GENETIC ANALYSIS OF YIELD AND YIELD ATTRIBUTES IN A LINE X TESTER ANALYSIS OF OKRA (*Abelmoschus esculentus* (L.) Moench)

By

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CERTIFICATE

This is to certify that the thesis entitled **"Genetic analysis of yield and yield attributes in a Line X Tester analysis of okra (*Abelmoschus esculentus* (L.) Moench)"** submitted in partial fulfilment of the requirements for the degree of **'Master of Science in Agriculture'** of the Acharya N.G. Ranga Agricultural University, Hyderabad, is a record of the bonafide research work carried out by **Mr. V. Sasidhar** under our guidance and supervision. The subject of the thesis has been approved by the Student's Advisory Committee.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part has been fully acknowledged. All assistance and help received during the course of the investigations have been duly acknowledged by the author of the thesis.

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This is to certify that **Mr. V. SASIDHAR,** has satisfactorily prosecuted the course of research and that the thesis entitled **"GENETIC ANALYSIS OF YIELD AND YIELD ATTRIBUTES IN A LINE X TESTER ANALYSIS OF OKRA (*Abelmoschus esculentus* (L.) Moench)"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that the thesis or part there of has not been previously submitted by him for a degree of any University.

Date :

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Place :

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DECLARATION

I, **Mr. V. SASIDHAR,** here by declare that the thesis entitled **“GENETIC ANALYSIS OF YIELD AND YIELD ATTRIBUTES IN A LINE X TESTER ANALYSIS OF OKRA (*Abelmoschus esculentus* (L.) Moench)"** submitted to Acharya N.G. Ranga Agricultural University, Hyderabad for the degree of **MASTER OF SCIENCE IN AGRICULTURE** is the result of original research work done by me. I also declare that the material contained in this thesis has not been published earlier.

Date : **(V. SASIDHAR)**

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LIST OF SYMBOLS AND ABBREVIATIONS

%	-	Percentage
CD	-	Critical difference
cm	-	centimetre
df	-	degrees of freedom
et al.,	-	and others
Fig.	-	Figure
g	-	gram
gca	-	general combining ability
GCV	-	genotypic coefficient of variation
h^2(b)	-	heritability (broad sense)
i.e.,	-	which is to say in other words
PCV	-	phenotypic coefficient of variation
r	-	correlation coefficient
r_g	-	genotypic correlation coefficient
r_p	-	phenotypic correlation coefficient
sca	-	specific combining ability
SEd	-	standard error of difference
viz.	-	Namely
YVMV	-	Yellow vein mosaic virus

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ABSTRACT

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The present investigation was undertaken with the objective of identifying the superior parents and cross combinations and to conceputalise breeding strategy for yield improvement in Okra. The study was conducted by raising six lines and three testers as parents and their 18 F_1 crosses at wet land farm, S.V.Agricultural College, Tirupati. (13.27°N latitude and 79.36°E longitude) in a randomised block design with three replications during spring summer 2003-2004. The data recorded for fruit yield and its eleven component characters were subjected to analyse the mean performance, variability, heritability, genetic advance, heterosis, combining ability and path analysis.

Analysis of variance revealed existence of significant genotypic differences for all the characters except branches per plant, node at which first flower appeared, fruit girth and 100-seed weight. The lines Gourav, Co-1, Naveen and Varsha Upahar, the testers Arka Anamika and Jagdish-111, and the cross combinations Gourav x Parbhani Kranti, Varsha Upahar x Jagdish-111, Pusa Makhmali x Jagdish-111, Gourav x Jagdish-111 and Co-1x Parbhani Kranti were found to be superior for yield and its

contributing characters. The F_1 hybrids Pusa Makhmali x Parbhani Kranti, Gourav x Parbhani Kranti, Co-1 x Parbhani Kranti, Varsha Upahar x Jagdish-111 and Varsha Upahar x Parbhani Kranti revealed high degree of hybrid vigour for fruit yield and its component characters.

Combining ability studies revealed the importance of both additive and non-additive gene action for all the characters studied. The lines Gourav, Varsha Upahar and Co-1, the testers Parbhani Kranti and Arka Anamika as best general combiners and the cross combinations Co-1 x Parbhani Kranti, Naveen x Arka Anamika, Co-1 x Arka Anamika, Gourav x Parbhani Kranti and Varsha Upahar x Parbhani Kranti as good specific combiners were adjudged for yield and yield attributing economic characters.

The parents and crosses exhibited high heterosis for all the characters and high genetic advance as percentage of mean for plant height, branches per plant, fruit length, fruit weight and seeds per fruit and fruit yield lending scope for improvement of these traits by simple selection procedure. High estimates of heterosis obtained in hybrid combinations revealed considerable genetic divergence among the parental lines.

The fruit yield was found to be strongly associated with fruits per plant, fruit length and fruit weight in both parents and crosses. These characters could be employed in selection programme. The positive associations between plant height, nodes on the main stem, branches per plant, seed per fruit, 100 seed weight and fruit yield and negative association of fruit girth with fruit yield per plant established in parents were however broken in crosses.

Few cycles of recurrent selection or biparental mating could be adopted for handling the present experimental populations in order to exploit both additive and non-additive genes governing all the traits as observed in the present investigation in Okra.

COMBINING ABILITY IN OKRA*
(*Abelmoschus esculentus* (L.) Moench)

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ABSTRACT

Combining ability (gca and sca) variances and effects for twelve quantitative characters were studied in F_1 generation of the parents of okra in a line x tester analysis. The variances due to gca and sca were significant for all the characters suggesting that both additive and non-additive gene effects were involved in their expression. The parent Gourav, Varsha Upahar, Co-1, Naveen, Parbhani Kranti and Arka Anamika were observed to be good general combiners for fruit yield and its contributing traits. Considering the prevalence of both additive and non-additive genetic variances for these traits recurrent selection or biparental mating may give fruitful results for yield improvement.

INTRODUCTION

Okra (2n = 2x = 130) is a warm season fruit vegetable grown in tropical countries of the world for fresh fruit market as well as processed produce. In India it is grown over an area of 3.26 lakh hectares with an annual production of 33.8 lakh tonnes and productivity of 10.37 t/ha. In Andhra Pradesh it is grown over an area of 25,414 ha with a production of 2,51,669 tonnes and productivity of 9.09 t/ha. However its productivity is least in both India and Andhra Pradesh although having a very high yield potentiality of 20 t/ha due to its allopolyploid (n = 65) nature. In this crop yield level has been reached a plateau in the existing varieties. Yield improvement through heterosis breeding is an alternative by adopting a line x tester analysis. It provides opportunity to involve large number of parents and information on genetic architecture of yield components to conceptualise efficient breeding strategy for yield improvement. Combining ability studies also useful in evaluation of parental lines and their cross combinations which aid in selecting parents for breeding purpose. Hence the present investigation was undertaken in Okra to evaluate the parents and their crosses.

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MATERIALS AND METHODS

Nine genetically diverse parents namely Pusa Makhmali, Gourav, Co-1, SK-403, Naveen and Varsha Upahar as lines, Arka Anamika, Parbhani Kranti and Jagdish-111 as testers were crossed in a line x tester mating design as suggested by Kempthorne (1957). Nine parents and 18 crosses were raised in a randomized block design with three replications at wet land farm, S.V. Agricultural College, Tirupati during spring-summer 2004. Each entry consists of ten plants raised in a single row on one side of the ridges with an inter and intra row spacing of 45 cm x 30 cm respectively. Recommended package of practices were followed to tend a good crop. Observations were recorded on five randomly selected plants in each entry for twelve quantitative traits namely plant height, nodes on the main stem, branches per plant, days to first flower, node of first flower appearance, fruits per plant, fruit length, fruit girth, fruit weight, seeds per fruit, 100 seed weight and fruit yield per plant. The statistical procedure given by Kempthorne (1957) was used for analysis of combining ability.

RESULTS AND DISCUSSION

Combining ability analysis revealed the existence of non-significant mean squares for lines except in number of branches and fruit yield per plant and testers. Whereas for line x tester interactions highly significant mean squares were observed for all the characters (Table 1) indicating that the lines and testers used in the present investigation represented wide genetic divergence. Significant line x tester interactions suggested the predominance of non-additive genetic effects in inheritance of all characters. The lines however exhibited greater magnitude of mean squares for all characters except fruit length and fruit weight than testers, and except for number of branches per plant and 100 seed weight than line x tester interactions indicating the presence of considerable amount of additive gene action in expression of all traits. This is in accordance with the findings of Singh (1979) for pod length, girth and weight, Singh and Singh (1979) for days to first flower and fruit yield per plant, Pratap and Dhankar (1980) for pod girth, length and weight and pod yield per plant.

The variances due to general combining ability (gca) and specific combining ability (sca) revealed greater magnitude of sca than gca and lesser (<1) ratios of gca : sca (Table 1) indicated the predominance of non-additive gene action for all the characters. Similar to present findings predominance of non-additive gene action was also reported by Kulakarni *et al*. (1976) for days to flowering, Singh and Singh (1979) for plant height, branches per plant and fruit yield per plant, Patel *et al.* (1994) for number and weight of seeds per pod and 100 seed weight, Rajani and Manju (1999) for fruits per plant, fruit length, fruit girth, and fruit weight. Analysis of variance for combining ability however showed significant differences for gca and sca effects for all the characters revealing that both additive and non-additive types of gene effects were involved in the inheritance of these traits in okra. These results are in close agreement with the findings of Sharma and Mahajan (1979) for plant height, marketable fruit maturity, fruit length, fruit girth, fruit weight and fruit yield per plant, Armugam and Muthukrishnan (1979) for plant height, branches per plant, days to flowering and Veeraraghavathatham and Irulappan (1990) for plant height, pods per plant, pod length and pod girth in Okra.

In the present study gca effects (Table 2) revealed that the lines Gourav, Varsha Upahar, Co-1 for fruit yield per plant, fruit characters and days to first flower / branches per plant / seed characters, Naveen and SK-403 for vegetative vigour and seed characters and the testers Parbhani Kranti, Jagdish-111 for fruit yield per plant, fruit characters and plant height and Arka Anamika for vegetative vigour and 100 seed weight were found to be good general combiners. These parents can be exploited through heterosis breeding for developing high yielding hybrids. The estimates of sca effects (Table 3) showed that the cross combinations Co-1 x Parbhani Kranti, Naveen x Arka Anamika, Co-1 x Arka Anamika for fruit yield and its contributing characters , Gourav x Parbhani Kranti and Varsha Upahar x Arka Anamika for fruits per plant and seed characters were adjudged to be the best specific combiners. These hybrids can be advanced in further generations for selecting superior transgressive segregants.

A perusal of the results suggested that all the quantitative characters are under the governance of both additive and non-additive gene actions. Under such situation, a few cycles of recurrent selection or biparental mating between the genotypes of the selected cross could be adopted for handling of such population.

SUMMARY

Nine parents and 18 F_1 hybrids of okra obtained from line x tester mating design were studied to investigate their combining ability. Greater mean squares exhibited by the lines than line x tester interactions suggested the presence of considerable amount of additive gene action whereas the variance ratio gca / sca was less than unity indicated the predominance of non-

additive gene action in the inheritance of twelve metric traits studied. Significant differences for gca and sca for all the characters revealed both additive and non-additive types of gene effects. An overall appraisal of gca effects revealed that the parents Gourav, Varsha Upahar, Co-1 (lines) Parbhani Kranti and Arka Anamika (testers) were good general combiners. The SCA effects revealed that the cross combinations Co-1 x Parbhani Kranti, Naveen x Arka Anamika, Co-1 x Arka Anamika, Gourav x Parbhani Kranti and Varsha Upahar x Arka Anamika were the best specific combiners for yield and its contributing characters.

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Table 1 : Line x Tester analysis mean squares for 12 characters in Okra

Source of variation	d.F	Plant height	Number of nodes on main stem	Number of branches per plant	Days to first flower	Node at which first flower appeared	Number of fruits per plant	Fruit length	Fruit girth	Fruit weight	Number of seeds per fruit	100 seed weight	Fruit yield per plant
Lines	5	289.1043	8.2569	0.1661	5.027	0.1150	21.0092**	7.1275	0.0207	3.8232	95.1052	0.2580	2096.6724*
Testers	2	9.2539	0.6536	0.0763	5.0569	0.0386	7.2452	9.7050	0.0146	4.7612	60.9060	0.1192	1977.2361
Line x Tester	10	273.7249**	5.6371**	0.3092**	4.8755**	6.0581**	4.9823**	3.1539**	0.0164**	2.1151**	40.4660**	1.7269**	627.7583**
Error	52	0.2743	0.1016	0.0088	1.5608	0.0138	0.1263	0.0496	0.0008	0.0305	0.1816	0.0013	0.6722
σ^2gca	-	-0.7973	0.0055	-0.0021	0.0019	0.0004	0.1493	0.581	0.0000	0.0294	0.5531	-0.0186	17.7134
σ^2sca		91.1520	1.8452	0.1001	1.1056	0.0147	1.6187	1.0348	0.0052	0.6949	13.4281	0.5752	209.0287
σ^2gca / σ^2sca		0.009	0.0030	0.0021	0.002	0.027	0.0922	0.0561	0.00	0.0351	0.0398	0.0323	0.0847

* Significant a 0.05
** Significant at 0.01

Table 2 : General combining ability effects of 9 parents for 12 characters in Okra.

Sl. No.	Treatments	Plant height	Number of nodes on main stem	Number of branches per plant	Days to first flower	Node at which first flower appear	Number of fruits per plant	Length of fruit	Girth of fruit	Weight of fruit	Number of seeds per fruit	100 seed weight	Fruit yield per plant
	LINES												
1.	Pusa Makhmali	-5.28**	-0.85**	-0.04	-0.44	-0.05	2.07**	-0.43**	0.01	0.13*	-4.70**	-0.04**	13.60**
2.	Gourav	-0.75**	0.174	-0.02	-1.00*	0.08*	0.89**	0.32**	0.01	0.73**	-0.87**	-0.21**	16.96**
3.	Co-1	-1.56**	-0.54**	-0.20**	1.11*	-0.20**	-1.75**	0.74**	-0.03**	0.15*	4.81**	0.12**	-8.85**
4.	SK-403	10.65**	1.64**	-0.04	0.00	0.03	-1.80**	-1.47**	-0.04**	-0.42**	-1.83**	0.03*	-16.90**
5.	Naveen	0.87**	0.41**	0.09**	0.55	0.08*	0.06	-0.14	-0.03**	-1.07**	1.43**	0.25**	-14.97**
6.	Varsha Uphar	-3.94**	-0.83**	0.20**	-0.22	0.05	0.53**	0.97**	0.08**	0.47**	1.16**	-0.15**	10..16**
	TESTERS												
7.	Arka Anamika	-0.51**	0.20**	0.05*	-0.33	-0.05	-0.61**	-0.85**	-0.003	-0.59**	-0.29**	0.08**	-12.08**
8.	Parbhani Kranti	-0.30*	-0.03	-0.07**	0.61*	0.01	-0.04	0.39**	0.03**	0.35**	-1.68**	0.01	5.48**
9.	Jagdish-111	0.82**	-0.17*	0.02	-2.77	0.03	0.65**	0.45**	-0.03**	0.24**	1.97**	-0.08**	6.60**
	SE (Lines)	0.17	0.10	0.03	0.42	0.04	0.12	0..07	0.01	0.06	0.14	0.01	0.27
	S.E (testers)	0.12	0.07	0.02	0.30	0.02	0.08	0.05	0.01	0.04	0.10	0.01	0.19

* Significant at 0.05
** Significant at 0.01

Table 3 : Specific combining ability effects of 18 crosses for 12 characters in okra

Sl. No.	Treatments	Plant height	Number of nodes on main stem	Number of branches per plant	Days to first flower	Node at which first flower appear	Number of fruits per plant	Length of fruit	Girth of fruit	Weight of fruit	Number of seeds per fruit	100 seed weight	Fruit yield per plant
1	Pusa Makhmali x Araka Anamika	-1.69**	-0.25	-0.23**	1.56*	0.07	-1.32**	0.72**	-0.05**	0.26*	-0.44	-0.36**	-4.57**
2	Pusa Makhmali x Parbhani Kranti	-0.03	0.12	0.10	-0.06	-0.13	0.04	-0.28*	0.03*	0.25*	-0.79**	0.22**	6.39**
3	Pusa Makhmali x Jagdish -111	1.71**	0.13	0.13*	-1.50*	0.05	1.28**	-0.43**	0.02	-0.51**	1.23**	0.14**	-1.83**
4	Gourav x Arka Anamika	2.45**	-0.54**	0.09	0.44	0.01	-0.54*	-0.34*	-0.05**	-0.08	-6.27**	-0.01	-5.90**
5.	Gourav x Parbhani Kranti	-4.70**	0.16	-0.39**	-0.83	-0.06	0.96**	-0.19	0.01	0.45**	1.46**	-0.11**	12.14**
6.	Gourav x Jagdish-111	2.25**	0.37*	0.31**	0.39	0.05	-0.41	0.53**	0.04*	-0.38**	4.81**	0.13**	-6.24**
7.	Co-1x Arka Anamika	6.86**	1.84**	0.06	-1.67*	0.03	-0.63**	-1.91**	-0.10**	-1.36**	1.31**	0.78**	-18.09**
8.	Co-1 x Parbhani Kranti	-6.52**	-1.93**	-0.35**	2.06**	-0.04	0.73**	0.61**	0.03	1.30**	-0.97**	-0.52**	18.27**
9.	Co-1 x Jagdish-111	-0.34	0.09	0.29**	-0.39	0.01	-0.10	1.30**	0.07**	0.07	-0.34	-0.26**	-0.18
10.	SK-403 x Arka Anamika	-14.55**	-1.54**	-0.03	-0.56	-0.01	-0.32	0.46**	0.00	0.08	0.42	-0.47**	1.16*
11.	SK-403 x Parbhani Kranti	19.77**	1.90**	0.30**	0.17	-0.01	0.04	0.09	0.01	-0.26*	0.21	0.63**	-4.77**
12.	SK-403 x Jagdish-111	-5.22**	-0.36	-0.27**	0.39	0.03	0.28	-0.55**	-0.02	0.18	-0.63*	-0.15**	3.62**
13.	Naveen x Araka Anamika	2.03**	0.35	0.24**	-0.44	-0.19**	2.54**	-0.30*	0.12**	0.46**	2.69**	-0.69**	19.19**
14.	Naveen x Parbhani Kranti	-8.19**	-1.28**	-0.04	-0.06	0.07	-1.02**	0.37**	-0.04*	-0.55**	3.08**	1.01**	-13.30**
15.	Naveen x Jagdish-111	6.16**	0.93**	-0.20**	0.50	0.12	-1.52**	-0.06	-0.07**	0.09	-5.77**	-0.32**	-5.89**
16.	Varsha Uphar x Arka Anamika	4.90**	0.13	-0.14*	0.67	0.10	0.28	1.37**	0.07**	0.65**	2.29**	0.76**	8.20**
17.	Varsha Uphar x Parbhani Kranti	-0.34	1.03**	0.39**	-1.28	0.16*	-0.76**	-0.59**	-0.05**	-1.19**	-2.99**	-1.23**	-18.72**
18.	Varsha Uphar x Jagadish-111	-4.56**	-1.16**	-0.25**	0.61	-0.26**	0.48*	-0.78**	-0.02	0.55**	0.70**	0.48**	10.52**
	SE (S_{ij})	0.30	0.18	0.05	0.72	0.07	0.20	0.13	0.02	0.10	0.25	0.02	0.47

* Significant at 0.05
** Significant at 0.01

CHAPTER - I

INTRODUCTION

Okra or 'Lady's finger' (*Abelmoschus esculentus* (L.) Moench.), [2n = 2x = 130] is a warm season fruit vegetable grown in the tropical and sub tropical countries of the world. In India it is commonly known as bhendi, commercially cultivated in the states of Gujarat, Maharastra, Andhra Pradesh, Uttar Pradesh, Tamil Nadu, Karnataka, Haryana and Punjab due to it's well adaptability. In India, it is grown over an area of 3.26 lakh hectares with an annual production of 33.8 lakh tonnes. It ranks 4^{th} in area and 7^{th} in production but least in productivity (10.37 t/ha). In Andhra Pradesh it is grown over an area of 25,414 ha with a production of 2,51,669 tonnes and productivity of 9.09 t/ha (Kalloo and Pandey, 2002).

The crop is grown over a wide range of soils and climatic conditions both in summer and rainy seasons. Okra is especially valued for its tender and delicious pods in different parts of the country for internal and export markets as fresh vegetable. Along with soothing properties for digestion, bhendi is an important source of calcium, iron, iodine and Vitamin A, B and C. Cultivated okra seed contains 16 to 22 per cent edible oil (Anonymous, 1959) and 11.8 to 17.3% non-edible oil (Sujatha *et al.*, 1986). Our country has shortage of both types of oil. Okra seed could be used to augment the sources of oil. Bhendi is also processed in the form of canned, dehydrated or frozen produce to a limited extent for preservation and export. Keeping in view of these characters, there is a pressing demand for a suitable variety with high production potential. The average yield (10.37 t/ha) shows that there is a wide gap in productivity and is inadequate to meet the requirements of the country for both internal and export markets. However, there is ample scope to double the yield in view of its high genetic potential (20.0 t/ha).

Higher yield and better fruit quality are universally desired. Increase in production through exploitation of hybrid vigour is one of the most important tools of plant breeding for improvement of any crop. Hybrid vigour could be successfully employed in improving the quality and production of many crops while this is true in some developed countries. The use of F_1 hybrids in India is not fully exploited in bhendi crop due to lack of suitable heterotic combinations for commercial exploitation. Further, lack of male sterile lines and high cost of production by hand emasculation and pollination are the limitations at the moment.

Yield is a complex attribute, which is mostly influenced by a number of component characters either directly or indirectly through other components. Most of the quantitative characters like plant height, number of branches, number of nodes and internodal length, earliness, fruit length, fruit girth and number of fruits are mostly governed by polygenic systems in which large number of genes contribute to the expression of the character, besides influenced by the fluctuating environmental components.

