genotypes) revealed significant variation among genotypes. The genetic parameters *viz.* phenotypic and genotypic coefficients of variation, heritability and genetic advance for each character under study were estimated. The highest value of phenotypic as well as genotypic coefficients of variation were observed for number of primary branches followed by leafhopper population count. High heritability was exhibited by yield per plant followed by duration. Maximum genetic advance was observed for number of primary branches followed by yield per plant.

Correlation analysis indicated that most of the character combinations had higher genotypic correlation coefficient than phenotypic correlation coefficient. Environmental correlation coefficients were the low in many cases.

Yield exhibited significant and positive correlation with its components number of fruits and average fruit weight and negative significant negative association with leaf axil bearing first flower, leafhopper population count and leafhopper injury score.

The direct and indirect effects of nine biometric characters as well as two leafhopper injury indices which had high correlation with yield were estimated through path analysis. Highest positive direct effect on yield was exhibited by number of fruits. Highest negative direct effect on yield was recorded for leafhopper population count. Among the indirect effects, minimum values in the positive direction was observed for number of fruits through plant duration. Lowest indirect effect has been observed for length of fruit through number of primary branches. Maximum negative indirect effects were exerted by leafhopper injury score through number of fruits and minimum indirect negative effect was exerted by days to first flowering through number of primary branches.

Resistant as well as susceptible genotypes were selected based on the leafhopper population count. Five resistant lines, Nemom local, IC45792, Venjaramood local, AE279 and Palappur local and three susceptible testers Venganoor local, Aruna and Kalliyoor local were selected as parents for Line x Tester analysis.

Line x Tester analysis was performed for nine biometric characters and two leafhopper injury indices. Parents varied significantly for all traits except length of fruits while crosses recorded significant variation except leaf axil bearing first flower. Interaction effect of plants and hybrids were not significant for number of fruits, fruit length and duration.

Line x Tester mean square was significant for all the characters under study. Lines varied significantly for leaf axil bearing first flower, number of fruits, weight of fruits, yield and duration while the testers exhibited variation for duration.

Heterosis was estimated for all the fifteen hybrids over mid, standard and better parents. Relative heterosis was highest for number of primary branches followed by number of fruits and yield. Heterosis over standard parent recorded high values for days to first flower, number and girth of fruit, leaf axil bearing first flower and yield while heterobeltiosis was high for number of fruits and leaf axil bearing first flower.

L_1 was the best line due to its all round performance with respect to yield and the least population of leafhopper it harboured. The best performing tester was T_2 followed by T_1.

Highly significant *gca* as well as *sca* effects were obtained for yield. L_1 exhibited significant *gca* effects for days to first flower, number of primary branches, number of fruits, girth and weight of fruits and leafhopper population counts while T_2 recorded good *gca* effects for days to first flowering, leaf axil bearing first flower, number of primary branches, number of fruits, duration and leafhopper score.

Among the hybrids, L_3 x T_2 was the best hybrid considering leafhopper resistance as well as yield and yield attributes. Negative and significant *sca* effects were recorded for days to first flowering and leafhopper population count.

The ratio of additive to dominance variance was less than one for all the traits. This indicates the predominance of non-additive gene action for most characters including yield and leafhopper resistance indices.

L_3 x T_2 was the leafhopper resistant hybrid identified during the study. The *sca* effect was high. It possessed all the desirable characters like high yield, greater weight and number of fruits and more girth of fruit. It is also an early flowering type.

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INHERITANCE OF RESISTANCE TO LEAF HOPPER, *Amrasca biguttula biguttula* (Ishida) IN OKRA, *Abelmoschus esculentus* (L.) Moench.

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ABSTRACT

Okra is an important vegetable crop grown in India and abroad for its fresh green pods. The leafhopper *Amrasca biguttula biguttula* is a major sucking pest of okra causing high damage to plants. High frequency of fruit picking and repeated application of chemical pesticides to tackle the hopper menace, often leaves toxic residues in the fruits. So it is inevitable that pest resistant varieties should be developed. Hence a study was undertaken to study the genetic variability, for yield and its component characters as well leafhopper resistance indices in a collection of okra genotypes, to estimate the combining ability and heterosis as well as gene effects involved in the inheritance of these characters using line x tester analysis.

Forty okra germplasms collected from various sources were evaluated simultaneously for yield and leaf hopper resistance. ANOVA revealed that the treatments varied significantly for leafhopper resistance and also there was significant variation among treatments for yield and yield attributes *viz.*, days to first flowering, leaf axil bearing first flower, number of primary branches, number of fruits per plant, length of fruit, girth of fruit, weight of fruit, yield per plant duration. Six genotypes exhibited resistance to the leafhopper throughout the crop duration.

High values for phenotypic and genotypic coefficients of variation was recorded for number of primary branches followed by leafhopper population count. High heritability was exhibited by yield per plant followed by duration. Maximum genetic advance was observed for number of primary branches followed by yield per plant.

Correlation analysis indicated that most character combinations had higher genotypic correlation coefficient than phenotypic correlation coefficient. Yield exhibited significant and positive correlation with number of fruits and average

fruit weight and negative significant association with leaf axil bearing first flower, leafhopper population count and leafhopper injury score.

Path analysis was carried out for nine biometric as well as two leafhopper injury indices which had high correlation with yield. Highest positive direct effect was exhibited by number of fruits while the highest negative direct effect on yield was recorded for leafhopper population count per plant.

Resistant as well as susceptible genotypes were selected based on leafhopper population counts and leafhopper injury score. Five resistant lines (female parent) *viz.*, Nemom (T_{21}), IC 45792, Venjaramood (T_{23}), AE 279 and Palappur (T_{20}) and three susceptible testers (male parent) *viz.*, Venganoor (T_{18}), Aruna (T_{37}) and Kalliyur (T_{24}) were selected as parents for L x T analysis. These were crossed in a line x tester fashion to produce 15 hybrids.

During L x T programme highly significant *sca* as well as *gca* effects were obtained for yield. L_1 was the best line while T_2 was the best tester. Among hybrids L_3 x T_2 was the best considering leafhopper resistance as well as yield and yield attributes. Negative and significant *sca* effects were observed for days to first flowering and leafhopper population count. It possessed all the desirable characters like high yield, greater weight and girth of fruits and number of fruits. It is also an early flowering type.

The ratio of additive to dominance variance was less than one for most of the traits studied including leafhopper population counts and leafhopper injury scores, indicates the predominance of non-additive gene action.

Since there is preponderance of non additive gene effects for characters such as yield and its components as well as leafhopper resistance parameters, exploitation of hybrid vigour is an appropriate breeding approach where yield and leafhopper resistance are considered.