Any improvement in breeding programme could have direct bearing on the productivity of the crop. Okra being an allopolyploid (n = 65), there is scope for variation in chromosomes which can be utilised in breeding programme for yield improvement. For developing better varieties through hybridization, the choice of desirable parents is a matter of great concern to the plant breeder. This can be effected by combining ability analysis which would not only help in selection of parents and crosses, could transmit high yield and other economic traits to the progeny for crop improvement but also indicates the relation between additive and non-additive portion of genetic variance in the material. However, a high yielding genotype may not necessarily transmit its superiority in its cross combination. In such contest, among the several biometrical procedures, the Line x Tester analysis proposed by Kempthorne (1957) appears to be the most useful technique for screening large number of lines with reasonable confidence. This indicates relative capacity of female and male parents as best combiners to produce desirable recombinants and to sort out the best combiners. An effective breeding programme in order to evaluate varieties having high yield potential to break the existing plateau of productivity requires information on genetic variability, estimates of heritability and genetic advance of polygenic characters, association of characters, heterosis and combining ability of yield and its attributes. Meagre work has been done in Okra along this direction. Therefore, the present study has been carried using Line x Tester mating method with the following objectives.

Objectives of investigation

1. To assess the breeding potentialities of selected genotypes for various economic characters.
2. To find out the extent of heterosis and to isolate high heterotic crosses with specific combining ability effects for commercial exploitation of hybrid vigour.
3. To identify superior parents and crosses as well as to detect gene action of yield and its components through combining ability.
4. To estimate the genetic parameters viz., variability, heritability, and genetic advance as per cent of mean for yield and its components.
5. To identify the effective components of yield and to understand the pattern of association among the component traits.
6. To assess the direct and indirect effects of component characters influencing yield based on path coefficient analysis and to formulate selection criteria for yield improvement.

CHAPTER - II

REVIEW OF LITERATURE

Bhendi (*Abelmoschus esculentus* (L.) Moench.) is extensively cultivated throughout the continent for its long slender and immature green fruits (capsule) during summer and rainy seasons. Deterioration takes place in old varieties and to overcome the problem, crop improvement is needed. The breeding methodology to be adopted for the improvement of a crop primarily depends upon the genetic variability present in the crop. A suitable variety can be achieved effectively by adopting proper breeding techniques for which recognition of genotypic and qualitative assessment of the population for yield and its contributing characters is necessary. Expression of yield is due to interaction of several fitness characters. Further the expression is not only polygenetically controlled but is also influenced by the fluctuating environmental components. An understanding of the association between the component characters is essential to bring a rational improvement in the desirable trait. An effective selection programme recognizes the degree of heritable and environmental variation.

It is of immense importance that hybrids or segregates are obtained only from the desirable parental combinations. Hence it is important to identify or select the desirable parents which could transmit high yield and other economic traits including resistance to yellow vein mosaic virus to the progeny.

Work on crop improvement programme in bhendi towards the selection of inbredlines, hybridization based on combining ability and character association is not adequate and existing variability has not been fully exploited to produce recombinants with desirable attributes like high fruit yield with light green, thin, medium long, smooth, tapering shaped fruits at marketable stage and free from conspicuous pubescence. More number of nodes, branching, resistance to YVM and early maturing with prolonged harvest are the other economic characters of a good variety.

Literature available on bhendi pertaining to variability, heritability, genetic advance, heterosis, combining ability and gene action, character association and path co-efficient analysis are reviewed below.

2.1 VARIABILITY

A programme of breeding for improvement of yield and disease resistance require information on the extent of variation in the available material and association of characters among themselves. In evaluation trial for genetic variability of six characters conducted on 21 varieties of okra at Punjab Agricultural University, Ludhiana by Padda *et al.* (1970) it was revealed that the genetic coefficient of variation was highest for seeds per fruit. For all the other characters it was moderate to low (12.6-4.4). Kirti Singh *et al.* (1974) reported that the variability for yield in bhendi is primarily dependent on weight of fruit, number of fruits per plant and number of flowers per plant. Variability studies conducted on forty one okra genotypes for yield and its attributes at Pant Nagar by Agarwal *et al.* (1984) indicated considerable variability among the genotypes for earliness (60-74 days), fruits per plant (8.5-17.8), length of mature fruit (12.4-21.0 cm) girth of the mature fruit (6.3-9.8 cm), fruit yield per plant (60.0-395.0 g), seeds per fruit (40-76), hundred seed weight (5.9-6.8 g) and seed yield per plant (14.45-24.25 g).

In similar studies conducted on 40 F_1's of okra obtained from a line x tester programme , Panda and Singh (1997) reported high genotypic as well as phenotypic coefficient of variation for number of branches per plant, number of fruits and total yield per plant in both summer and rainy seasons. Ramesh Pathak and Arun Kumar Singh (1999) working on Okra at Varanasi observed that PCV was high than GCV for all the characters indicating the role of environment in expression of genotypes. High variability as indicated by highest estimates of GCV and PCV were noted for plant spread (34.72 and 35.15), number of branches per plant (34.45 and 35.71), followed by fruit weight (26.19 and 26.50) fruit diameter (18.76 and

18.840 and number of fruits per plant (16.20 and 16.58) which are the important yield components that can be better utilized in selection of programme.

Gandhi *et al.* (2001) noted high GCV and PCV estimates for number of branches per plant, dry fruit yield per plant and height at first fruit set, on screening forty two genotypes of Okra collected from NBPGR. High magnitudinal differences between GCV and PCV were observed for traits like number of branches per plant and seed yield per plant indicating the role of environment in the expression of characters. Among the bhendi germplasm representing from nine species collected from NBPGR, New Delhi and Akola, maximum variability was observed for most of the characters in *Abelmoschus esculentus* at IIVR, Varanasi. Several lines and species found resistant against major pests and diseases were identified besides noting the lines for small, long and smooth fruited types, The elite parents namely, Arka Anamika, Parbhani Kranti, Seven Dhari, HRB-55 and HRB-9-2 have been also identified for heterosis breeding (Ghosh and Kalloo, 2001).

2.2 HERITABILITY AND GENETIC ADVANCE

In any crop improvement it was suggested that genetic variability along with heritability should be considered for effective selection. A knowledge of the estimates of heritability and the expected genetic gain in the next cycle of selection would help the breeder in planning of a breeding programme to evaluate varieties having high yield potential to break the existing plateau of productivity.

Malik (1968) reported high heritability and high genetic advance for fruit diameter, fruit length, crude fibre, total sugars and Vitamin C content in bhendi .

In an evaluation trial conducted on 21 okra varieties, at Ludhiana, Padda *et al.* (1970) observed high heritability in broad sense for plant height, days to flowering, yield per plant, thousand seed weight and mosaic infection (48.8 to 77.6%). In case of seeds per fruit, it was very high (93.8%). The magnitude of genetic advance in per cent of mean noted was moderate to high for all the characters (7.4 to 51.3). High heritability and high genetic advance were also observed for plant height and number of days to flowering in bhendi by Rao (1972). Kirti Singh *et al.* (1974) reported high values of heritability and genetic advance for fruit diameter, crude fibre, fruit length and Vitamin C content. Rao further in 1977 when working on bhendi observed additive gene effects for days to flowering and dominance for plant height, both additive and dominance effects for number of fruits per plant. Rao and Ramu (1977) also reported additive gene effects for days to flowering, number of fruits and yield per plant and non-additive effects for plant height and number of seeds per fruit.

Singh and Singh (1979b) observed high rate of heritability for plant height, number of branches per plant, number of fruits per plant, days to flower and fruit yield per plant in Okra.

In biometrical analysis for earliness, fruit yield, seed yield and their components in Okra, Agarwal *et al.* (1984) observed high heritability estimates for days to first fruit harvest (79.49%), but it had a low estimates of genetic advance as percentage of mean (10.10) due to low coefficient of genotypic and phenotypic variability (5.49 and 6.17). They also observed fair heritability associated with high estimates of variability for fruit yield per plant (41.49%), fruits per plant (41.49%), seed yield per plant (59.23%), nodes on the main stem (37.61%) and girth of the edible fruit (44.06%). This resulted in higher estimates of genetic advance as percentage of mean for these characters (26.83, 13.73, 13.46, 12.79 and 10.98 respectively). According to Randhawa and Sharma (1988) heritability and genetic advance were high for number of fruits and branches per plant in F_3 generation suggesting there by the possibility of following selection in the early segregating generation for developing plants with more number of fruits in Okra.

In a 7 x 7 diallel cross of okra Veeraraghavathatham and Irulappan (1990) reported high heritability in narrow sense for fruit length (97.67%) fruit girth (86.5%) and YVMV incidence (68.6%), moderate heritability for plant height, lower node number of first flower bud appearance and low heritability for number of fruits per plant and fruit weight.

Siva Kumar *et al.* (1996) also reported very high heritability in narrow sense for fruit yield per plant (99.95%), plant height (96.97%), number of fruits per plant (85.38%) there by offering wide scope for improvement through selection while moderate heritability was observed for days to first flowering (58.63%) and node number of first flowering (22.08%) which provide scope for improvement through pedigree breeding in Okra. The narrow sense heritability was noted to be low for individual fruit weight (10.87%) suggesting the importance of heterosis breeding. Whereas fruit length and girth ratio, it was meagre (-32.9%) which limits the scope for pedigree breeding due to non-additive genes governing this trait.

Panda and Singh (1997) reported that all the characters under study except days to first flower appearance and girth of fruit were highly heritable in nature in all 41 F_1s of okra. High heritability coupled with high genetic advance was also observed for plant height, number of fruits and total fruit yield per plant which indicated that these traits are more reliable for improvement through selection.

In M_4 generation of bhendi cultivars of Pusa Sawani and Parbhani Kranti as obtained by irradiating them with gamma rays (0.80 K_R), Sathiyamurthy *et al.* (1998) noticed high heritability with high genetic advance as per cent of mean for nodes per plant, fruits per plant and yield per plant indicating the action of additive genes while high heritability and moderate genetic advance indicated the action of both additive and non-additive factors for fruit weight and seeds per fruit and thus shows possibility of adhering to these characters for selection in advanced generation. High heritability and low genetic advance were observed in other characters revealed non-additive gene action which would not be depended upon for selection.

Ramesh Pathak and Arun Kumar Singh (1999) observed high estimates of heritability for fruit diameter (98.2%), fruit weight (97.7%), fruit yield per plant (97.7%) and earliness (97.3%). Fruit weight and fruit diameter had higher heritability along with high GCV thus imparting greater scope for effective selection in these characters. They further observed high genetic advance for fruit weight, plant spread, plant height and fruit yield per plant indicating importance of additive gene effects which are more reliable for effective selection in these traits for bringing improvement.

In variability studies involving forty four genotypes Gandhi *et al.* (2001) observed medium to high heritability for all the 13 characters studied. The characters namely fruit length (64.4%), plant height at first fruit set (58.85%) and fruit girth (43.6%) showed high heritability estimates. However, these characters were coupled with varied genetic advance (i.e., high, medium and low respectively) suggesting complexity of genetic mechanism in expression of these traits. The additive genetic variance was reported for the traits like plant height, height of first fruit set, internodal length, fruit length, number of fruits and number of branches per plant.

2.3 HETEROSIS

Variability along with high heritability and high to medium genetic advance provide enough scope for selection of a particular trait or traits in crop improvement. An opposite of this suggests hybridization as the potential method for crop improvement. Bhendi is a cross pollinated crop. It manifested vigour for yield and its attributes. Exploitation of hybrid vigour in bhendi has been recognised as a practical tool in providing the breeder one of the means of increasing yield and other economic characters.

Manifestation of hybrid vigour in inter-specific and intervarietal hybrids has been reported in bhendi for different quantitative traits earlier by several workers (Pal *et al.* 1952).

According to Venkataramani (1952) increase in yield is contributed by number of fruits per plant which ranged from 5.4 to 14.5 per cent over the better parent in bhendi. Joshi *et al.* (1959) reported hybrid vigour per plant height, fruit size, number of fruits per plant and yield per plants in bhendi. Number of fruits contributed to as high of 60 per cent increase in yield of hybrid over the standard variety Pusa Makhmali. The increase in yield over the respective parents of the heterotic crosses ranged from 11.8 to 101.7 per cent. Raman and Ramu (1963) observed heterosis for spread of plants, early flowering and fruit weight and yield in bhendi. Significant heterosis was also reported by Sharma (1965) for plant height, early flowering, fruit weight, number of fruits and fruit yield in okra. Hybrid vigour for early flowering, early maturity, higher fruit weight and yield was also reported in F_1 hybrids obtained from crosses between Pusa Sawani and Pusa Makhmali and Pusa Sawani and H 938 by Joshi *et al.* (1959) and Raman (1965).

Lal and Srivastava (1973) while examining twelve crosses of bhendi obtained from the nine parents for hybrid vigour in respect of seven quantitative characters at Kanpur, observed that one cross KB x 6103 for plant height, two crosses 6102 x Kalianpur T_1 and 5704 x 6102 for fruit length, one cross 5614 x Kalianpur for fruit thickness, two crosses KB x 6102 and 6120 x Kalianpur T_1 for fruit yield have shown positive hybrid vigour. The cross Kalianpur Bonia x 6102 excelled all the crosses as it showed hybrid vigour for plant height, number of fruits and yield per plant.

Sharma and Mahajan (1978) reported that heterosis over mid parental value was in the range of 0.03 to 68.03 per cent for days to first flowering, marketable maturity, number of fruits per plant, fruit length, weight and diameter, number of ridges on the fruit, plant height and fruit yield per plant. They observed more fruits per plant and higher yield in F_1 hybrid Pusa Sawani x Smooth Long Green and more plant height and higher yield in American Seven Dhari x Pusa Sawani. Singh (1979) observed residual heterosis in F_2's for early flowering, fruit maturity, number of fruits and fruit yield due to their dominance expression in F_1's. Manifestation of heterosis over better parent was evident in inter-specific crosses for number of fruits per plant, plant height and number of branches, speed of seed germination, early flowering and marketable maturity (Dhillon and Sharma, 1982). Heterosis for plant height, fruits per plant and fruit weight in Balady x American Gold coast (Poshiya and Shukla, 1986) was also reported.

Nirmaladevi and Peter (1991) observed significant heterosis for all the characters in an inter-specific cross between *Abelmoschus manihot* var Ghana x *Abelmoschus esculentus*. Sivagamasundari *et al.* (1992a) reported positive heterosis over the best parent for number of fruits per plant in crosses Arka Abhaya x Arka Anamika and Arka Abhaya x AE 974, individual fruit weight in AE 974 x EMS 8, Parbhani Kranti x Arka Anamika, Parbhani Kranti x EMS 8, fruit length in AE 974 x Parbhani Kranti, Arka anamika x Parbhani Kranti and fruit girth in Arka Abhaya x Arka Anamika and AE 974 x EMS 8. Expression of hybrid vigour in okra with respect to increase in fruit size, fruit weight , fruit number and yield were observed and reported by Babu *et al.* (1994).

Anitha Vasline and Ganesan (1995) in a line x tester analysis of bhendi involving 12 lines and 3 testers reported that among 36 hybrids the best one for high heterotic expression was Pusa Sawani x CO-2 followed by Parbhani Kranti x CO-2. In a line x tester analysis involving 14 lines and 4 testers at TNAU Coimbatore, Elangovan *et al.* (1979) indicated that manifestation of heterosis over the mid and higher parents was evident over all the characters studied. Among the 56 F_1 hybrids, AE 1068 x AE 180 was found to be heterotic one exhibiting high heterosis for yield (44.67% over mid parents, 31.42% over better and best parents) and its components indicating its utility for commercial cultivation. This was followed by AE 800 x AE 142 and AE 828 x AE 142. The hybrid AE 711 x AE 106 recorded the highest favourable heterosis for earliness.

Singh and Sonia Sood (1999) reported that the crosses having high heterosis also showed inbreeding depression suggesting the importance of non-additive (dominant) gene action which contributes equally to both by activating additively or non-additively. The dominant gene represents the most desirable gene action where heterotic effects through recombination are converted into additive and fixable effects leading to stability of hybrid vigour in F_2 with absence of inbreeding depression. They also identified the crosses especially SB-3 x Pusa Sawani, Perkins Long Green x SB-5 and Perkins Long Green x Parbhani Kranti as potential hybrids for commercial exploitation.

In a 8 x 8 half diallel cross of bhendi Ahmed *et al.* (1999) reported high heterobeltiosis for number of fruits per pant (74.77%), average fruit weight (62.5%), number of branches per plant (52.5%), moderate heterobeltiosis for height of first fruiting node (44.83%), fruit yield per plant (36.42%), node of first fruit appearance (-32.09%), plant height (26.75%) and internodal length (-26.11%) and low heterobeltiosis for fruit length (17.29%), days to first fruit set (-12.12%) and fruit girth (1.12%).

Most of the crosses revealed presence of inbreeding depression in F_2 generation which may be due to reduction in intra and interallelic non additive gene action as opined by Mather and Jinks (1982).

In evaluation of hybrids of Okra collected from local dealers along with two open pollinated varieties as check at Bhubaneswar, Dash *et al.* (2001) reported significant variation in total yield in the range of 35.24 to 152.63 q/ha in different hybrids. All hybrids had better values over Parbhani Kranti and Pusa Sawani. Maximum yield was recorded with Prabha (152.63 q/ha) which was statistically superior over the other hybrids followed by hybrid-312 (110.25 q/ha) and DSBH-1 (104.56 q/ha), while the lowest was with Bankim-F_1 (45.91 q/ha). The maximum per cent increase in the yield over control was recorded with (294.18%) followed by hybrid-312 (184.73%), DSBH-1 (170.04%) and SE-22 (133.65%). Bankim-F_1 recorded only 18.5% increase in yield over control. They also found that most of the hybrids and open pollinated varieties were free from YVMV incidence except the hybrid Lahari (18.75%) Panchali (12.81%), DSBH-1 (6.76%) and Reshma (1.2%).

From the foregoing review it is clear that the standard heterosis over commercial varieties is of much practical value. Over dominance observed for days to first flowering, fruit length and weight, plant height and fruit yield suggest that hybrid vigour can be exploited in okra for increasing fruit yield through these characters. Potential of this approach is evident from the reports where more than 100 per cent increase in yield over the better parent has been recorded and also presence of dominant gene effects for yield and yield contributing traits.

2.4 COMBINING ABILITY AND GENE ACTION

In crop improvement especially through hybridisation programme, it is important to choose varieties with desirable characters based on genetic diversity, nature and magnitude of heritability, *per se* performance and combining ability.

Combining ability would help not only in the selection of parents and crosses for crop improvement but also indicate the relation between additive and non-additive portion of genetic variance in the material. The component of variance analysis is commonly employed to elucidate gene action for different characters. The estimates of genetic parameters and their ratios indicate the nature of gene action namely additive or non-additive, dominance or recessive etc. The nature of gene action for a number of biometrical traits has been studied in okra by different workers through Diallel and Line x tester analysis.

According to Kulkarni *et al.* (1976) number of fruits had predominance of additive gene action, whereas days to first flower and plant height were controlled by non-additive gene effects in Okra. Both additive and non-additive components of variance were high for plant height, number of fruits and yield per plant in bhendi (Ramu, 1976). Through a partial diallel analysis Kulkarni *et al.* (1976) found dominant genes to govern days to flowering with unequal distribution of positive and negative alleles whereas action of four groups of additive genes was indicated for plant height and dominance operated in the direction of lowering the number of fruits. In genetic analysis of F_1, F_2 and back cross progenies of inter-specific hybrids of *Abelmoschus*, Arumugam (1977) reported that resistance to YVM was controlled by one group of genes with additive effects.

Rao and Satyavathi (1977) reported additive gene effects for days to flowering and plant height. Rao (1977) reported additive genetic effects for days to flowering and dominance for plant height and both additive and dominance for number of fruits per plant in bhendi. Rao and Ramu (1977) also reported additive gene effects for days to flowering, number of fruits and yield per plant and non-additive for plant height and number of seeds per fruit in Okra. For number of fruits per plant dominance or additive gene action was observed by Kulakarni and Thimmappaiah (1977). Depending on the parents involved both additive and dominance gene effects were observed for days to first flowering and marketable maturity, number of fruits per plant, fruit length, weight and girth, number of ridges per fruit, plant height and yield per plant in Okra (Sharma and Mahajan, 1978) and suggested few cycles of recurrent selection or biparental mating for improvement of fruit yield in Okra.

In an inter-specific cross involving *Abelmoschus esculentus* cvs and *Abelmoschus manihot* strains from Africa and Japan, Arumugam and Muthukrishnan (1979) inferred the presence of additive and dominance gene effects for plant height, number of branches per plant, days to flowering and leaf index. Predominance of additive gene effects for fruit length, girth and weight, number of ridges per fruit, internodal length and dominance for days to flowering and marketable maturity were observed by Singh (1979). In a line x tester analysis of Okra involving 10 lines and 2 testers Singh and Singh (1979b) reported predominantly non-additive gene action for plant height, number of branches and fruits per plant and additive gene action for days to flowering and fruit yield per plant. The parents KB, 7103 and 6302 were identified as best general combiners for the improvement of different characters. They further reported that in general the crosses involving high x high, high x medium and low x low general combiners appeared to be potential material for exploiting hybrid vigour in developing high yielding lines through pedigree breeding. Additive gene effects were indicted by Pratap and Dhankar (1980) for fruit girth, length and weight and yield in bhendi. Similarly Arora (1980) also reported the presence of additive gene effects for days to first flower, length and weight of fruit, seed weight, number of ridges per fruit, fruits per plant, nodes per plant, days to marketable maturity, total yield and protein content. Additive gene effects were also observed by Singh (1983) for days to first flower, fruit weight and length, number of ridges per fruit, internodal length and plant height .

In genetic analysis of P_1, P_2, F_1, F_2 BC_1 and BC_4 developed by crossing the commercial cultivars of Okra with exotic collections at Solan, Korla *et al.* (1985) noted dominance and dominance x dominance gene effects for plant height and number of fruits per plant whereas additive and additive x additive gene effects for node of first fruit set and days to first flower. In a 7 x 7 diallel analysis of Okra at Coimbatore, Veeraraghavatha-tham and Irulappan (1990) observed operation of additive and non-additive gene actions for plant height, number of fruits per plant, fruit length and fruit girth whereas additive gene played significant role in YVMV incidence. The importance of dominant genes was also stressed for individual fruit weight and yield. Further the plant height and yield were much under the influence of environment. In similar studies Sharma *et al.* (1983) reported that two complementary dominant genes with additive effect were governing the resistance to YVMV.

The presence of over dominance and highly assymetrical distribution of genes with positive and negative effects for all the characters indicating scope for development of superior hybrids through heterosis breeding was reported by Kulkarni *et al.* (1991). In a line x tester analysis of Okra, Chaudhury *et al.* (1991) indicated the importance of additive gene action for all the characters. Pusa Makhmali (line) and Punjab Padmini (tester) were identified as good general combiners for yield and its components.

In a 10 x 10 half diallel cross of Okra carried out at Parbhani, Patel *et al.* (1994) observed significant *gca* and *sca* effects for all the characters studied except number of fruiting branches per plant. The ratio of *gca* : *sca* indicated predominance of non-additive gene action for dry seed yield per plant, number and weight of seeds per fruit and 1000 seed weight and additive for rest of the characters. Gujarat bhendi was found to be the best general combiner for dry seed yield per plant and 1000 seed weight.

In a line x tester analysis of bhendi involving 14 lines and 4 testers studied at Coimbatore by Elangovan *et al.* (1979) revealed that the variance components due to lines x testers were significant for yield of fruits per plant and its component characters. The ratio of *gca* : *sca* indicated the predominance of non-additive gene action. The line AE 1068 and the tester AE 108 proved to be the best general combiners for fruit yield and its components. The high specific combining ability effect was expressed in hybrids involving high x high or high x medium or low x low combiners.

In similar studies involving 12 lines and 3 testers conducted at Annamalai nagar, Anitha Vasline and Ganesan (1995) reported that the combining ability analysis showed absence of relationship between the parental *per se* performance and *gca* and *sca* effect. The parents AE 110 and AE 158 were found to be good general combiners for fruit yield and other yield attributing characters.

In a 8 x 8 half diallel analysis of Okra. Shinde *et al.* (1995) observed the predominance of non-additive gene effects in governance of all characters except fruit weight for which additive effects were found more important. The parents AE 91 for number of fruits and nodes per plant, NO100 and IIHR-10 for plant height and fruit weight, Parbhani Kranti and NO 100 for number of seeds per fruit were adjudged as best general combiners. In a 4 x 4 full diallel cross of Okra, Siva Kumar *et al.* (1995) reported the importance of additive gene action for plant height and days to first flowering whereas non-additive gene action for fruit yield and number of fruits per plant. The parents Punjab-7 for plant height, number of fruits per plant, AE-129 for lower node of first flower appearance and days to first flower, hybrid-8 for dwarf plant stature, Punjab-7 for tall plant stature and EMS-8 for early flowering with fruiting at lowest node number were identified as good general combiners.

In Genetic analysis studies of bhendi involving four inbred lines of diverse origin in a full diallel cross, Siva Kumar *et al.* (1996) indicated the predominance of dominance factors in controlling the plant height with greater proportion of recessive genes, whereas both additive and non-additive genetic factors for lower node of first flower appearance with more of dominant alleles, partial dominance (i.e., additive factors) for days to first flower, fruit length / girth ratio, fruit yield and number of fruits per plant with more of recessive alleles. In a 6 x 6 full diallel cross of Okra from NBPGR centre, Rajani and Manju (1999) observed predominance of dominance genes in parents for fruit length, weight and yield and the presence of both additive and dominance genes for fruit girth and incidence of YVMV. The fruit number was seen to be influenced by environment alone while the flower number was affected by dominance effect. They further reported that the positive 'F' value was observed for all the characters studied except flower number indicating more of increasing alleles with dominance effect in parents. The higher value of H_1 than D and the dominance (H_1/D) indicated over dominance for all the characters. Further the value of H2/4H, deviated significantly from 0.25 indicating a highly assymetrical distribution of genes with positive and negative effects. Hence heterosis breeding can be resorted for developing superior hybrids with high production potential.

Panda and Singh (2000) reported that almost all characters were controlled predominantly by additive gene effects in both summer and rainy seasons except girth of the fruit which was governed by over dominance in summer season.

2.5 CHARACTER ASSOCIATION

In any crop improvement programme knowledge of association of traits between each other and their influence on yield of fruits to aid in selection programme is of significant importance as it contributes indirectly to the success of selection. Association between the traits especially in crosses reflect gene linkages and thus helps the breeder in assembling specific combination of traits from two parents of a cross. Further, selection of one trait invariably affects a number of other associated characters. A programme of breeding for improvement of yield and disease resistance require information on extent of variation in the available material and the association of characters among themselves. In bhendi inheritance of yield and its component characters and association between themselves have not been assessed in detail and the information available is meagre.

Studies in interrelationship of six characters on 21 okra varieties conducted at Ludhiana by Padda *et al.* (1970) indicated that there were positive correlations of plant height with mosaic infection, yield per plant and seeds per fruit. Similarly mosaic infection was positively correlated with days to flower, seeds per fruit and 1000 seed weight. Positive correlations were also observed between days to flower and seeds per fruit, between yield per plant and 1000 seed weight and between seeds per fruit and 1000 seed weight. Only positive correlation observed between days to flower and seeds per plant was statistically significant. Kirti Singh *et al.* (1974) observed that inter relation between yield and other contributing characters like number of flowers, height of plant, branch number, stem diameter, leaves per plant, fruits per branch and fruits per plant were positive and significant. Kaul *et al.* (1978) studied the correlation and path analysis components namely earliness, fruit yield and seed yield in Okra and found to be effective factors. Their casual factors were also identified and was stated that selections of plants having more primary branches per plant and plant height would result in the selection of high yielding genotype. Since fruit yield and seed yield were highly correlated, any programme for improvement of fruit yield would result in improvement of seed yield also.

Elangovan *et al.* (1980) reported that the traits namely number of fruits per plant, fruit length, fruit width and number of branches could be considered as the primary yield determining components for exercising selection in bhendi. Correlation studies carried out in F_2 generation of Okra crosses between Pusa Sawani (*Abelmoschus esculentus*) x *A. manihot* (African) and CO1 (*A. esculentus*) x *A. manihot* (African) by Arumugam and Muthukrishanan (1981) revealed that the fruit yield was found to be highly correlated with number of fruits, fruit length and number of seeds per fruit and to a lesser degree with the plant height and days taken for flowering. The selection for number of fruits will indirectly help in improvement of yield of fruit. Agarwal *et al.* (1984) working on Okra Pantnagar pertaining to correlation studies reported that fruits per plant, seed yield per plant, primary branches per plant, 100 seed weight, leaves per plant, seeds per fruit and plant height showed significant positive phenotypic correlation with fruit yield per plant. Fruits per plant followed by primary branches had maximum values of positive direct phenotypic effects on fruit yield. They further reported that the overall positive correlation between fruits per plant and fruit resulted from the positive values of its indirect effects through plant height, primary branches per plant, leaves per plant, seeds per fruit, 100 seed weight, and seed yield per plant. Seed yield was also reported to be correlated significantly and positively with 100 seed weight, fruits per plant, fruit yield per plant and leaves per plant. The highest direct effect was noted for 100 seed weight followed by fruits per plant. The high significant correlations of fruit per plant and fruit yield per plant with seed yield were also influenced through indirect effects of 100 seed weight. The leaves per plant showing significant correlation with seed yield had very low direct effect via 100 seed weight and fruits per plant.

Correlation studies carried out on 18 cultivars of Okra at Varanasi by Mishra and Singh (1985) revealed that the number of fruits per plant, fruit weight, fruit length, 1000 seed weight, plant height and number of nodes per plant had high positive and significant correlations with yield per plant. While YVM, seeds per fruit and branches per plant showed significant negative association with yield per plant.

Sivagamasundari *et al.* (1992b) reported significant positive association of internodal length, number of fruits per plant, fruit length, fruit girth and individual fruit weight with yield. The correlation coefficient between yield and number of fruits per plant was the highest (0.884). Intercorrelations among the characters revealed that the genotypic correlation for internodal length with number of fruits per plant (0.359) was positive and significant. Number of fruits per plant, fruit length and fruit girth had positive and significant association with individual fruit weight. Association was strong between fruit length and fruit girth. They further observed that the individual fruit weight exhibited a positive and significant relationship with number of fruits per plant, fruit length, fruit girth and internodal length. This suggests that the number of fruits per plant, fruit weight, fruit girth and fruit length and internodal length should be considered together as primary yield determining components in Okra.

2.6 PATH COEFFICIENT ANALYSIS

Correlations and path coefficient analysis of quantitative characters would be of help in choosing the component characters whose selection would result in the improvement of complex characters that are positively correlated. Path coefficient analysis facilitates partitioning of the correlation coefficients of genetic parameters of crop plants into direct and indirect effects of various traits influencing the yield per plant.

Swamy Rao *et al*. (1977) in their studies on path coefficient analysis of yield and its components observed that the number of fruits per plant had a potential role in making up the yield. Number of fruits showed the highest positive effect on yield compared to other characters viz., plant height and number of seeds per fruit, which also exhibited positive direct effect. Days to flowering had negative direct effect which could not be nullified with its indirect effects with number of fruits / plant or any other characters. However, the plant height exhibited a strong positive correlation with yield as positive direct effect on yield. This character also exhibited positive indirect effect with number of fruits . Finally they stated that the number of fruits per plant and plant height should be given major emphasis while selecting for high yield in Okra.

Korla and Rastogi (1978) recorded maximum direct effect of fruit thickness on fruit yield followed by fruit length and number of fruits per plant.

Singh and Singh (1979a) from their path coefficient analysis study found a positive and significant genotypic association between plant height and yield.

Sriramachandra Murthy and Bavaji (1980) observed that the number of fruits per plant has high direct effect but its effect is being reduced by its negative contributions through flowering. Days to flowering has high direct contributions, but this positive effect is nullified by negative contribution of fruit number. As such, the two characters appear to be in contrast to each other in the final expression of yield.

Agarwal *et al.* (1984) in their biometrical analysis showed days to seedling emergence has the maximum direct effect on earliness.

In path coefficient analysis studies of Okra, Mishra and Singh (1985) reported that fruit weight and fruits per plant were found to be most important variables which may be viewed in selection and hybridization programme for further improvement.

Balakrishnan (1988) revealed that the path coefficient analysis showed number of fruits per plant and fruit weight exhibiting profound positive direct effect on yield per plant in both the generations. The number of ridges per fruit had negative direct effect on yield. Most of the economic traits exerted positive and high indirect effect through number of fruits per plant. So selection based on the character viz., number of fruits per plant and fruit weight can lead to crop improvement in bhendi.

In similar studies Balakrishnan and Balakrishnan (1990) observed that yield per plant recorded high correlation values for number of fruits per plant and fruit weight. This indicate that the superior yielding ability is associated with these two yield components. They further observed that number of fruits per plant and fruit weight have the direct and positive contributory traits to the yield due to their direct effects. Between these two traits, number of fruits per plant showed the highest direct effect on yield. Significant negative association of number of seeds per fruit with number of fruits per plant and yield per plant, and highly significant positive correlations between fruit length and fruit weight, fruit girth and fruit weight were observed. Fruit length had highly significant negative correlation with fruit girth. The number of fruits per plant had positive correlation with fruit weight and 100 seed weight. The association between fruit weight and 100 seed weight was reported to be positive due to contribution of seeds towards the increase in fruit weight although a negative association was noticed between the fruit weight and number of seeds per fruit. This was attributed to the increased fresh weight of fruit. Significant negative correlation between the number of seeds per fruit and 100 seed weight was also reported. Hence emphasis must be given primarily to the number of fruits per plant followed by weight of fruit in exercising selection for achieving high yielding genotypes (Mishra and Singh, 1985).

CHAPTER - IV

RESULTS

"Studies on genetic analysis of yield and yield attributes" was conducted involving nine parents and their eighteen F_1 progenies of okra for twelve characters in Line x Tester analysis. The results obtained from the present investigation are presented in this chapter under the following headings.

4.1 ANALYSIS OF VARIANCE

4.2 MEAN PERFORMANCE

4.3 GENETIC PARAMETERS

4.4 HETEROSIS EFFECTS OF HYBRIDS-RELATIVE HETEROSIS AND HETEROBELTIOSIS

4.5 COMBINING ABILITY ANALYSIS

4.6 CHARACTER ASSOCIATION

4.7 PATH COEFFICIENT ANALYSIS

4.1 ANALYSIS OF VARIANCE :

Analysis of variance revealed highly significant differences among the treatments (crosses and parents) for characters viz. plant height, number of nodes on main stem, days to first flower, number of fruits per plant, length of fruit, weight of fruit, number of seeds per fruit and fruit yield per plant and non-significant differences among treatments for characters viz., number of branches per plant, node at which first flower appeared, girth of fruit and 100-seed weight (Table 1 and 2).

Table 1 : Analysis of variance for twelve characters in F_1 generation of Line x Tester analysis of Okra.

S. No.	Character	Mean sum of squares		
		Replications df=2	Treatments df=17	Error df=34
1.	Plant height	0.299	247.132**	0.293
2.	Number of nodes on main stem	0.270	5.821**	0.092
3.	Number of branches per plant	0.014	0.294	0.009
4.	Days to first flower	6.223	4.941**	1.202
5.	Node at which first flower appeared	0.094	0.072	0.009
6.	Number of fruits per plant	0.296	9.963**	0.147
7.	Fruit length	0.020	5.093**	0.058
8.	Fruit girth	0.001	0.017	0.001
9.	Fruit weight	0.011	2.929**	0.032
10.	Number of seeds per fruit	0.043	58.913**	0.183
11.	Hundred seed weight	0.002	1.105	0.001
12.	Fruit yield per plant	0.920	1218.554**	0.776

** Significant at P = 0.01

Table 2 : Analysis of variance for twelve characters in parents of Okra.

S. No.	Character	Mean sum of squares		
		Replications df=2	**Treatments df=17**	**Error df=34**
1.	Plant height	0.516	72.994**	0.223
2.	Number of nodes on main stem	0.135	3.532**	0.134
3.	Number of branches per plant	0.018	0.701	0.008
4.	Days to first flower	1.952	18.981**	2.467
5.	Node at which first flower appeared	0.040	0.2134	0.025
6.	Number of fruits per plant	0.092	6.905**	0.097
7.	Fruit length	0.00	7.595**	0.036
8.	Fruit girth	0.001	0.0050	0.001
9.	Fruit weight	0.049	3.1350**	0.028
10.	Number of seeds per fruit	0.230	29.883**	0.194
11.	Hundred seed weight	0.001	0.065	0.003
12.	Fruit yield per plant	1.357	665.117**	0.416

** Significant at P = 0.01

4.2 MEAN PERFORMANCE OF PARENTS AND F_1'S

The analysis of variance for twelve plant attributes indicted significant differences among genotypes (parents and F_1 crosses) for eight characters. The mean performance values of parents and crosses for 12 characters are presented in Table 3.

4.2.1 Plant height

The mean plant height of the parents was 42.79 cm. The lines SK-403 (51.77 cm), Gourav (46.40 cm) and the testers, Arka Anamika (45.07 cm), Jagdish - 111 (46.00 cm) were significantly taller among the parents.

In crosses, the mean plant height was 46.48 cm. Highest plant height was registered in the cross SK-403 x Parbhani Kranti (76.60) and least plant height in cross Co-1 x Parbhani Kranti (38.10 cm). Seven hybrids were significantly taller compared to the grand mean (46.48 cm).

4.2.2 Number of nodes on main stem :

The mean of parents for this trait was 16.45 only SK-403 (18.20), in lines and Arka Anamika (18.00) in testers recorded significantly more number of nodes on main stem.

In crosses, more number of nodes on main stem were recorded in the cross SK-403 x Parbhani Kranti (20.06) and least number of nodes on main stem was recorded in the cross Co-1 x Parbhani Kranti (14.06).

Significantly more number of nodes on main stem over the grand mean (16.56) were recorded in 5 crosses.

4.2.3 Branches per plant :

The mean of parents for this trait was 1.99. The lines Gourav (2.27) and Naveen (3.07) and the tester Arka Anamika (2.27) recorded significantly more number of branches per plant.

In crosses, Varsha Uphar x Prabhani Kranti recorded more number of branches per plant (2.53) and the cross Co-1 x Parbhani Kranti recorded less number of branches per plant (1.40). Four crosses recorded significantly more number of branches over the grand mean (2.02).

4.2.4 Days to first flower :

None of the lines recorded significantly early flowering. Parbhani Kranti (40.33 days) and Jagdish - 111 (39.67 days) recorded significantly early flowering among testers.

In crosses Pusa Makhmali x Jagdish-111 (39.33 days) recorded significantly early flowering over the grand mean (41.55).

4.2.5 Node at which first flower appeared :

None of the lines significantly flowered at the lower node. Arka Anamika (4.13) and Jagdish-111 (4.07) in testers significantly flowered at the lower node.

Among 18 crosses, six crosses significantly flowered at the lower node.

4.2.6 Number of fruits per plant :

The mean of parents for this trait was 17.85. The lines Gourav (20.41) and Varsha Uphar (19.33) and the tester Jagdish-111 (19.00) recorded significantly more number of fruits per plant.

In crosses, Pusa Makhmali x Jagdish-111 recorded maximum number of fruits per plant (22.40) and the cross Co-1 x Arka Anamika recorded minimum number of fruits per plant (15.40). Six crosses recorded significantly more number of fruits per plant over the grand mean (18.40).

4.2.7 Length of fruit :

The mean of parents for this trait was 13.16 cm. The lines Co-1 (15.41 cm) and Varsha Uphar (13.56 cm) and the testers Parbhani Kranti (14.28 cm) and Jagdish-111 (15.11 cm) recorded significantly maximum fruit length.

In crosses, Co-1 x Jagdish-111 recorded maximum fruit length (15.35 cm) and the cross Co-1 x Arka Anamika recorded minimum fruit length (10.84 cm). Eight crosses recorded significantly higher fruit length over the grand mean (12.85 cm).

4.2.8 Girth of fruit

The mean of parents for this trait was 1.55 cm. Among lines Pusa Makhmali recorded significantly maximum fruit girth (1.61 cm). None of the tester recorded significant fruit girth.

In crosses, Varsha Uphar x Arka Anamika recorded maximum fruit girth (1.68 cm) and the cross Naveen x Jagdish-111 recorded minimum fruit girth (1.38 cm). Four crosses recorded significantly higher fruit girth over the grand mean (1.53 cm).

4.2.9 Weight of fruit :

The mean of parents for this trait was 9.10 g. The lines Co-1 (10.27) and SK-403 (9.73 g) and the testers Arka Anamika (10.07 g) and Jagdish-111 (9.80 g) recorded significantly higher fruit weight.

In crosses, Co-1 x Parbhani Kranti recorded maximum fruit weight (10.47 g) and the cross Co-1 x Arka Anamika recorded minimum fruit weight (6.87 g). Seven crosses significantly recorded higher fruit weight over the grand mean (8.67 g).

4.2.10 Number of seeds per fruit :

Among the lines, Gourav, recorded maximum number of seeds per fruit (35.13) while Pusa Makhmali registered the lowest number of seeds per fruit (28.20). Among testers, Arka Anamika (35.00) and Jagdish - 111

(38.07) recorded significantly more number of seeds per fruit. In general, the parents have recorded a mean of 32.4

In crosses, Co-1 x Jagdish-111 recorded more number of seeds per fruit (40.66) and the cross Gourav x Arka Anamika recorded less number of seeds per fruit (26.80). Eight crosses recorded significantly more number of seeds per fruit over the grand mean (34.23).

4.2.11 100-Seed weight :

The mean of parents for this trait was 6.17 g. The lines Gourav (7.04 g) and Naveen (6.34 g) and the testers Arka Anamika (6.41 g) and Parbhani Kranti (6.77 g) recorded significantly higher seed weight.

In crosses, Naveen x Parbhani Kranti recorded the maximum seed weight (7.46 g) whereas the cross Varsha Upahar x Parbhani Kranti recorded lesser seed weight (4.82 g). Six crosses significantly recorded higher weight of 100 seeds compared to the grand mean (6.19 g).

4.2.12 Fruit yield per plant :

The mean of parents for this trait was 165.39 g. The lines Gourav (174.91 g) and Co- 1 (174.75 g) and the testers Arka Anamika (177.25 g) and Jagdish (185.62 g) recorded significantly more fruit yield per plant.

In crosses, Gourav x Parbhani Kranti recorded the highest fruit yield per plant (200.23 g) and the cross Co-1 x Arka Anamika recorded the lowest fruit yield per plant (126.61 g). Seven crosses recorded significantly more fruit yield per plant over the grand mean (165.64 g).

4.3 GENETIC PARAMETERS

Genetic variability, heritability and genetic advance

The results on phenotypic and genotypic variance, phenotypic and genotypic coefficients of variation, heritability and genetic advance for 12 characters are presented in Table 4 and Fig. 1, 2 and 3.

4.3.1 Plant height

The plant height in parents showed moderate genotypic (11.51) and phenotypic co-efficient of variation (11.56) with a mean of 42.79 cm and it ranged from 36.53 to 51.77cm.The observed heritability estimate for this trait was high (99.09%) with high genetic advance (10.10) and high expected genetic advance as per cent of mean (23.60).

In F_1's, this trait ranged from 38.10 to 76.60 cm with a mean of 46.49 cm. The GCV and PCV estimates observed for this trait were high (19.51 and 19.54). The observed heritability estimate for this trait was high (99.64%) with high expected genetic advance (18.65) and high expected genetic advance as per cent of mean (40.12).

4.3.2 No. of nodes on main stem

In parents this trait ranged from 15.40 to 18.20 with a mean of 16.45. Low GCV (6.46) and PCV (6.84) were observed. The heritability estimate was high (89.36%) with low genetic advance (2.07) and moderate genetic advance as per cent of mean (12.59).

The mean of crosses for this trait was 16.56 and it ranged from 14.07 to 20.07. The GCV and PCV were low (8.34 and 8.54). The heritability estimate was high (95.41%) with low expected genetic advance (2.78) and moderate genetic advance as per cent of mean (16.78).

4.3.3 No. of branches per plant :

In parents this trait ranged form 1.47 to 3.07 with a mean of 1.99. The GCV and PCV observed were high (24.12 and 24.54). The heritability estimate was high (96.60%) with low genetic advance (0.97) and high genetic advance as per cent of mean (48.84).

The mean of crosses was 2.01 and it ranged from 1.40 to 2.53. The GCV and PCV were 13.72 and 14.54 respectively. High heritability estimate (89.12%) coupled with low expected genetic advance 0.53 and high genetic advance as per cent of mean were observed (26.69).

4.3.4 Days to first flower :

Days to first flower in parents showed low GCV (5.36) and PCV (6.45) with a mean of 43.74 days and it ranged from 39.67to 47.00. The observed heritability estimate for this trait was high (69.05%) with moderate expected genetic advance 4.01 and low expected genetic advance as per cent of mean of 9.18.

In F_1's this trait ranged from 39.33 to 45.33 days with a mean of 41.55 days. The GCV and PCV estimates observed for this trait were low (2.68 and 3.76). The observed heritability estimate was high (50.89%) with low expected genetic advance (1.64) and expected genetic advance as per cent of mean (3.94).

4.3.5 Node at which first flower appear :

Mean of parents for this trait was 4.44 and it ranged from 4.07 to 4.87. The GCV and PCV estimates observed were low (5.63 and 6.66). The observed heritability estimates for this trait was high (71.54%) with low genetic advance 0.43 and genetic advance as per cent of mean (9.82).

The mean of crosses for this trait was 4.30 with a range from 4.07 to 4.53. The GCV and PCV estimates observed were 3.37 and 4.06 respectively. High heritability (69.24%) estimates were recorded for this trait with low genetic advance (0.24) and genetic advance as per cent of mean (5.78).

4.3.6 Number of fruits per plant :

In parents, this trait ranged from 15.73 to 20.41 with a mean of 17.84. The GCV and PCV values recorded were 8.44 and 8.62 respectively. High heritability estimate (95.58%) along with moderate genetic advance (3.03) and genetic advance as per cent of mean (17.06) were witnessed for this trait.

Mean of this trait in F_1 crosses recorded was 18.40 with a range of 15.40 to 22.40. The GCV and PCV estimates were 9.83 and 10.05 respectively. Heritability estimate recorded was high (95.70%). The genetic advance (3.64) and with genetic advance as per cent of mean (19.81) were observed to be moderate to high.

4.3.7 Length of fruit :

In parents, this trait ranged from 11.06 to 15.41 with mean of 13.15 cm. The GCV and PCV estimates recorded were moderate (12.06 and 12.15). The high heritability estimate (98.56%) coupled with high genetic advance (3.243) and genetic advance as per cent of mean (24.67) were registered for this trait.

In case of crosses it ranged from 10.84 to 15.35 with a mean of 12.85 cm. In crosses the GCV and PCV were moderate (10.08 and 10.25). The heritability estimate was high (96.64%). Genetic advance (2.62) and genetic advance as per cent of mean (20.41) were moderate to high.

4.3.8 Girth of fruit :

In parents, this trait ranged from 1.50 to 1.61 with a mean of 1.55 cm. Low GCV and PCV estimates were observed (2.36 and 2.95). High heritability estimates (64.03%) along with low genetic advance (0.060) and genetic advance as per cent of mean (3.90) were also registered.

In case of crosses it ranged from 1.38 to 1.68 with a mean of 1.52 cm. The GCV and PCV estimates were 4.86 and 5.23 respectively. High heritability estimate (86.52%) coupled with low genetic advance (0.140) and genetic advance as per cent of mean (9.32) were witnessed for this trait.

4.3.9 Weight of fruit :

In parents, this trait ranged from 7.30 to 10.27 with a mean of 9.10g. The GCV and PCV values were registered to be moderate (11.20 and 11.340). Heritability estimate recorded was high (97.40%). Genetic advance (2.06) and genetic advance as per cent of mean (22.75) were also high for this trait.

Mean of this trait in F_1 crosses recorded was 8.66 g with a range of 6.87 to 10.47. Moderate GCV and PCV estimates were witnessed (11.33 and 11.52). Heritability estimate recorded was high (96.74%). Genetic advance 2.00 and genetic advance as per cent of mean (22.96) were high.

4.3.10 Number of seeds per fruit :

In parents the mean was 32.40 and it ranged from 28.20 to 38.07 seeds. The GCV and PCV estimates were 9.70 and 9.80 respectively. High heritability estimate (98.07%) along with moderate to high genetic advance 6.41 and genetic advance as per cent of mean (19.80) were registered for this trait.

A mean of 34.23 seeds per fruit was recorded in crosses with a range from 26.80 to 40.67. The GCV and PCV estimates were moderate (12.92 and 12.98). High heritability (99.08%) coupled with high genetic advance 9.07 and genetic advance as per cent of mean (26.50) were recorded for this trait.

4.3.11 100-Seed weight :

This trait showed a mean of 6.16 g in parents and it ranged from 5.35 to 7.04 g. The GCV and PCV estimates were low (7.56 and 7.61). The high heritability estimate of (98.63%) was recorded with moderate genetic advance 0.95 and genetic advance as per cent of mean (15.46).

In crosses, the mean of this trait was 6.190 g and it ranged from 4.82 to 7.46 g. The GCV and PCV recorded were 9.79 and 9.80 respectively. High heritability estimate (99.85%) was recorded along with moderate to high genetic advance 1.24 and genetic advance as per cent of mean (20.17).

4.3.12 Fruit yield per plant :

In parents, this trait ranged from 138.67 to 185.62 g with a mean of 165.40 g. The GCV and PCV estimates were low (9.0 and 9.02). High heritability estimate (99.81%) along with moderate to high genetic advance (30.63) and expected genetic advance as per cent of mean (18.52) were discernable for this trait.

In case of crosses it ranged from 126.61 to 200.23 g with a mean of 165.63 g. The GCV and PCV estimates were 12.16 and 12.17 respectively. High heritability estimate (99.81%) coupled with high genetic advance (41.46) and genetic advance as per cent of mean (25.03) were observed for this trait.

Table 3 : Mean performance of parents and crosses for 12 characters in okra

Sl. No.	Treatments	Plant height (cm)	Number of nodes on main stem	Number of branches per plant	Days to first flower	Node at which first flower appeared	Number of fruits per plant	Length of fruit (cm)	Girth of fruit (cm)	Weight of fruit (g)	Number of seeds per fruit	100 seed weight (g)	Fruit yield per plant (g)
	LINES												
1.	Pusa Makhmali	39.06	16.46	1.60	44.66	4.26	16.50	12.50	1.61*	7.30	28.20	5.80	138.66
2.	Gourav	46.40*	16.60	2.27*	44.33	4.86	20.41*	11.85	1.54	8.26	35.13*	7.04*	174.91*
3.	Co-1	42.56	15.40	1.46	46.66	4.46	16.98	15.41*	1.59	10.27*	31.86	6.17	174.75*
4.	SK-403	51.77*	18.20*	1.86	47.00	4.53	16.80	11.06	1.52	9.73*	31.40	5.88	163.26
5.	Naveen	39.70	15.60	3.07*	44.66	4.46	17.62	11.32	1.54	9.26	32.00	6.34*	165.08
6.	Varsha Uphar	38.00	15.46	1.86	42.66	4.46	19.33*	13.56*	1.52	8.0	28.86	53.5	161.21
	Mean of Lines	42.91	16.28	2.08	45.00	4.57	17.94	12.61	1.55	8.80	31.24	6.09	162.98
	TESTERS												
7.	Arka Anamika	45.07*	18.00*	2.27*	43.66	4.13*	18.24	13.30	1.52	10.07*	35.00*	6.41*	177.25*
8.	Parbhani Kranti	36.53	15.46	1.73	40.33*	4.33	15.73	14.28*	1.60	9.13	31.06	6.77*	147.80
9.	Jagish-111	46.00*	16.86	1.80	39.67*	4.07*	19.00*	15.11*	1.50	9.80*	38.07*	6.26	185.62*
	Mean o f testers	42.53	16.77	1.93	41.22	4.17	17.65	14.23	1.54	9.766	34.71	6.30	170.22
	Mean of parents	42.79	16.45	1.99	43.74	4.44	17.85	13.15	1.55	9.09	32.40	6.17	165.39
	S.Ed	0.38	0.29	0.07	1.28	0.12	0.25	0.156	0.02	0.13	0.360	0.04	0.52
	C.d (0.05)	0.82	0.64	0.15	2.75	0.27	0.54	0.33	0.05	0.291	0.772	0.10	1.13
	CROSSES												
1	Pusa Makhmali x Araka Anamika	39.00	15.66	1.80	42.33	4.26	18.53	12.27	1.48	8.46	28.80	5.86	162.58
2	Pusa Makhmali x Parbhani Kranti	40.86	15.80	2.00	41.66	4.13*	20.46*	12.53	1.60*	9.40*	27.06	6.38*	191.11
3	Pusa Makhmali x Jagdish -111	43.73	15.66	2.13	39.33*	4.33	22.40*	12.44	1.53	3.53	32.73	6.20	184.01*
4	Gourav x Arka Anamika	47.66*	16.40	2.13	40.66	4.33	18.13	11.99	1.48	3.73	26.80	6.05	164.62
5.	Gourav x Parbhani Kranti	40.73	16.86	1.53	40.33	4.33	20.20*	13.38*	1.57	10.20*	33.13	5.88	200.23*
6.	Gourav x Jagdish-111	48.80*	16.93	2.33*	40.66	4.46	19.53*	14.16*	1.54	9.26*	40.13*	6.02	182.96*
7.	Co-1x Arka Anamika	51.26*	18.06*	1.93	40.66	4.06*	15.40	10.84	1.39	6.87	40.06*	7.17*	126.61
8.	Co-1 x Parbhani Kranti	38.10	14.06	1.40	45.33	4.06*	17.33	14.59*	1.55	10.47	36.400*	5.80	180.53*
9.	Co-1 x Jagdish-111	45.40	15.93	2.13	42.00	4.13*	17.20	15.35*	1.55	9.13*	40.66*	5.96	163.20
10.	SK-403 x Arka Anamika	42.06	16.86	2.00	40.66	4.26	15.66	10.99	1.48	7.73	32.53	5.83	137.80
11.	SK-403 x Parbhani Kranti	76.60*	20.06*	2.20*	42.33	4.33	16.60	11.86	1.53	3.33	30.93	6.85*	149.44
12.	SK-403 x Jagdish-111	52.73*	17.66*	1.73	41.66	4.40	17.53	11.28	1.44	8.66	33.73	5.98	158.94
13.	Naveen x Araka Anamika	48.86*	17.53*	2.40*	41.33	4.13*	20.40*	11.56	1.61*	7.46	38.06*	5.82	157.77
14.	Naveen x Parbhani Kranti	38.86	15.66	2.00	42.66	4.46	17.40	13.46*	1.48	7.40	37.06*	7.46*	142.84
15.	Naveen x Jagdish-111	54.33*	17.33*	1.93	42.33	4.53	17.60	13.10	1.38	7.933	31.867	6.03	151.37
16.	Varsha Uphar x Arka Anamika	46.93	16.06	2.13	41.66	4.40	18.60	14.34*	1.68*	9.20*	37.40*	6.88*	171.92*
17.	Varsha Uphar x Parbhani Kranti	41.90	1.73	2.53*	40.66	4.53	18.13	13.62*	1.59*	8.30	30.73	4.82	162.56
18.	Varsha Uphar x Jagadish-111	38.80	14.40	2.00	41.66	4.13*	20.06*	13.49*	1.56	9.93*	38.06*	6.44*	192.93*
	Mean	46.48	16.56	2.02	41.55	4.29	18.40	12.85	1.52	8.67	34.23	6.19	165.64
	CD (0.05)	0.90	0.50	0.16	1.82	0.16	0.63	0.40	0.05	0.30	0.71	0.04	1.46

Table 4 : Mean, range, coefficient of variation, heritability, genetic advance and genetic advance as per cent mean for 12 characters in 9 parents and 18 crosses in okra

Sl. No	Character	General Mean		Range		Co-efficient of variation				Heritability		Genetic advance		Genetic advance per cent of mean	
						Genotypic		Phenotypic							
		Parents	F_1's	Parents	F_1's	Parents	F_1's	Parents	F_1's	Parents	F_1's	Parents	F_1's	Parents	F_1's
1.	Plant height (cm)	42.79	46.49	36.53-51.77	38.10-76.60	11.51	19.51	11.56	19.59	99.09	99.46	10.10	18.65	23.60	40.12
2.	Number of nodes on main stem	16.45	16.56	15.40-18.20	14.67-20.07	6.46	8.34	6.84	8.54	89.36	95.41	2.07	2.78	12.59	16.78
3.	No. of branches per plant	1.99	2.01	1.47-3.07	1.40-2.53	24.12	13.72	24.54	14.54	96.60	89.12	0.97	0.53	48.84	26.69
4.	Days to first flower	43.74	41.55	39.67-47.00	39.33-45.3	5.36	2.68	6.45	3.76	68.05	50.89	4.01	1.64	9.18	3.94
5.	Node at which first flower appeared	4.44	4.30	4.07-4.87	4.07-4.53	5.63	3.37	6.66	4.06	71.54	69.24	0.43	0.24	9.82	5.78
6.	No. of fruits per plant	17.84	18.40	15.73-20.41	15.40-22.40	8.44	9.83	8.62	10.05	95.88	95.70	3.03	3.64	17.02	19.81
7.	Length of fruit (cm)	13.15	12.85	1.06-154.1	10.84-15.35	12.06	10.08	12.15	10.25	98.56	96.64	3.24	2.62	24.67	20.41
8.	Girth of fruit (cm)	1.55	1.52	1.50-1.61	1.38-1.68	2.36	4.86	2.95	5.23	64.03	86.52	0.06	0.14	3.90	9.32
9.	Weight of fruit (g)	9.10	8.66	7.30-10.27	6.87-10.47	11.90	1.33	1.34	11.52	97.40	96.74	2.06	2.00	22.75	22.96
10.	No. of seeds per fruit	32.40	34.23	28.20-38.07	26.80-40.67	9.70	12.92	9.80	12.98	98.07	99.08	6.41	9.07	19.80	26.50
11.	100 Seed weight (g)	6.16	6.19	5.35-7.04	4.82-7.46	6.56	9.79	7.61	9.80	98.63	99.85	0.95	1.24	15.46	20.17
12.	Fruit yield per plant (g)	165.40	165.63	138.67-185.62	126.61-200.23	9.00	12.16	9.01	12.17	99.81	99.81	30.63	41.46	18.52	25.03

4.4 HETEROSIS AND HETEROBELTIOSIS

The results pertaining to the magnitude of heterosis expressed as per cent increase or decrease in 18 F_1 hybrids over the values of mid parent (relative heterosis) and better parent (heterobeltiosis) for 12 characters are presented in the Table 5 and Fig. 4 and 5.

4.4.1 Plant height

The cross SK-403 x Parbhani Kranti recorded maximum per cent positive significant heterosis over mid parent (73.50%) and better parent (109.67%) followed by the cross Naveen x Jagdish-111 (26.80% and 36.86%) respectively. The relative heterosis was positive and significant in 12 crosses while heterobeltiosis was in 15 crosses.

4.4.2 No. of nodes on main stem

The relative heterosis for this attribute varied from -10.93% (Varsha Uphar x Jagadish-111) to 19.21% (SK-403 x Parbhani Kranti). The maximum heterobeltiosis (29.74%) was observed in the cross SK-403 x Parbhani Kranti and minimum (-8.66%) in Co-1 x Parbhani Kranti. Heterobeltiosis was significant and positive in nine hybrids while in five hybrids it was significant and negative.

4.4.3 Number of branches per plant

The cross Varsha Uphar x Parbhani Kranti recorded maximum per cent positive significant heterosis over mid parent (40.74%) and better parent (46.15%) followed by the cross Co-1 x Jagdish-111 i.e. 30.61% and 45.45% respectively.

4.4.4 Days to first flower :

The cross SK-403 x Arka Anamika recorded maximum per cent negative significant heterosis over mid parent (-10.29%) and better parent (-13.48%) followed by the cross Co-1 x Arka Anamika (-9.96% and -12.86%) and Pusa Makhmali x Jagdish-111 (-6.72% and -11.94%). These crosses were considered to be early flowering hybrids.

4.4.5 Node at which first flower appeared

The cross Co-1 x Parbhani Kranti recorded maximum per cent negative significant heterosis over mid parent (-7.58%) followed by the cross Naveen x Arka Anamika (-6.06%) for this trait which were also considered to be early flowering hybrids.

The crosses Naveen x Arka Anamika and Varsha Uphar x Jagdish-111 recorded maximum per cent negative significant heterosis over better parent (-11.43%) followed by the crosses involving Gourav with Arka Anamika and Parbhani Kranti (-10.96%).

4.4.6 Number of fruits per plant :

For this trait, the per cent deviation of F1's from mid parental values ranged between -12.57% (Co-1 x Araka Anamika) and 26.99% (Pusa Makhmali x Parbhani Kranti). Nine hybrids were observed to possess significant relative heterosis in positive direction and five in negative direction. Heterobeltiosis ranged from -15.57% (Co-1 x Arka Anamika) to 24.04% (Pusa Makhamalli x Parbhani Kranti). Four hybrids registered significant positive heterobeltiosis while 9 hybrid had significant negative heterobeltiosis.

4.4.7 Fruit length :

The cross Varsha Uphar x Arka Anamika recorded maximum per cent positive significant heterosis over mid parent (6.83%) and better parent (5.80%), while the cross Co-1 x Arka Anamika recorded maximum negative heterosis over mid parent (-24.50%) and better parent (-29.67%).

4.4.8 Girth of fruit :

The cross Varsha Uphar x Arka Anamika recorded maximum per cent heterosis over mid parent (10.04%) and better parent (10.04%) followed by the cross Naveen x Arka Anamika i.e. 4.99% and 4.31% respectively. Maximum negative heterosis was recorded in the cross Co-1 x Arka Anamika over mid parent (-10.68%) and better parent (-12.55%).

4.4.9 Fruit weight

Relative heterosis for this trait varied from -32.46% (Co-1 x Arka Anamika) to 17.24% (Gourav x Parbhani Kranti). Four hybrids had significant positive and nine hybrids had significant negative heterosis for this trait. The maximum heterobeltiosis was observed in the cross Gourav x Parbhani Kranti (11.68%). Heterobeltiosis was significant and positive in one cross and negative in 14 crosses.

4.4.10 Number of seeds per fruit :

The cross Co-1 x Arka Anamika recorded maximum per cent positive significant heterosis over mid parent (19.84%) followed by the crosses Naveen x Parbhani Kranti (17.55%) and Varsha Uphar x Arka Anamika (17.12%) respectively. The cross Naveen x Parbhani Kranti also recorded maximum positive significant heterosis over better parent (15.83) followed by the crosses Co-1 x Arka Anamika (14.48%) and Co-1 x Parbhani Kranti (14.23%).

4.4.11 100-Seed weight :

The cross Naveen x Parbhani Kranti recorded maximum per cent significant positive heterosis over mid parent (18.40%) and over better parent (17.72%) followed by the cross Varsha Uphar x Arka Anamika over mid parent (17.10%) and the cross Co-1 x Arka Anamika over better parent (11.97).

The cross Varsha Uphar x Parbhani Kranti recorded maximum significant negative heterosis over mid parent (-17.02%) and over better parent (-23.09%).

4.4.12 Fruit yield per plant :

The cross Pusa Makhmali x Parbhani Kranti recorded maximum per cent significant positive heterosis over mid parent (33.43%) and over better parent (29.31%) followed by the cross Gourav x Parbhani Kranti over mid parent (24.09%) and better parent (14.48%).

The cross Co-1 x Arka Anamika recorded maximum significant negative heterosis over mid parent (-28.06%) and over better parent (-28.57%).

4.5 COMBINING ABILITY ANALYSIS

The combining ability analysis was carried out based on mean of 5 plants for nine parents and 18 crosses derived from 6 lines x 3 testers programme. Combining ability analysis is presented in the table 6 and 7 and Fig. 6 and the results are presented here under.

Table 5 : Per cent heterosis for plant height, number of nodes on main stem, number of branches per plant and days to first flower in okra

Hybrids	Plant height		No. of nodes on main stem		No. of branches per plant		Days to first flower	
	d_i	d_{ii}	d_i	d_{ii}	d_i	d_{ii}	d_i	d_{ii}
Pusa Makhmali x Araka Anamika	-7.29**	-0.17	-9.09**	-4.86**	-6.90	12.50*	-4.15	-5.22*
Pusa Makhmali x Parbhani Kranti	8.11**	11.86**	-1.04	2.61	20.00**	25.00**	-1.96	-6.72**
Pusa Makhmali x Jagdish -111	2.82**	11.95**	-6.00**	-4.86**	25.49**	33.33**	-6.72**	-11.94**
Gourav x Arka Anamika	4.23**	5.77**	-5.20**	-1.20	-5.88	-5.88	-7.58**	-8.27**
Gourav x Parbhani Kranti	-1.77	11.50**	5.20**	9.05**	-23.33**	-11.54*	-4.72	-9.02**
Gourav x Jagdish-111	5.63**	6.09**	1.20	2.01	14.75**	29.63**	-3.17	-8.27**
Co-1x Arka Anamika	17.00**	20.44**	8.18**	17.32**	3.57	31.82**	-9.96**	-12.86**
Co-1 x Parbhani Kranti	-3.67**	4.29**	-8.86**	-8.66**	-12.50*	-4.55	4.21	-2.86
Co-1 x Jagdish-111	2.52**	6.66**	-1.24	3.46*	30.61**	45.45**	-2.70	-10.00**
SK-403 x Arka Anamika	-13.12**	-6.66**	-6.81**	-6.30**	-3.23	7.14	-10.29**	-13.48**
SK-403 x Parbhani Kranti	73.50**	109.67**	19.21**	29.74**	22.22**	26.92**	-3.05	-9.93**
SK-403 x Jagdish-111	7.88**	14.64**	0.76	4.74**	-5.45	-3.70	-3.85	-11.35**
Naveen x Araka Anamika	15.30**	23.09**	4.37**	12.39**	-10.00**	5.8	-6.42**	-7.46**
Naveen x Parbhani Kranti	1.97	6.39**	0.86	1.29	-16.67**	15.38**	0.39	-4.48
Naveen x Jagdish-111	26.80**	36.86**	9.24**	13.68**	-20.55**	7.41	0.40	-5.22*
Varsha Uphar x Arka Anamika	13.00**	23.51**	-3.98**	3.88*	3.23	14.29**	-3.47	-4.58
Varsha Uphar x Parbhani Kranti	12.43**	14.69**	8.19**	8.19**	40.74**	46.15**	-2.01	-4.69
Varsha Uphar x Jagadish-111	-7.62**	2.11	-10.93**	-6.90**	9.09*	11.11*	1.21	-2.34
SE	0.37	0.42	0.22	0.26	0.06	0.07	0.88	1.01

d_i = relative heterosis * Significant at 5% level
d_{ii} = heterobeltiosis ** Significant at 1% level

Table 5 : Per cent heterosis for node at which first flower appear, number of fruits per plant, length of fruit and girth of fruit in Okra.

Contd..

Hybrids	Node at which first flower appear		No. of fruits per plant		Length of fruit		Girth of fruit	
	d_i	d_{ii}	d_i	d_{ii}	d_i	d_{ii}	d_i	d_{ii}
Pusa Makhmali x Araka Anamika	1.59	0.00	6.70**	1.61	-4.70**	-7.57**	-5.31**	-7.85**
Pusa Makhmali x Parbhani Kranti	-3.88	-4.62*	26.99**	24.04**	-6.42**	-12.27**	0.00	-0.41
Pusa Makhmali x Jagdish -111	4.00	1.56	26.20**	17.89**	-9.83**	-17.61**	-1.50	-4.96**
Gourav x Arka Anamika	-3.70	-10.96**	-6.16**	-11.14**	-4.64**	-9.82**	-3.25*	-3.88*
Gourav x Parbhani Kranti	-5.80**	-10.96**	11.79**	-1.01	2.37	-6.35**	0.00	-1.67
Gourav x Jagdish-111	-0.00	-8.22**	-0.86	-4.28**	5.04**	-6.27**	1.53	0.00
Co-1x Arka Anamika	-5.43*	-8.96**	-12.57**	-15.57**	-24.50**	-29.67**	-10.68**	-12.55**
Co-1 x Parbhani Kranti	-7.58**	-8.96**	5.95**	2.04	-1.73	-5.32**	-2.71	-2.92*
Co-1 x Jagdish-111	-3.12	-7.46**	-4.41**	-9.47**	0.61	-0.39	-0.86	-3.77*
SK-403 x Arka Anamika	-1.54	-5.88**	-10.58**	-14.11**	-9.74**	-17.34**	-2.41	-2.62
SK-403 x Parbhani Kranti	-2.26	-4.41*	2.05	-1.19	-6.37**	-16.94**	-1.71	-4.17**
SK-403 x Jagdish-111	2.33	-2.94	-2.05	-7.72**	-13.73**	-25.29**	-4.19**	-4.82**
Naveen x Araka Anamika	-6.06**	-11.43**	13.78**	11.84**	-6.09**	-13.08**	4.99**	4.31**
Naveen x Parbhani Kranti	-0.74	-4.29*	4.34*	-1.25	5.18**	-5.74**	-5.51**	-7.08**
Naveen x Jagdish-111	3.82	2.86	-3.88*	-7.37**	-0.86	-13.28**	-9.41**	-10.78**
Varsha Uphar x Arka Anamika	0.00	-5.71**	-0.99	-3.79*	6.83**	5.80**	10.04**	10.04**
Varsha Uphar x Parbhani Kranti	0.74	-2.86	3.42*	-6.21**	-2.18	-4.67**	1.92	-0.42
Varsha Uphar x Jagadish-111	-5.34*	-11.43**	4.70**	3.79*	-5.86**	-10.68**	3.52*	2.62
SE	0.08	0.09	0.25	0.29	0.15	0.18	0.02	0.07

d_i = relative heterosis * Significant at 5% level

d_{ii} = heterobeltiosis ** Significant at 1% level

Table 5 : Per cent heterosis for weight of fruit, number of seeds per fruit, 100 seed weight and fruit yield per plant in okra

Hybrids	Weight of fruit		No. of seeds per fruit		100 seed weight		Fruit yield per plant	
	d_i	d_{ii}	d_i	d_{ii}	d_i	d_{ii}	d_i	d_{ii}
Pusa Makhmali x Araka Anamika	-2.50	-15.89**	-8.86**	-17.71**	-3.88**	-8.43**	2.93**	-8.27**
Pusa Makhmali x Parbhani Kranti	14.40**	2.92	-8.66**	-12.88**	5.75**	1.81**	33.43**	29.31**
Pusa Makhmali x Jagdish -111	-0.19	-12.93**	-1.21	-14.01**	3.07**	-0.53	13.49**	-0.87*
Gourav x Arka Anamika	-4.73**	-13.25**	-23.57**	-23.72**	-10.01**	-14.06**	-6.50**	-7.12**
Gourav x Parbhani Kranti	17.24**	11.68**	0.10	-5.69**	-11.62**	-16.48**	24.09**	14.48**
Gourav x Jagdish-111	2.58	-5.44**	9.65**	5.43**	-9.21**	-14.39**	1.50**	-1.43**
Co-1x Arka Anamika	-32.46**	-33.12**	19.84**	14.48**	14.07**	11.97**	-28.06**	-28.57**
Co-1 x Parbhani Kranti	7.90**	1.95	15.68**	14.23**	-6.73**	-7.45**	11.94**	3.31**
Co-1 x Jagdish-111	-8.97**	-11.04**	16.30**	6.83**	-3.87**	-4.38**	-9.42**	-12.07**
SK-403 x Arka Anamika	-21.89**	-23.18**	-2.01	-7.05**	-5.13**	-9.00**	-19.06**	-22.26**
SK-403 x Parbhani Kranti	-11.66**	-14.38**	-0.96	-1.49	12.87**	9.41**	-3.92**	-8.47**
SK-403 x Jagdish-111	-11.26**	-11.56**	-2.88**	-11.38**	-1.21*	-4.01**	-8.88**	-14.37**
Naveen x Araka Anamika	-22.76**	-25.83**	13.63**	8.76**	-8.58**	-9.05**	-7.82**	-10.99**
Naveen x Parbhani Kranti	-19.57**	-20.14**	17.55**	15.83**	18.40**	17.72**	-8.69**	-13.47**
Naveen x Jagdish-111	-16.78**	-19.05**	-9.04**	-16.29**	-4.00**	-4.78**	-13.67**	-18.45**
Varsha Uphar x Arka Anamika	1.85	-8.61**	17.12**	6.86**	17.10**	7.44**	1.59**	-3.01**
Varsha Uphar x Parbhani Kranti	-3.11	-9.12**	2.56*	-1.07	-17.02**	-23.09**	5.22*	0.84*
Varsha Uphar x Jagadish-111	11.61**	1.36	13.75**	0.00	11.16**	3.26**	11.25**	3.94**
SE	0.12	0.14	0.30	0.34	0.02	0.02	0.57	0.66

d_i = relative heterosis * Significant at 5% level

d_{ii} = heterobeltiosis ** Significant at 1% level

4.5.1 Analysis of variance

The analysis of variance showed significant differences among the genotypes in respect of all the characters. The total variance due to genotypes was further partitioned into parents, crosses and parents vs crosses. Significant variances among the parents and F_1's were observed for all the characters. The component of variance due to parents vs crosses was significant for all the characters except for number of nodes on main stem, number of branches per plant and fruit yield per plant. The mean squares due to line x tester interactions were found to be highly significant for all the characters.

4.5.2 General combining ability and specific combining ability variances

The estimates of sca variances were greater than gca variances for all the characters which indicates the presence of non-additive gene action in all yield attributing characters.

4.5.3 GCA and SCA effects :

The estimates of gca and sca effects of nine parents and eighteen crosses are furnished in table 8 and 9, respectively.

Table 6 : Analysis of variance for combining ability for 12 characters in Okra

Source of variation	d.F	Plant height	Number of nodes on main stem	Number of branches per plant	Days to first flower	Node at which first flower appear	Number of fruits per plant	Fruit length	Fruit girth	Fruit weight	Number of seeds per fruit	100 seed weight	Fruit yield per plant
Replications	2	0.463	0.401*	0.027	7.753*	0.133**	0.386	0.023	0.001	0.042	0.214	0.003	1.189
Treatments	26	193.485**	4.902**	0.373**	12.77**	0.128*	8.850**	5.731**	0.013**	3.004**	50.043**	0.925**	1001.458**
Crosses	17	247.133**	5.821**	0.247**	4.941**	0.072**	9.962**	5.093**	0.017**	2.929**	58.915**	1.105**	1218.552**
Parents	8	72.995**	3.53**	0.701**	18.981**	0.213**	6.905**	7.595**	0.005**	3.135**	29.883**	0.655**	665.117**
Parents Vs Crosses	1	245.383**	0.228	0.012	85.950**	0.394**	5.518**	1.667**	0.011**	3.235**	60.526**	0.012**	1.588
Error	52	0.274	0.101	0.008	1.560	0.013	0.126	0.049	0.001	0.030	0.181	0.001	0.672

* Significant at 0.05
** Significant at 0.01

Table 7 : Line x Tester analysis mean squares for 12 characters in Okra

Source of variation	d.F	Plant height	Number of nodes on main stem	Number of branches per plant	Days to first flower	Node at which first flower appeared	Number of fruits per plant	Fruit length	Fruit girth	Fruit weight	Number of seeds per fruit	100 seed weight	Fruit yield per plant
Lines	5	289.1043	8.2569	0.1661	5.027	0.1150	21.0092**	7.1275	0.0207	3.8232	95.1052	0.2580	2096.6724*
Testers	2	9.2539	0.6536	0.0763	5.0569	0.0386	7.2452	9.7050	0.0146	4.7612	60.9060	0.1192	1977.2361
Line x Tester	10	273.7249**	5.6371**	0.3092**	4.8755**	6.0581**	4.9823**	3.1539**	0.0164**	2.1151**	40.4660**	1.7269**	627.7583**
Error	52	0.2743	0.1016	0.0088	1.5608	0.0138	0.1263	0.0496	0.0008	0.0305	0.1816	0.0013	0.6722
σ^2gca	-	-0.7973	0.0055	-0.0021	0.0019	0.0004	0.1493	0.581	0.0000	0.0294	0.5531	-0.0186	17.7134
σ^2sca		91.1520	1.8452	0.1001	1.1056	0.0147	1.6187	1.0348	0.0052	0.6949	13.4281	0.5752	209.0287
σ^2gca / σ^2sca		0.009	0.0030	0.0021	0.002	0.027	0.0922	0.0561	0.00	0.0351	0.0398	0.0323	0.0847

* Significant a 0.05
** Significant at 0.01

4.5.3.1 Plant height

Among the lines SK-403 (10.65) and Naveen (0.87) had highly significant positive gca effect. In testers Jagdish-111 (0.82) had highly significant positive gca effect.

Among the crosses, SK-403 x Parbhani Kranti (19.77) had highly significant sca effect followed by the crosses Co-1 x Arka Anamika (6.86) and Naveen x Jagdish-111 (6.16). The cross SK-403 x Arka Anamika (-14.55) showed highly negative and significant sca effect followed by Naveen x Parbhani Kranti (-8.19).

4.5.3.2 Number of nodes on main stem

For number of nodes on main stem, two lines SK-403 (1.64) and Naveen (0.41) and one tester Arka Anamika (0.20) expressed highly significant positive gca effects.

Estimates of sca effects among crosses ranged from -1.93 (Co-1 x Parbhani Kranti) to 1.90 (SK-403 x Parbhani Kranti) for number of nodes on main stem. Highly significant positive sca effects were observed in 4 hybrids while significant negative sca effects were recorded in 5 hybrids. Non-significant positive and negative effects were observed in six and seven hybrids respectively.

4.5.3.3 Number of branches per plant :

Positive highly significant gca effect was observed in the lines Naveen (0.09) and Varsha Uphar (0.20). The tester Arka Anamika (0.05) has positive significant gca effect.

Among the crosses, Varsha Uphar x Parbhani Kranti (0.39) had highly significant sca effect followed by the crosses Gourav x Jagdish-111 (0.31) and SK-403 x Parbhani Kranti (0.30). The cross Gourav x Parbhani Kranti (-0.39) had highly significant negative sca effect followed by the crosses Co-1 x Parbhani Kranti (-0.35) and SK-403 x Jagdish-111 (-0.27).

4.5.3.4 Days to first flower :

The line Gourav (-1.00) had significant negative gca effect among the lines while the line Co-1 (1.11) has significant positive gca effect.

The crosses Co-1 x Parbhani Kranti (2.06) and Pusa Makhmali x Arka Anamika (1.56) had positive and significant sca effects, whereas the crosses Co-1 x Arka Anamika (-1.67) and Pusa Makhmali x Jagidsh-111 (-1.50) had negative and significant sca effects.

4.5.3.5 Node at which first flower appeared :

Highly negative significant gca effect was recorded in the line Co-1 (-0.20) and the lines Gourav (0.08) and Naveen (0.08) recorded positive significant gca effects.

The cross Varsha Uphar x Parbhani Kranti (0.16) recorded significant positive sca effect, whereas the crosses Varsha Uphar x Jagdish-111 (-0.26) and Naveen x Arka Anamika (-0.19) recorded negative significant sca effects.

4.5.3.6 Number of fruits per plant :

The gca effects for number of fruits per plant ranged from -1.80 (SK-403) to 20.7 (Pusa Makhmali) among the lines and from -0.61 (Arka Anamika) to 0.65 (Jagdish-111) among the testers.

For number of fruits per plant, the sca effects varied from -1.52 (Naveen x Jagdish-111) to 2.54 (Naveen x Arka Anamika). Significant and positive sca effects were observed in five hybrids. Significant negative effects were recorded in six hybrids. Four crosses exhibited non-significant positive effects while non-significant negative effects were observed in three crosses.

4.5.3.7 Fruit length :

Three lines Gourav (0.32), Co-1 (0.74), Varsha Uphar (0.97) and two testers Parbhani Kranti (0.39) and Jagdish-111 (0.45) recorded highly significant positive gca effects.

Among the crosses, Varsha Uphar x Arka Anamika (1.37) had highly significant sca effect followed by the crosses Co-1 x Jagdish-111 (1.30) and

Pusa Makhmali x Arka Anamika (0.72) respectively. The cross Co-1 x Arka Anamika (-1.91) recorded negative but highly significant sca effect.

4.5.3.8 Fruit girth

Among the parents one line Varsha Uphar (0.08) and one tester Parbhani Kranti (0.03) recorded highly significant positive gca effect.

Among the crosses Naveen x Arka Anamika (0.12) recorded highest significant sca effect followed by the crosses Co-1 x Jg-111 (0.07) and Varsha Uphar x Arka Anamika (0.07).

4.5.3.9 Fruit weight :

Two lines Gourav (0.73) and Varsha Uphar (0.47) and two testers Prabhani Kranti (0.35) and Jagdish-111 (0.24) recorded highly significant positive gca effects among the parents.

Among the crosses Co-1 x Parbhani Kranti (1.30) recorded positive and significant sca effect followed by the crosses Varsha Uphar x Arka Anamika (0.65) and Varsha Uphar x Jagdish-111 (0.55), whereas the cross Co-1 x Arka Anamika (-1.36) recorded negative but highly significant sca effect.

4.5.3.10 Number of seeds per fruit :

For number of seeds per fruit, three lines Co-1 (4.81), Naveen (1.43) and Varsha Uphar (1.16) and one tester Jagdish-111 (1.97) recorded highly significant positive gca effects.

Eight crosses Gourav x Jagdish-111 (4.81), Naveen x Parbhan Kranti (3.08), Naveen x Arka Anamika (2.69), Varsha Uphar x Arka Anamika (2.29), Gourav x Parbhani Kranti (1.46), Co-1 x Arka Anamika (1.31), Pusa Makhmali x Jagdish-111 (1.23) and Varsha Uphar x Jagdish-111 (0.70) recorded positive and significant sca effects.

4.5.3.11 100-Seed weight :

The gca effects for 100 seed weight ranged from -0.212 (Gourav) to 0.25 (Naveen) among the lines and from -0.08 (Jagdish-111) to 0.08 (Arka Anamika) among the testers.

For 100 seed weight, the sca effects varied from -1.23 (Varsha Uphar x Parbhani Kranti) to 1.01 (Naveen x Parbhani Kranti). Significant and positive sca effects were observed in eight hybrids while significant negative effects were recorded in nine hybrids.

4.5.3.12 Fruit yield per plant :

The lines Pusa Makhmali (13.60), Gourav (16.96) and Varsha Uphar (10.16) and the testers Parbhani Kranti (5.48) and Jagdish-111 (6.60) recorded positive and significant gca effects.

Among the crosses, Naveen x Arka Anamika (19.19) recorded highest positive significant sca effect followed by the crosses Co-1 x Parbhani Kranti (18.27) and Gourav x Parbhani Kranti (12.14). The cross

Varshau Uphar x Parbhani Kranti (-18.72) showed negative but highly significant sca effect.

4.6 CHARACTER ASSOCIATION

Phenotypic and genotypic correlation co-efficients between yield and yield components and interaction among the attributes were computed and presented in Table 10 and 11 and Fig. 7. In general, genotypic correlations were high than corresponding phenotypic correlations.

4.6.1 Plant height

In parents, this trait had significant positive correlation with number of nodes on main stem (r_p = 0.7788, r_g = 0.8303). Positive non-significant correlation was observed with number of branches per plant, days to first flower, number of fruits per plant, fruit weight, number of seeds per fruit, 100 seed weight and fruit yield per plant at both phenotypic and genotypic level. It had negative correlation with node at which first flower appeared at phenotypic level and length of fruit and girth of fruit at both levels.

In F_1's, the plant height had highly significant positive correlation with number of nodes on main stem (r_p = 0.8518, r_g = 0.8738) while it had positive non-significant correlation with number of branches per plant, node of first flower appearance and 100-seed weight at both levels.

Table 8 : General combining ability effects of 9 parents for 12 characters in Okra.

Sl. No.	Treatments	Plant height	Number of nodes on main stem	Number of branches per plant	Days to first flower	Node at which first flower appear	Number of fruits per plant	Length of fruit	Girth of fruit	Weight of fruit	Number of seeds per fruit	100 seed weight	Fruit yield per plant
	LINES												
1.	Pusa Makhmali	-5.28**	-0.85**	-0.04	-0.44	-0.05	2.07**	-0.43**	0.01	0.13*	-4.70**	-0.04**	13.60**
2.	Gourav	-0.75**	0.174	-0.02	-1.00*	0.08*	0.89**	0.32**	0.01	0.73**	-0.87**	-0.21**	16.96**
3.	Co-1	-1.56**	-0.54**	-0.20**	1.11*	-0.20**	-1.75**	0.74**	-0.03**	0.15*	4.81**	0.12**	-8.85**
4.	SK-403	10.65**	1.64**	-0.04	0.00	0.03	-1.80**	-1.47**	-0.04**	-0.42**	-1.83**	0.03*	-16.90**
5.	Naveen	0.87**	0.41**	0.09**	0.55	0.08*	0.06	-0.14	-0.03**	-1.07**	1.43**	0.25**	-14.97**
6.	Varsha Uphar	-3.94**	-0.83**	0.20**	-0.22	0.05	0.53**	0.97**	0.08**	0.47**	1.16**	-0.15**	10..16**
	TESTERS												
7.	Arka Anamika	-0.51**	0.20**	0.05*	-0.33	-0.05	-0.61**	-0.85**	-0.003	-0.59**	-0.29**	0.08**	-12.08**
8.	Parbhani Kranti	-0.30*	-0.03	-0.07**	0.61*	0.01	-0.04	0.39**	0.03**	0.35**	-1.68**	0.01	5.48**
9.	Jagdish-111	0.82**	-0.17*	0.02	-2.77	0.03	0.65**	0.45**	-0.03**	0.24**	1.97**	-0.08**	6.60**
	SE (Lines)	0.17	0.10	0.03	0.42	0.04	0.12	0..07	0.01	0.06	0.14	0.01	0.27
	S.E (testers)	0.12	0.07	0.02	0.30	0.02	0.08	0.05	0.01	0.04	0.10	0.01	0.19

* Significant at 0.05
** Significant at 0.01

Table 9 : Specific combining ability effects of 18 crosses for 12 characters in okra

Sl. No.	Treatments	Plant height	Number of nodes on main stem	Number of branches per plant	Days to first flower	Node at which first flower appear	Number of fruits per plant	Length of fruit	Girth of fruit	Weight of fruit	Number of seeds per fruit	100 seed weight	Fruit yield per plant
1	Pusa Makhmali x Araka Anamika	-1.69**	-0.25	-0.23**	1.56*	0.07	-1.32**	0.72**	-0.05**	0.26*	-0.44	-0.36**	-4.57**
2	Pusa Makhmali x Parbhani Kranti	-0.03	0.12	0.10	-0.06	-0.13	0.04	-0.28*	0.03*	0.25*	-0.79**	0.22**	6.39**
3	Pusa Makhmali x Jagdish -111	1.71**	0.13	0.13*	-1.50*	0.05	1.28**	-0.43**	0.02	-0.51**	1.23**	0.14**	-1.83**
4	Gourav x Arka Anamika	2.45**	-0.54**	0.09	0.44	0.01	-0.54*	-0.34*	-0.05**	-0.08	-6.27**	-0.01	-5.90**
5.	Gourav x Parbhani Kranti	-4.70**	0.16	-0.39**	-0.83	-0.06	0.96**	-0.19	0.01	0.45**	1.46**	-0.11**	12.14**
6.	Gourav x Jagdish-111	2.25**	0.37*	0.31**	0.39	0.05	-0.41	0.53**	0.04*	-0.38**	4.81**	0.13**	-6.24**
7.	Co-1x Arka Anamika	6.86**	1.84**	0.06	-1.67*	0.03	-0.63**	-1.91**	-0.10**	-1.36**	1.31**	0.78**	-18.09**
8.	Co-1 x Parbhani Kranti	-6.52**	-1.93**	-0.35**	2.06**	-0.04	0.73**	0.61**	0.03	1.30**	-0.97**	-0.52**	18.27**
9.	Co-1 x Jagdish-111	-0.34	0.09	0.29**	-0.39	0.01	-0.10	1.30**	0.07**	0.07	-0.34	-0.26**	-0.18
10.	SK-403 x Arka Anamika	-14.55**	-1.54**	-0.03	-0.56	-0.01	-0.32	0.46**	0.00	0.08	0.42	-0.47**	1.16*
11.	SK-403 x Parbhani Kranti	19.77**	1.90**	0.30**	0.17	-0.01	0.04	0.09	0.01	-0.26*	0.21	0.63**	-4.77**
12.	SK-403 x Jagdish-111	-5.22**	-0.36	-0.27**	0.39	0.03	0.28	-0.55**	-0.02	0.18	-0.63*	-0.15**	3.62**
13.	Naveen x Araka Anamika	2.03**	0.35	0.24**	-0.44	-0.19**	2.54**	-0.30*	0.12**	0.46**	2.69**	-0.69**	19.19**
14.	Naveen x Parbhani Kranti	-8.19**	-1.28**	-0.04	-0.06	0.07	-1.02**	0.37**	-0.04*	-0.55**	3.08**	1.01**	-13.30**
15.	Naveen x Jagdish-111	6.16**	0.93**	-0.20**	0.50	0.12	-1.52**	-0.06	-0.07**	0.09	-5.77**	-0.32**	-5.89**
16.	Varsha Uphar x Arka Anamika	4.90**	0.13	-0.14*	0.67	0.10	0.28	1.37**	0.07**	0.65**	2.29**	0.76**	8.20**
17.	Varsha Uphar x Parbhani Kranti	-0.34	1.03**	0.39**	-1.28	0.16*	-0.76**	-0.59**	-0.05**	-1.19**	-2.99**	-1.23**	-18.72**
18.	Varsha Uphar x Jagadish-111	-4.56**	-1.16**	-0.25**	0.61	-0.26**	0.48*	-0.78**	-0.02	0.55**	0.70**	0.48**	10.52**
	SE (S_{ij})	0.30	0.18	0.05	0.72	0.07	0.20	0.13	0.02	0.10	0.25	0.02	0.47

* Significant at 0.05

** Significant at 0.01

4.6.2. Number of nodes on main stem

In parents, this trait had negative non- significant correlation with node of first flower appearance (r_p = -0.3043, r_g = -0.0336), length of fruit (r_p = -0.3669, r_g = -0.3769) and girth of fruit (r_p = -0.4625, r_g = -0.5466), while it had positive and non-significant correlation with number of number of branches per plant, days to first flower, number of fruits per plant, weight of fruit, number of seeds per fruit, 100 seed weight and fruit yield per plant.

In crosses, this trait had negative and significant correlation with length of fruit (r_p = -0.5138, r_g = -0.5363) weight of the fruit (r_p = -0.5163, r_g = -0.5425) and fruit yield (r_p = -0.5153, r_g = -0.5269), while it had positive and non-significant correlation with number of branches per plant, node of first flower appearance and 100 seed weight.

4.6.3 Number of braches per plant

In parents, this trait showed positive and non-significant correlation with days to first flower, node of first flower appearance, number of fruits per plant, weight of fruit, number of seeds per fruit, 100 seed weight and fruit yield per plant, while it had negative and non-significant correlation with length and girth of fruit.

In crosses this trait exhibited non-significant and positive correlation with node of first flower appearance, number of fruits per plant, girth of fruit and number of seeds per fruit, while it showed significant and non-significant negative correlations with days to first flower at genotypic and phenotypic levels respectively. The association of number of branches per plant was also negative and non-significant with fruit length, fruit weight, 100 seed weight and fruit yield per plant.

4.6.4 Days to first flower

In parents, this trait had negative and non-significant correlation with number of fruits per plant, fruit length, number of seeds per fruit, 100 seed weight and fruit yield per plant, while it had positive and non-significant correlation with node of first flower appearance, girth of fruit and weight of fruit both at phenotypic and genotypic level.

In crosses, this trait had non-significant and negative correlation with node of first flower appearance (r_p = -0.2826, r_g = -0.2136), number of fruits per plant (r_p = -0.2445, r_g = -0.4462), fruit girth (at r_g = -0.0622), and fruit yield per plant (r_p = -0.0462, r_g = -0.0621).

4.6.5 Node at which first flower appeared :

In parents, this trait had negative and non-significant correlation with length of fruit, weight of fruit, number of seeds per fruit, fruit yield per plant and number of nodes on main stem, while it had positive and non-significant correlation with number of fruits per plant, girth of fruit, 100 seed weight, number of branches per plant and days to first flower.

In crosses, this trait had negative and non-significant correlation with girth of fruit, weight of fruit, number of seeds per fruit, 100 seed weight, fruit yield per plant and days to first flower, while it had positive but non-significant correlation with number of fruits per plant, length of fruit, plant height, number of nodes on main stem and number of branches per plant.

4.6.6 Number of fruits per plant

In parents, this trait had significant negative correlation with girth of fruit (r_g = -0.6893) at genotypic level, while it had negative and non-significant correlation with length of fruit, weight of fruit, and days to first flower at both levels. It showed non-significant and positive correlation with number of seeds per fruit, 100 seed weight, fruit yield per plant node of first flower appearance, number of branches per plant, number of nodes on main stem and plant height. In crosses, this trait had positive and significant correlation with girth of fruit (r_p = 0.4936, r_g = 0.5448) and fruit yield per plant (r_p = 0.7727, r_g = 0.7889),while it had positive non-significant correlation with length of fruit, weight of fruit, number of branches per plant and node of first flower appearance.

4.6.7 Length of fruit

In parents, fruit length had positive and non-significant correlation with girth of fruit, weight of fruit, number of seeds per fruit and fruit yield per plant, while it had negative and non-significant association with the other traits.

In crosses, this trait had positive and significant correlation with weight of fruit (r_p = 0.6008, r_g = 0.6164) and fruit yield per plant, (r_p = 0.4900, rg = 0.4998), positive but non significant association with fruit girth, number of seeds per fruit, number of fruits per plant, node of first flower appearance and days to first flower) whereas negative and significant correlation was exhibited with number of nodes on main stem (r_p = -0.5138, r_g = -0.5363).

4.6.8 Girth of fruit

None of the character exhibited significant and positive correlation with this trait. It had positive and non-significant correlation with days to first flower, node of first flower appearance and length of fruit, while it had negative and significant correlation with fruit yield per plant (r_g = -0.7601) and number of fruits per plant (r_g = -0.6893) at genotypic level.

In crosses, this trait had significant and positive correlation with fruit weight (r_p = 0.4809, r_g = 0.5038), fruit yield per plant (r_p = 0.5664, r_g =

0.6126) number of fruits per plant (r_p = 0.4936, r_g = 0.5448), while it had positive but non-significant correlation with number of branches per plant at both levels and days to first flower at phenotypic level.

4.6.9 Weight of fruit

In parents, none of the characters exhibited significant and positive correlation with this trait. It has non-significant and positive correlation with number of seeds per fruit, 100 seed weight, fruit yield per plant, plant height, number of nodes on main stem, number of branches per plant, days to first flower and length of fruit.

In crosses, weight of fruit had positive and significant correlation with fruit yield per plant (r_p = 0.8622, r_g = 0.8776), length of fruit (r_p = 0.6008, r_g = 0.6164) and girth of fruit (r_p = 0.4809, r_g = 0.5038), whereas it had positive correlation with days to first flower. It had negative and significant correlation with nodes on main stem (r_p = -0.5163, r_g = -0.5425).

4.6.10 Number of seeds per fruit

In parents, this trait had significant positive correlation with 100 seed weight (r_g = 0.6742) at genotypic level and fruit yield per plant (r_p = 0.8434, r_g = 0.8518) at both levels. It had positive non-significant correlation with plant height, number of nodes on main stem, number of branches per plant, number of fruits per lant, length of fruit and weight of fruit.

In crosses, none of the character exhibited significant and positive correlation with this trait. It had positive and non-significant correlation with 100 seed weight (r_p =0.2891, r_g = 0.2905), number of branches per plant (r_p = 0.0497, r_g = 0.0646), days to first flower (r_p = 0.0849, r_g = 0.1208), length of fruit (r_p = 0.3524, r_g = 0.3660) and girth of fruit (r_p = 0.0615, r_g = 0.0682).

4.6.11 100 seed weight

In parents, this trait had positive and significant correlation with number of seeds per fruit (r_g = 0.6742) at genotypic level and non-significant positive correlations with fruit yield per plant, fruit weight, number of fruits per plant, node at first flower appear, number of branches per plant, number of nodes on main stem and plant height at both levels. It had negative and non-significant correlation with days to first flower (r_p = -0.0388, r_g = -0.0350), length of fruit (r_p = -0.1117, r_g = -0.1105) and girth of fruit (r_p = -0.0043, r_g = -0.0311).

In crosses none of the character exhibited significant and positive correlation with this trait. It had positive and non-significant correlation with plant height (r_p = 0.2562, r_g =0.2574), number of nodes on main stem (r_p = 0.1232, r_g =0.1269), days to first flower (r_p = 0.0911, r_g = 0.1255) and number of seeds per fruit (r_p = 0.2891, r_g =0.2905).

4.6.12 Fruit yield per plant

In parents, this trait had positive and significant correlation with number of seeds per fruit (r_p = 0.8434, r_g = 0.85158) both at phenotypic and genotypic level, whereas positive but non-significant correlations were registered with 100 seed weight, fruit weight, length of fruit, number of fruits per plant, number of branches per plant, number of nodes on main stem and plant height.

It had negative and significant correlation with girth of fruit at genotypic level (r_g = -0.7601) and non-significant negative correlations with node of first flower appearance and days to first flower at both levels.

In crosses, this trait had positive and significant correlations with number of fruits per plant (r_p = 0.727, r_g =0.7789), length of fruit (r_p = 0.4900, r_g = 0.4998), girth of fruit (r_p = 0.5664, r_g = 0.6126) and weight of fruit (r_p = 0.8622, r_g = 0.8776), while it had negative and significant correlation with number of nodes on main stem (r_p = -0.5153, r_g = -0.5629). Whereas negative and non-significant correlations were seen with plant height, number of branches per plant, days to first flower, node of first flower appearance, number of seeds per fruit and 100 seed weight at both levels.

4.7 PATH COEFFICIENT ANALYSIS

Path coefficient analysis facilitates the partitioning of correlation coefficients into direct and indirect effects of various characters on fruit yield per plant. It provides an effective means of finding out direct and indirect causes of association and presents a critical examination of the specific factors acting to produce a given correlation and measures the relative importance of each causal factor. The path coefficients of different attributes on fruit yield per plant based on phenotypic and genotypic correlation in parents and F_1's for twelve characters are presented in Table 12 and 13 and Fig. 8 and 9 respectively.

4.7.1 Plant height

This trait in parents had a positive direct effect on fruit yield per plant (0.3430). It had positive indirect effect on yield through nodes on main stem (0.0401), branches per plant (0.0051), days to first flower (0.0320), fruits per plant (0.091), girth of fruit (0.0195) and number of seeds per fruit (0.1211), while it had negative indirect effect on yield through length of fruit (-0.161) and 100 seed weight (-0.0204). Both at phenotypic and genotypic level. It also had both positive and negative indirect effects on fruit yield at phenotypic and genotypic level respectively.

In crosses, this trait had a negative direct effect on fruit yield per plant (-0.0976) but nullified by its greater positive direct effect. It showed positive indirect effects on fruit yield through nodes on main stem (0.0851), at phenotypic level, node of first flower appearance (0.0086) and 1000 seed weight (0.0054) at genotypic level and seeds per fruit (0.0023) at both levels, while it had negative indirect effects on fruit yield through branches per plant (-0.0067), fruits per plant (-0.1521), length of fruit (-0.0205), weight of fruit (-0.2010) at both levels, node of first flower appearance (-0.0021), at phenotypic level, girth of fruit weight (-0.0403) at phenotypic and 100 seed weight (-0.0224) at genotypic level.

4.7.2 Number of nodes on main stem :

This trait in parents had a positive direct effect on fruit yield per plant (0.0515) and positive indirect effects through plant height (0.02610 number of branches per plant (0.0128), days to first flower (0.0100), number of fruits per plant (0.0330), girth of fruit (0.0175) seeds per fruit (0.0867) at both levels and weight of fruit (0.06130 at phenotypic level. Whereas it had negative indirect effect on fruit yield through node of first flower appearance (-0.0416), length of fruit (-0.215), 100 seed weight (-0.0096) at both levels and weight of fruit (-0.703) at genotypic level.

In crosses this trait had both positive and negative direct effect at phenotypic and genotypic level respectively on fruit yield per plant (0.0999 and -0.49203). It had positive indirect effects on fruit yield through days to first flower (0.0185), number of seeds per fruit (0.0041) both levels, plant height (0.3939) and node of first flower appearance (0.0136) at genotypic level. It showed negative indirect effect on fruit yield through plant height (-0.0831), node of first flower appearance (-0.0029) at phenotypic level, nodes on the main set (-0.4920) at genotypic level branches per plant (-0.0076), nodes of first flower appearance (-0.0029) , fruits per plant (-0.1683), length of fruit (-0.330) and weight of fruit (-0.3461) at both levels.

4.7.3 Number of branches per plant

In parents, this trait had a direct positive effect on fruit yield (P = 0.3509, G = 0.7527). It had positive indirect effect on fruit yield through number of fruits per plant (0.1047), node at which first flower appears (0.0469), girth of fruit (0.0118), plant height (0.0050), days to first flower (0.0050), number of nodes on main stem (0.0019), number of seeds per fruit at both levels and weight of fruit (0.0128 at phenotypic level). It had negative indirect effect on fruit yield through length of fruit (-0.3468), 100 seed weight (-0.0279) at both levels and weight of fruit (0.0145) at genotypic level.

In crosses, this trait has a negative direct effect on fruit yield (P = -0.0258, G = -0.3209). It exerted positive indirect effects on fruit yield through plant height (0.1231), girth of fruit (0.0520) 100-seed weight at genotypic and phenotypic level. It also had its indirect effects through nodes on main stem (0.0293), days to first flower (0.0335) and number of fruits per plant (0.0680) at both levels. It showed negative indirect effect on fruit yield through plant height (-0.0254) at phenotypic level, nodes on the main stem (-0.1569) at genotypic level, length of fruit (-0.0001), and weight of fruit (-0.2579) at both levels.

4.7.4 Days to first flower

In parents, this trait had a direct positive effect on fruit yield per plant (P = 0.0958, G = 0.3698). It had positive indirect effect on fruit yield through plant height (0.1144), nodes on main stem (0.0054), branches per plant (0.0185), node of first flower appearance (0.0461), 100 seed weight at both levels and weight of fruit (0.0220) at phenotypic level. On the contrary, it had negative indirect effect on fruit yield through fruits per plant (-0.0401), length of fruit (-0.2376), girth of fruit (-0.0102) and seeds per fruit (-0.0760) at both levels and weight of fruit (-0.0176) at genotypic level.

In crosses, this trait had a direct negative effect on fruit yield per plant (P = -0.0871, G = -0.4116). It had positive indirect effects on fruit yield through nodes on the main stem (0.1659) at genotypic level, node of first flower appearance (0.0033), 100 seed weight (0.0019) at phenotypic level, plant height (0.0027), branches per plant (0.0099), length of fruit (0.0189), and weight of fruit (0.1486) at both levels. It showed negative indirect effect on fruit yield through plant height (-0.0084), node of first flower appearance (-0.0093), 100 seed weight (-0.0109) at genotypic level, nodes on main stem (-0.0212) at phenotypic level, fruits per plant (-0.1195), girth of fruit (-0.0001) and seeds per fruit (-0.0035) at both levels.

4.7.5 Node at which first flower appear

This trait in parents had a positive direct effect on fruit yield per plant (P = 0.1366, G = 0.1625). It had positive indirect effect on fruit yield through branches per plant (0.1206), days to first flower (0.0324), fruits per plant (0.1065), at both levels and fruit weight (0.0872) at genotypic level, while it exhibited negative indirect effect through plant height (-0.0022) at phenotypic level, nodes on main stem (-0.0157), length of fruit (-0.2806), girth of fruit (-0.0003), seeds per fruit (-0.0597) and 100 seed weight (-0.0092) at both levels.

In crosses, this trait had a positive direct effect on fruit yield per plant (0.0438) at genotypic level and positive indirect effect on fruit yield through plant height (0.0896), 100 seed weight at genotypic level, days to first flower (0.0246), fruits per plant (0.0010), length of fruit (0.0064), girth of fruit (0.0003) and seeds per fruit (0.0090) at both levels. It had negative indirect effect on fruit yield through branches per plant (-0.0065), weight of fruit (-0.0989) at both levels and nodes on the main stem (-0.1540) and fruit girth (-0.0195) at genotypic level.

4.7.6 Number of fruits per plant :

In parents, this trait had a positive direct effect on fruit yield (0.3417) and positive indirect effect on fruit yield through plant height (0.0925), nodes on main stem (0.0050), branches per plant (0.0175), nodes of first flower appearance (0.0426), girth of fruit (0.0206), seeds per fruit (0.1122) at both levels and weight of fruit (0.0388) at genotypic level. It had negative indirect effect on fruit yield through days to first flower (-0.0112), length of fruit (-0.0352), and 100 seed weight (-0.0203) at both levels.

In crosses, this trait has a positive direct effect on fruit yield per plant (0.4887) and positive indirect effect on fruit yield through plant height

(0.0304), days to first flower (0.0213), length of fruit (0.0115), weight of fruit (0.2589) and number of seeds per fruit (0.0050) at both levels, nodes on the main stem (0.1772), girth of fruit (0.0961) and 100 seed weight at genotypic level. It had negative indirect effect on fruit yield through plant height (-0.1481) at genotypic level and branches per plant (-0.0036), at both levels.

4.7.7 Length of fruit

In parents, this trait had a positive direct effect on fruit yield per plant (0.5848). It had positive indirect effect on fruit yield through number of seeds per fruit (0.0505and 0.0929) at both levels, weight of fruit (0.0796) at phenotypic level, 100 seed weight (0.0077) at genotypic level. It exhibited indirect effect on fruit yield through plant height (-0.0986), nodes on main stem (-0.0189), branches per plant (-0.2081), days to first flower (-0.0389), node at first flower appear (-0.0655), number of fruits per plant (-0.0206), and girth of fruit (-0.0055) at both levels.

In crosses, this trait had a positive direct effect on fruit yield per plant (P = 0.0643, G = 0.1559). It had positive indirect effect on fruit yield through fruit girth (0.0791), 100 seed weight, nodes on main stem (0.2369), branches per plant (0.0114) at genotypic level, fruits per plant (0.0877) and weight of fruit (0.4028) at both levels. It had negative indirect effect on fruit yield through plant height (-0.1481) at genotypic level, days to first flower (-0.0256) and seeds per fruit (-0.1047) at both levels.

4.7.8 Girth of fruit

In parents, this trait had a direct negative effect on fruit yield per plant (P = -0.0379, G = -0.1083), although it had positive indirect effect on fruit yield through days to first flower (0.0259), node at first flower appearance (0.0009), length of fruit (0.0845), 100 seed weight (0.0003) at both levels and fruit weight (0.0944) at genotypic level. The positive indirect effects of this trait seemed to have been nullified through its high negative indirect effect through plant height (-0.1761), nodes on main stem (-0.0238) number of branches per plant (-0.1096), fruits per plant (-0.1859), weight of fruit (-0.0654) and number of seeds per fruit (-0.1186) at both levels and weight of fruit at phenotypic level .

In crosses, this trait had a direct positive effect on fruit yield per plant (0.17630) at genotypic level. It had positive indirect effect on fruit yield through nodes on the main stem (0.1591), days to first flower (0.0256), girth of fruit (0.1763), 100 seed weight (0.0143) at genotypic level, fruits per plant (0.2413), length of fruit (0.0266), and weight of fruit (0.3224) at both levels. It had negative indirect effect on fruit yield through plant height (-0.1029), node of first flower appearance (-0.0048) at genotypic level and number of seeds per fruit (-0.0026) at both levels.

4.7.9 Weight of fruit

In parents, this trait had a equal influence of both positive (0.232 at phenotypic level) and negative direct effect (-0.2492 at genotypic level) on fruit yield. It had positive indirect effect on fruit yield through plant height (0.1517), nodes on main stem (0.0133), number of branches per plant (0.0189), days to first flower (0.0089), length of fruit (0.1984), girth of fruit (0.0104), number of seeds per fruit (0.1212) at both levels. It had negative indirect effect on fruit yield through node of first flower appearance (-0.0419), number of fruits per plant (-0.0532), 100 seed weight (-0.0174) at both levels, and fruit weight at genotypic level (-0.2492).

In crosses, this trait had a direct positive effect on fruit yield per plant (P = 0.6704, G = 0.4068) at both levels. It had positive indirect effect on fruit yield through number of branches per plant (0.0099) nodes on the main stem (0.1421), fruit girth (0.0888), 100 seed weight (0.0234) at genotypic level, number of fruits per plant (0.1887), length of fruit (0.0386) and number of seeds fruit (0.0012) at both levels. It had negative indirect effect on fruit yield through plant height (-0.1387), node of first flower appearance (-0.008) at genotypic level and days to flower (-0.0193 and -0.1253) at both levels.

4.7.10 Number of seeds per fruit :

In parents, this trait had a direct positive effect on fruit yield per plant (0.2258). It had indirect positive effect on fruit yield through plant height (0.1839), nodes on main stem (0.0198), branches per plant (0.0797), fruits per plant (0.1698), length of fruit (0.1309), girth of fruit (0.0199)at both levels and weight of fruit (0.1279) at phenotypic level. It had negative indirect effect on fruit yield through days to first flower (-0.0323), node of first flower appearance (-0.0361) and 100 seed weight (-0.0459) at both levels and fruit weight at genotypic level.

In crosses, this trait had a direct negative effect on fruit yield per plant (-0.0418) although it had positive indirect effect on fruit yield through plant height (0.0055), node of first flower appearance (0.0025), 100 seed weight (0.0061) at phenotypic level, nodes on the main stem (0.0510) girth of fruit at genotypic level and length of fruit (0.0227 and 0.0517) at both levels. But positive indirect effects were nullified by its negative indirect effect on fruit yield through plant height (-0.0259), node at which first flower appeared (-0.0115), 100 seed weight (-0.0253) at genotypic level, nodes on the main stem (-0.0097) girth of fruit (-0.002) at phenotypic level, number of branches per plant (-0.0013 and -0.0207), days to first flower (-0.0074 and -0.0497) and weight of fruit (-0.0192 and -0.0118) at both levels.

4.7.11 100 Seed weight :

This trait in parents had a direct negative effect on fruit yield per plant (P = -0.0692, G = -0.1486) although it had positive indirect effect on fruit yield through plant height (0.1014), nodes on main stem (0.0071), branches per plant (0.1416), node of first flower appearance (0.0182), fruits per plant (0.1004), girth of fruit (0.0002), number of seeds per fruit (0.2258) at both levels and weight of fruit (0.0599) at genotypic level. Its positive indirect effects were however, nullified by its negative indirect effect on fruit yield through days to first flower (-0.0037), length of fruit (-0.065) at both levels and weight of fruit (-0.0634) at genotypic level.

In crosses, this trait had a direct positive effect on fruit yield per plant (0.0210 at phenotypic and negative effect (-0.0871) at genotypic level. It had positive indirect effect on fruit yield through number of branches per plant (0.0026 and 0.0351) at both levels, plant height (0.1160) at genotypic level, nodes on the main stem (0.0123), node of first flower appearance (0.0014) and girth of fruit (0.0004) at phenotypic level.

It had negative indirect effect on fruit yield through days to first flower (-0.0079), number of fruits per plant (-0.6912), length of fruit (-0.0078), weight of fruit (-0.1770) and seeds per fruit (-0.0121) at both levels, plant height (-0.0250) at phenotypic level, nodes on the main stem (-0.0624) and girth of fruit (-0.0289) at genotypic level.

Table 10 : Phenotypic(r_p) and Genotypic (r_g) correlation coefficients between yield contributing characters and fruit yield per plant for nine parents in Okra

Sl. No.	Treatments		Plant height	Nodes on main stem	Number of branches per plant	Days to first flower	Node at which first flower appear	Number of fruits per plant	Length of fruit	Girth of fruit	Weight of fruit	Seeds per fruit	100 seed weight	Fruit yield per plant
1	Plant height	r_p	1.0000	0.7788*	0.0145	0.3336	-0.0063	0.2695	-0.2875	-0.5133	0.4424	0.5362	0.2956	0.5688
		r_g	1.0000	0.8303**	0.0230	0.4093	0.0041	0.2775	-0.2941	-0.6420	0.4523	0.5420	0.2993	0.5725
2.	Number of nodes on main stem	r_p		1.0000	0.0365	0.1043	-0.3043	0.0966	-0.3669	-0.4625	0.2575	0.3840	0.1385	0.2743
		r_g		1.0000	0.0452	0.2748	-0.3336	0.1036	-0.3769	-0.5466	0.2819	0.3923	0.1470	0.2798
3.	Number of branches per plant	r_p			1.0000	0.0526	0.3437	0.3064	-0.5930	-0.3123	0.0539	0.2272	0.4036	0.2518
		r_g			1.0000	0.0721	0.3997	0.3113	-0.5991	-0.3866	0.0581	0.2288	0.4062	0.2189
4.	Days to first flower	r_p				1.0000	0.3376	-0.1172	-0.4063	0.2699	0.0924	-0.3366	-0.0388	-0.0590
		r_g				1.0000	0.5088	-0.1928	-0.5367	0.1072	0.0705	-0.3646	-0.0350	-0.0600
5.	Node at which first flower appear	r_p					1.0000	0.3118	-0.4798	0.0068	-0.3070	-0.2645	0.1331	-0.0446
		r_g					1.0000	0.3904	-0.5605	0.0010	-0.3498	-0.2882	0.1674	-0.0533
6.	Number of fruits per plant	r_p						1.0000	-0.0602	-0.5439	-0.1558	0.4969	0.2937	0.6182
		r_g						1.0000	-0.0682	-0.6893*	-0.1556	0.5013	0.3118	0.6335
7.	Length of fruit	r_p							1.0000	0.1146	0.3341	0.2238	-0.1117	0.2664
		r_g							1.0000	0.1526	0.3361	0.2359	-0.1105	0.2695
8.	Girth of fruit	r_p								1.0000	-0.2746	-0.5255	-0.0043	-0.06057
		r_g								1.0000	-0.3788	-0.6332	-0.0311	-0.7601*
9.	Weight of fruit	r_p									1.0000	0.5370	0.2514	0.654
		r_g									1.0000	0.5617	0.2544	0.6546
10.	Number of seeds per fruit	r_p										1.0000	0.6636	0.8434**
		r_g										1.0000	0.6742*	0.8518**
11.	100 Seed weight	r_p											1.0000	0.4404
		r_g											1.0000	0.4428
12.	Fruit yield per plant	r_p												1.0000
		r_g												1.0000

* Significant at 5 % level

** Significant at 1% level

Table 11 : Phenotypic(r_p) and Genotypic (r_g) correlation coefficients between yield contributing characters and fruit yield per plant for 18 crosses in Okra

Sl. No.	Treatments		Plant height	Nodes on main stem	Number of branches per plant	Days to first flower	Node at which first flower appear	Number of fruits per plant	Length of fruit	Girth of fruit	Weight of fruit	Seeds per fruit	100 seed weight	Fruit yield per plant
1	Plant height	r_p	1.0000	0.8518**	0.2601	-0.0280	0.1761	-0.3111	-0.3233	-0.2105	-0.2998	-0.0561	0.2562	-0.3844
		r_g	1.0000	0.8738**	0.2732	-0.0186	0.1987	-0.3177	-0.3286	-0.2283	-0.3078	-0.0575	0.2574	-0.3849
2.	Number of nodes on main stem	r_p		1.0000	0.2934	-0.2126	0.2495	-0.3443	-0.5138*	-0.2768	-0.5163*	-0.0966	0.1232	-0.5153*
		r_g		1.0000	0.3189	-0.3372	0.3129	-0.3601	-0.5363*	-0.3234	-0.5425*	-0.1036	0.1269	-0.5268*
3.	Number of branches per plant	r_p			1.0000	-0.3842	0.2511	0.1392	-0.0017	0.2716	-0.3847	0.4097	-0.1012	-0.1862
		r_g			1.0000	-0.5473*	0.3354	0.1531	-0.0355	0.2947	-0.4427	0.0646	-0.1095	-0.1945
4.	Days to first flower	r_p				1.0000	-0.2826	-0.2445	0.2932	0.0294	0.2216	0.0849	0.0911	-0.462
		r_g				1.0000	-0.2136	-0.4462	0.4191	-0.0622	0.3045	0.1208	0.1255	-0.0621
5.	Node at which first flower appear	r_p					1.0000	0.0020	0.0998	-0.1062	-0.1475	-0.2149	-0.1177	-0.0705
		r_g					1.0000	0.0363	0.1182	-0.1104	-0.1883	-0.2654	-0.1338	-0.0850
6.	Number of fruits per plant	r_p						1.0000	0.1794	0.4936*	0.3862	-0.1202	-0.1865	0.7727**
		r_g						1.0000	0.1877	0.5448*	0.4059	-0.1221	-0.1908	0.7889**
7.	Length of fruit	r_p							1.0000	0.4138	0.6008**	0.3542	-0.1209	0.4900*
		r_g							1.0000	0.4485	0.6164**	0.3600	-0.1267	0.4998*
8.	Girth of fruit	r_p								1.0000	0.4809*	0.0615	-0.1564	0.56648
		r_g								1.0000	0.5038*	0.0682	-0.1638	0.6126**
9.	Weight of fruit	r_p									1.0000	-0.0287	-0.2641	0.8622**
		r_g									1.0000	-0.0289	-0.2682	0.8776**
10.	Number of seeds per fruit	r_p										1.0000	2.891	-0.1015
		r_g										1.0000	0.2905	-0.1018
11.	100 Seed weight	r_p											1.0000	-0.2833
		r_g											1.0000	-0.2837
12.	Fruit yield per plant	r_p												1.0000
		r_g												1.0000

* Significant at 5 % level

** Significant at 1% level

Table 12 : Phenotypic (P) and Genotypic (G) path coefficients of 11 yield components on fruit yield per plant in parents in Okra

Sl. No.	Treatments		Plant height	Nodes on main stem	Number of branches per plant	Days to first flower	Node at which first flower appear	Number of fruits per plant	Length of fruit	Girth of fruit	Weight of fruit	Seeds per fruit	100 seed weight	Correlation with fruit yield per plant
1	Plant height	P	**(0.3430)**	0.0401	0.0051	0.0320	-0.0009	0.0921	-0.1681	0.0195	0.1054	0.1211	-0.0204	0.5688
		G	**(0.5887)**	0.0257	0.0153	0.1513	0.0007	0.0148	-0.3498	0.0696	-0.1127	0.2314	-0.0445	0.5725
2.	Number of nodes on main stem	P	0.2671	**(0.0515)**	0.0128	0.0100	-0.0416	0.0330	-0.2145	0.0175	0.0613	0.0867	-0.0096	0.2743
		G	0.4888	**(0.0310)**	0.0340	0.1016	-0.0543	0.0055	-0.4484	0.0529	-0.0703	0.1545	-0.0604	0.2798
3.	Number of branches per plant	P	0.0050	0.0019	**(0.3509)**	0.0050	0.0469	0.1047	-0.3468	0.0118	0.0128	0.0513	-0.0279	0.2518
		G	0.0120	0.0014	**(0.7527)**	0.0266	0.0651	0.0166	-0.7127	0.0419	-0.0145	0.0901	-0.0604	0.2189
4.	Days to first flower	P	0.1144	0.0054	0.0185	**(0.0958)**	0.0461	-0.0401	-0.2376	-0.0102	0.0220	-0.0760	0.0027	-0.0590
		G	0.2410	0.0085	0.0542	**(0.3698)**	0.0829	-0.0103	-0.6385	-0.0116	-0.1076	-0.1436	0.0052	-0.0600
5.	Node at which first flower appear	P	-0.0022	-0.0157	0.1206	0.0324	**(0.1366)**	0.1065	-0.2806	-0.0003	-0.073	-0.0597	-0.0092	-0.0446
		G	0.0024	-0.0103	0.3009	0.181	**(0.1629)**	0.209	-0.6668	-0.0001	0.0872	-0.1135	-0.0249	-0.0533
6.	Number of fruits per plant	P	0.0925	0.0050	0.0175	-0.0112	0.0426	**(0.3417)**	-0.0352	0.0206	-0.0371	0.112	-0.0203	0.6182
		G	0.1634	0.0032	0.2343	-0.0713	0.0636	**(0.0534)**	-0.0812	0.0747	0.0388	0.2009	-0.0463	0.6335
7.	Length of fruit	P	-0.0986	-0.0189	-0.2081	-0.0389	-0.0655	-0.0206	**(0.5848)**	-0.0055	0.0796	0.0505	0.0077	0.2664
		G	-0.731	-0.0117	-0.4510	-0.1985	-0.0913	-0.0036	**(1.1896)**	-0.0165	-0.0837	0.0929	0.0164	0.2695
8.	Girth of fruit	P	-0.1761	-0.0238	-0.1096	0.0259	0.000	-0.1859	0.0845	**(-0.0379)**	-0.0654	-0.1186	0.0003	-0.0605
		G	-0.3780	-0.0169	-0.2910	0.0397	0.0002	-0.0368	0.1815	**(-0.1083)**	0.0944	-0.2493	0.0046	-0.7601*
9.	Weight of fruit	P	0.1517	0.0133	0.0189	0.0089	-0.0419	-0.0532	0.1954	0.0104	**(0.2382)**	0.21212	-0.0174	0.6540
		G	0.2663	0.0087	0.0437	0.0261	-0.0570	-0.0083	0.3998	0.0410	**(-0.2492)**	0.2212	-0.0378	0.6546
10.	Number of seeds per fruit	P	0.1839	0.0198	0.0797	-0.0323	-0.0361	0.1698	0.1309	0.0199	0.1279	**(0.2258)**	-0.0459	0.8434**
		G	0.3191	0.0122	0.1722	-0.1348	-0.0469	0.0273	0.2806	0.0686	-0.1400	**(0.3938)**	-0.1002	0.8518**
11.	100 Seed weight	P	0.1014	0.0071	0.1416	-0.0037	0.0182	0.1004	-0.0653	0.0002	0.0599	0.1498	**(-0.0692)**	0.4404
		G	0.1762	0.0046	0.3057	-0.0129	0.0273	0.0167	-0.1314	0.0034	-0.0634	0.2655	**(-0.1486)**	0.4428

Residual effect (Phenotypic) = 0.0456   Diagonal : Direct effects   *, ** Significant at 5% and 1% levels respectively

Residual effect (Genotypic) = 0.0462   Non-diagonal : Indirect effects

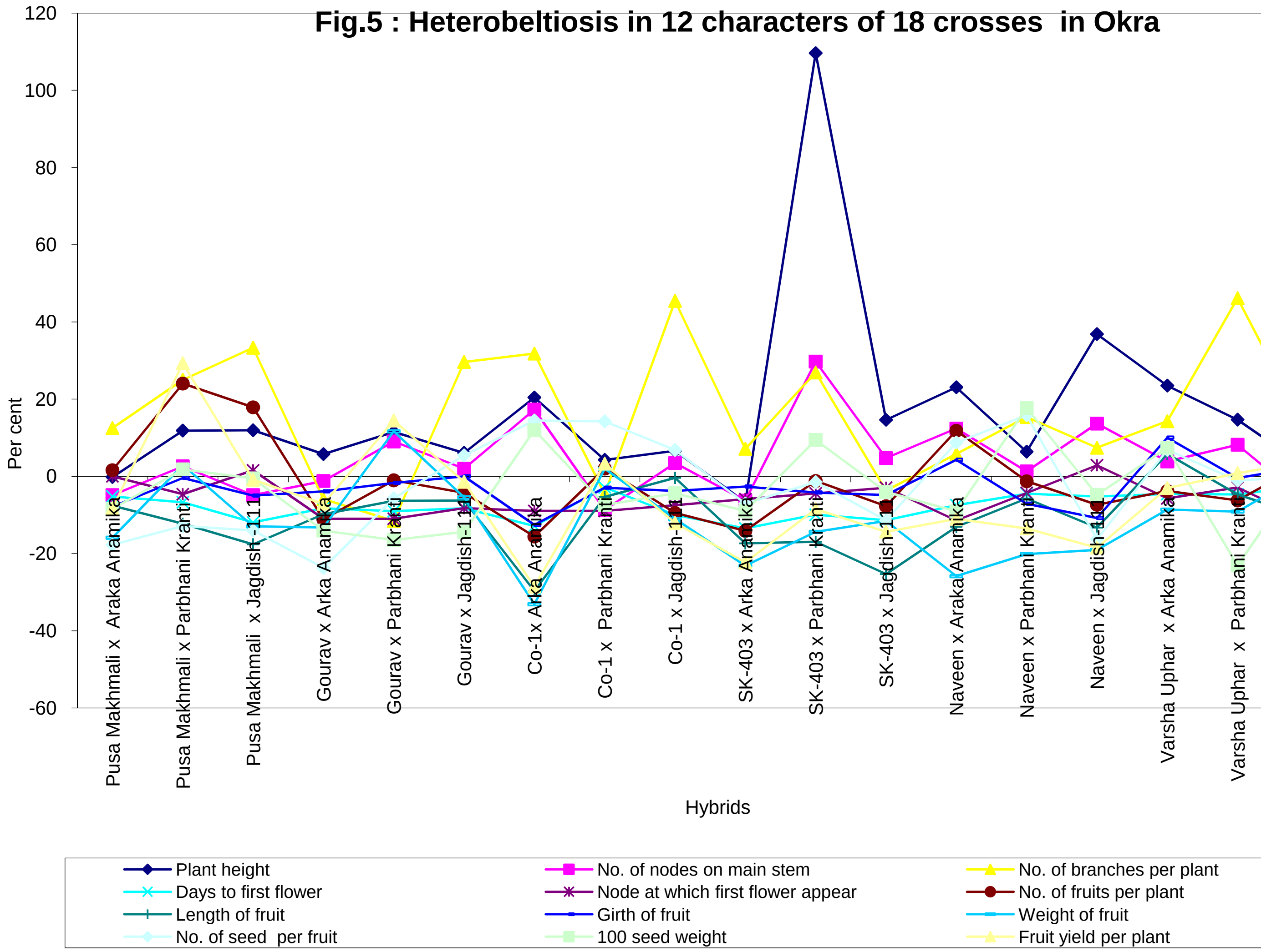
Table 13 : Phenotypic (P) and Genotypic (G) path coefficients of 11 yield components on fruit yield per plant in crosses in Okra

Sl. No.	Treatments		Plant height	Nodes on main stem	Number of branches per plant	Days to first flower	Node at which first flower appear	Number of fruits per plant	Length of fruit	Girth of fruit	Weight of fruit	Seeds per fruit	100 seed weight	Correlation with fruit yield / plant
1	Plant height	P	**(-0.0976)**	0.0851	0.0067	0.0024	-0.0021	-0.1521	-0.208	0.0005	-0.2010	0.0023	0.0054	-0.3844
		G	**(0.4508)**	-0.4299	-0.0877	0.007	0.0086	-0.0975	-0.0512	-0.0403	-0.1252	0.0023	-0.0224	-0.3849
2.	Nodes on main stem	P	-0.0831	**(0.0999)**	-0.0076	0.0185	-0.0029	-0.1683	-0.0300	0.0007	-0.3461	0.0040	0.0026	-0.5153*
		G	0.3939	**(-0.4920)**	-0.1023	0.1388	0.0136	-0.1105	-0.0836	-0.0570	-0.2207	0.0041	-0.0111	-0.5268*
3.	Number of branches per plant	P	-0.0254	0.0293	**(-0.2258)**	0.0335	-0.0030	0.0680	-0.0001	-0.0007	-0.2579	-0.0021	-0.0021	-0.1862
		G	0.1231	-0.1569	**(-0.3209)**	0.2253	0.0146	0.0470	-0.0055	0.0520	-0.1801	-0.0025	0.0095	-0.1945
4.	Days to first flower	P	0.0027	-0.0212	0.0099	**(-0.0871)**	0.0033	-0.1195	0.0189	-0.0001	0.1486	-0.035	0.0019	-0.4620
		G	-0.0084	0.1658	0.1756	**(-0.4116)**	-0.0093	-0.1370	0.0654	-0.0110	0.239	-0.0048	-0.109	-0.0621
5.	Node at which first flower appear	P	-0.0172	0.0249	-0.0065	0.0246	**(-0.0118)**	0.0010	0.00654	0.0003	-0.0989	0.0090	-0.0025	-0.0705
		G	0.0896	-0.1540	-0.1076	0.0879	**(0.0438)**	0.0111	0.0184	-0.0195	-0.0766	0.0105	0.0117	-0.0850
6.	Number of fruits per plant	P	0.0304	-0.0344	-0.0036	0.0213	-0.0000	**(0.4887)**	0.0115	-0.0013	0.2589	0.0050	-0.039	0.7727**
		G	-0.1432	0.172	-0.0491	0.1836	0.0016	**(0.3070)**	0.0293	0.0961	0.1651	0.0048	0.0166	0.7889**
7.	Length of fruit	P	0.0315	-0.0513	0.0000	-0.0256	-0.0012	0.0877	**(0.0643)**	-0.0011	0.4028	-0.0147	-0.0025	0.4900**
		G	-0.1481	0.2639	0.0114	-0.1725	0.0051	0.0576	**(0.1559)**	0.0791	0.2508	-0.0144	0.0110	0.4998**
8.	Girth of fruit	P	0.0250	-0.0276	-0.0070	-0.0026	0.0012	0.2413	0.0266	**(-0.0026)**	0.3224	-0.0026	-0.0033	0.5644
		G	-0.1209	0.1591	-0.0946	0.2056	-0.0048	0.1672	0.0699	**(0.1763)**	02.050	-0.0027	0.0143	0.6126**
9.	Weight of fruit	P	0.0292	-0.0516	0.0099	-0.0193	0.0017	0.1887	0.0386	-0.0012	**(0.6704)**	0.0012	-0.0055	0.8622**
		G	-0.1387	0.2669	0.1421	-0.1253	-0.0082	0.1246	0.0961	0.0888	**(0.4068)**	0.0011	0.0234	0.8776*8
10.	Number of seeds per fruit	P	0.0055	-0.0097	-0.0013	-0.0074	0.0025	-0.0588	0.0227	-0.0002	-0.0192	**(-0.0418)**	0.0061	-0.1015
		G	-0.0259	0.0510	-0.027	-0.0498	-0.0015	-0.0375	0.0571	0.0120	-0.0118	**(-0.0394)**	-0.0253	-0.1018
11.	100 Seed weight	P	-0.0250	0.0123	0.0026	-0.0079	0.0014	-0.0912	-0.0078	0.0004	-0.1770	-0.0121	**(0.0210)**	-0.2833
		G	0.1160	-0.0624	0.0351	-0.0517	-0.0058	-0.0586	-0.0198	-0.0289	-0.1091	-0.0115	**(-0.0871)**	-0.2837

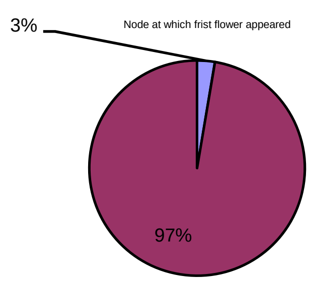
Residual effect (Phenotypic) = 0.4032 Diagonal = Direct effects *, ** Significant at 5% and 1% levels respectively
Residual effect (Genotypic) = 0.0319 Non-diagonal = Indirect effects

STANDARD WEEK WISE METEOROLOGICAL DATA DURING THE CROP GROWTH PERIOD (July 2003 - April 2004)

Month & Year 2003-04	Temperature (°C)		Relative humidity (%)		SS Hours	Rainfall (mm)	Wind speed (Kmph)	Evapora-tion (mm)
	Max	Min	I	II				
31 (30th July - 5th Aug)	32.31	23.91	79.57	58.85	2.81	27.9	6.74	4.2
32 (6th Aug. - 12th Aug.)	33.20	25.14	71.42	53.42	6.20	17.0	9.52	4.6
33 (13th Aug. - 19th Aug.)	33.84	24.82	71.85	53.57	7.24	35.2	9.84	4.1
34 (20th Aug - 26th Aug)	30.22	23.64	77.28	61.85	1.71	25.0	8.82	4.5
35 (27th Aug - 2nd Sept.)	32.94	24.18	74.00	53.85	3.72	42.4	5.35	4.7
36 (3rd Sept. - 9th Sept.)	34.32	25.10	64.28	44.85	6.60	-	8.54	4.3
37 (10th Sept. - 16th Sept.)	34.04	24.50	60.57	42.00	6.52	33.5	9.56	5.2
38 (17th Sept. - 23rd Sept.)	33.48	23.87	83.71	52.28	7.02	40.2	6.02	5.5
39 (24th Sept. - 30th Sept.)	32.38	19.71	83.28	57.85	11.48	45.6	4.15	5.3
40 (1st Oct. - 7th Oct.)	32.72	23.97	84.28	57.57	5.34	86.5	5.28	4.9
41 (8th Oct. - 14th Oct.)	33.30	23.04	75.28	54.57	72.7	00.8	5.26	4.6
42 (15th Oct. - 21st Oct.)	30.20	22.45	80.57	61.28	2.28	76.2	3.93	4.2
43 (22nd Oct. - 28th Oct.)	31.27	21.58	82.00	60.00	6.38	34.0	4.22	4.0
44 (29th Oct. - 4th Nov.)	31.25	21.10	81.71	59.71	8.18	6.4	5.48	4.0
45 (5th Nov. - 11th Nov.)	30.05	20.84	84.85	57.42	5.21	13.0	5.03	4.2
46 (12th Nov. - 18th Nov.)	30.37	21.32	82.85	53.42	7.17	1.4	5.83	4.6
47 (19th Nov - 25th Nov.)	29.42	19.61	72.42	53.14	5.70	-	8.00	4.8
48 (26th Nov. -2nd dec.)	29.55	18.75	79.14	51.57	6.05	-	7.58	4.5
49 (3rd Dec. - 9th Dec.)	29.57	15.85	69.28	40.71	9.05	-	6.88	4.7
50 (10th Dec. - 16th Dec.)	27.74	16.68	69.71	44.57	5.17	-	8.45	4.1
51 (17th Dec. - 23rd Dec.)	29.97	17.00	74.71	55.14	7.60	-	8.29	5.3
52 (24th Dec. - 31st Dec.)	28.62	20.07	87.25	65.00	5.42	10.6	6.43	3.7
1 (1st Jan. - 7th Jan. 2004)	28.6	17.9	79	49.2	6.9	-	8.10	5.1
2 (8th Jan.-14th Jan. 2004)	28.4	15.3	71.1	36.4	8.4	-	8.6	5.6
3 (15th Jan.-21st. Jan.2004	30.0	14.0	78.8	35.7	9.5	-	6.2	6.1
4 (22nd Jan.-28th Jan. 2004)	30.8	19.9	77.5	49.5	6.7	-	6.0	4.7
5 (29th Jan.-4th Feb. 2004)	31.4	195.	78.,7	41.5	8.1	-	6.9	5.5
6 (5th Feb.-11th Feb. 2004)	31.6	18.6	73.0	42.7	7.2	-	7.3	4.6
7 (12th Feb.-18th Feb.2004)	31.1	15.9	64.4	33.7	9.6	-	6.8	7.1
8 (19th Feb.-25th Feb.2004)	31.9	15.5	51.5	23.7	9.9	-	7.02	7.1
9 (26th Feb . -4th March 2004)	35.4	17.6	54.2	20.3	9.7	-	6.7	8.3
10 (5th Mach - 11th March 2004)	35.5	19.0	63	26.2	9.7	-	7.8	8.1
11 (12th March - 18th March 2004)	36.8	18.3	46.7	17.7	9.8	-	4.4	8.5
12 (19th March - 25th March 2004)	39.2	22.3	63.5	14.7	9.2	-	6.5	9.0
13 (26th March - 1st April, 2004)	37.1	23.8	68.8	35.1	8.1	27.7	6.7	7.6
14 (2nd April - 8th April, 20040	36.1	24.8	64.5	37.8	6.3	25.0	5.6	5.4
15 (9th April -15th April, 2004)	38.0	22.8	64.1	32.4	9.4	22.2	6.5	7.1
16 (16th April- 22nd April, 2004)	40.3	26.8	57.4	29.1	8.3	-	5.9	8.0
17 (23rd April - 29th April, 2004)	37.8	26.0	65.1	33.2	8.1	-	5.8	7.3

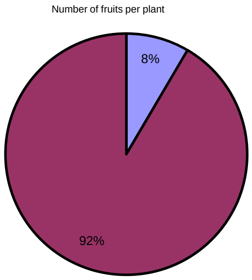


Node at which frist flower appeared	0.0004	0.0147



Number of fruits per	0.1493	1.6187

plant



Fruit length 0.581 1.0348

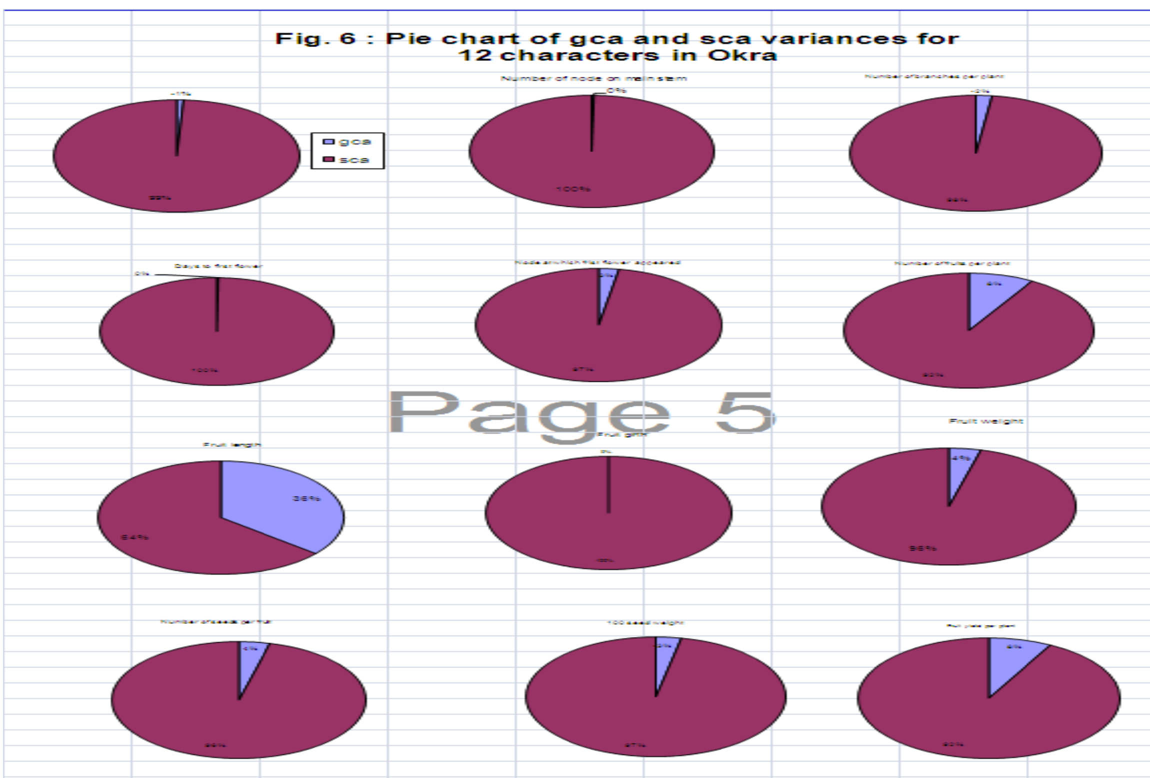
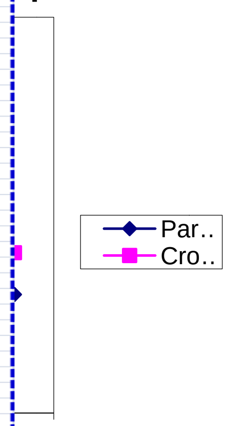
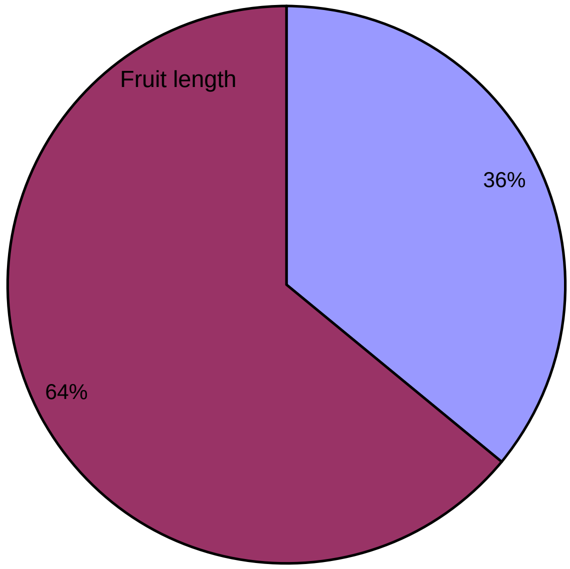
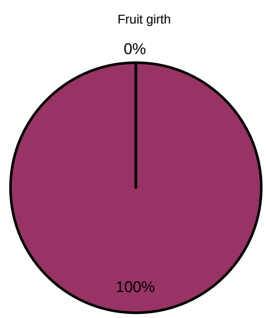


Fig. 6 : Pie chart of gca and sca variances for 12 characters in Okra

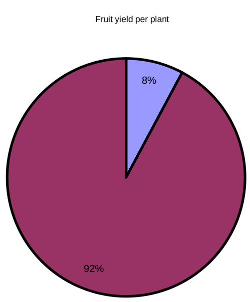
parents



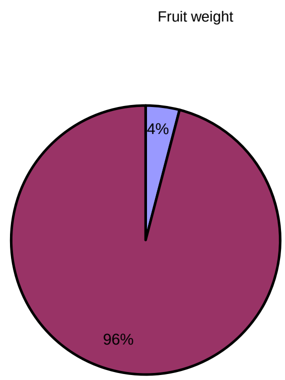




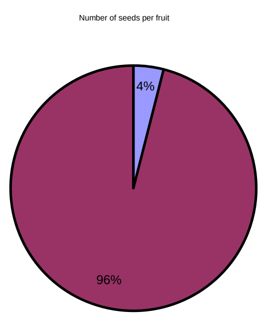
Fruit yield per plant	17.7134	209.0287



Fruit weight	0.0294	0.6949



Number of seeds per fruit	0.5531	13.4281



100 seed weight	-0.0186	0.5752

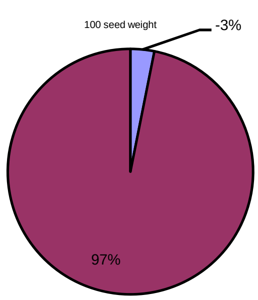


Fig. 4 : Relative heterosis in 12 characters of 18 crosses in Okra

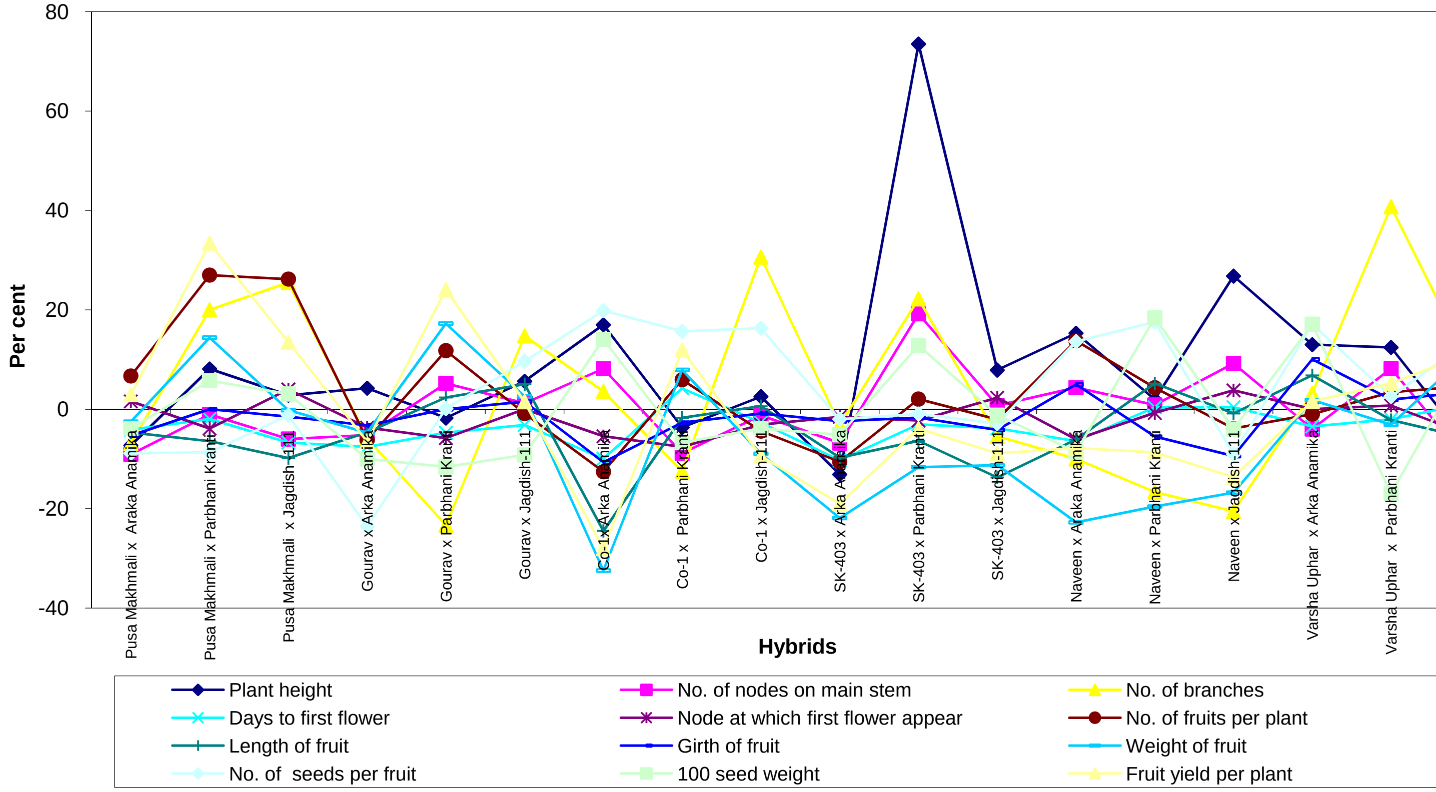


Fig. 7 : Correlation of 11 yield attributes with fruit yield inparents and

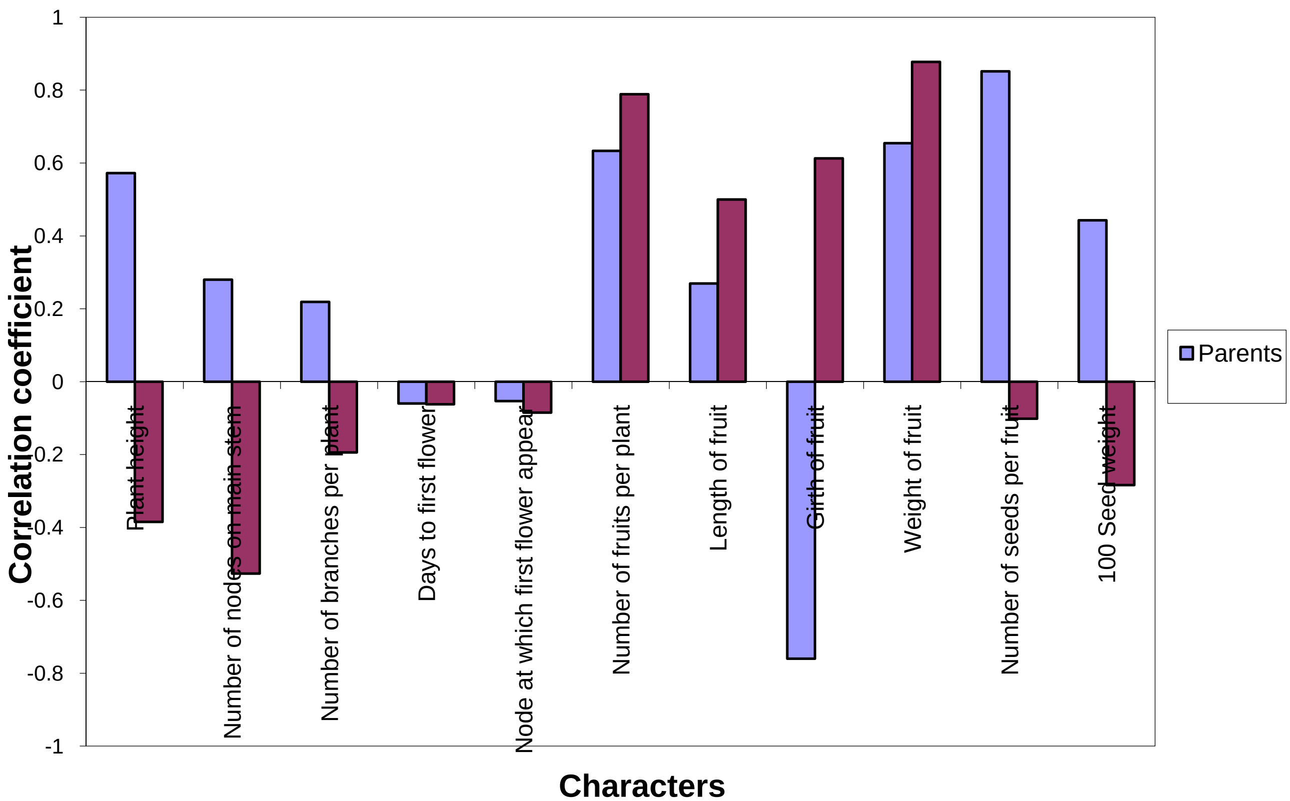


Fig. 8 : Phenotypic direct effects in parents and hybrids for 11 yield

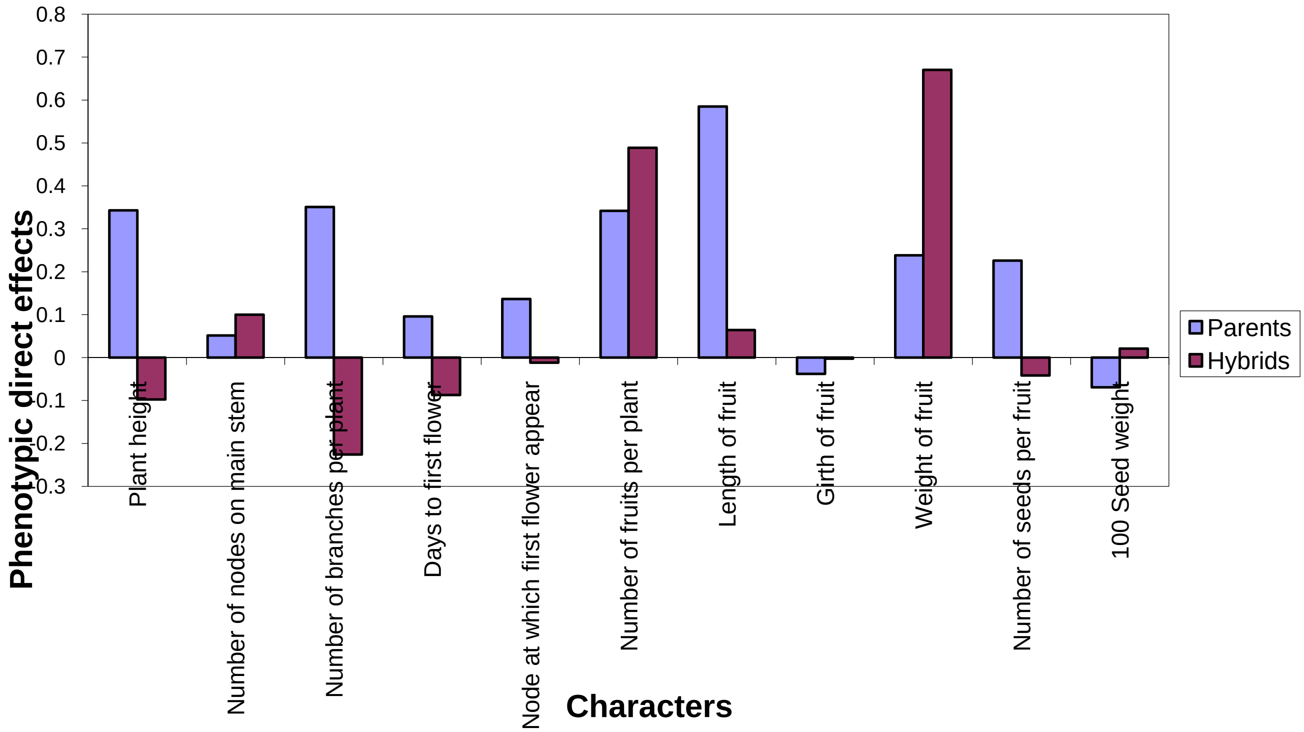
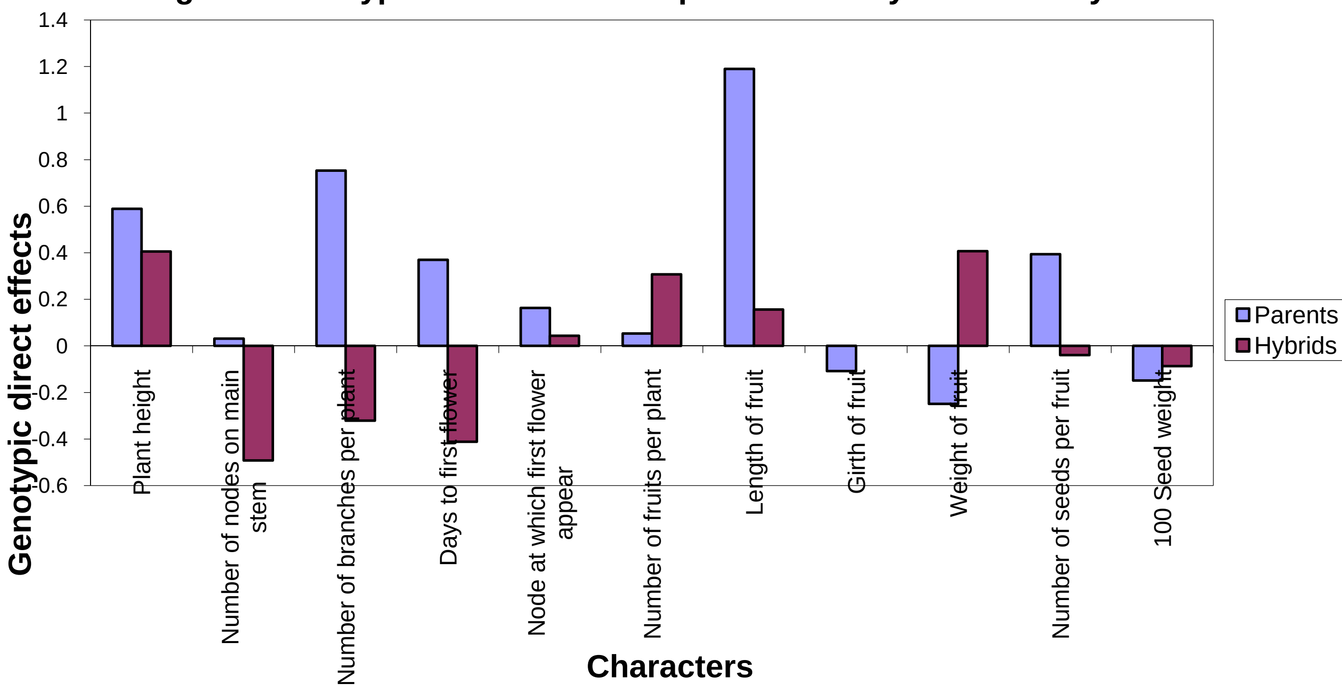


Fig. 9 : Genotypic direct effects in parents and hybrids for 11 yield



CHAPTER - V

DISCUSSION

Nine genetically diverse genotypes of okra were utilized to obtain 18 crosses in a line x tester crossing programme with six lines and three testers. The parents and crosses were subjected to line x tester analysis of Kempthorne (1957). In the present investigation the data collected for 9 parents and their 18 hybrids were discussed under the following sub heads. Evaluation of parents and crosses, heterosis (relative heterosis and heterobeltiosis), combining ability, variability, heritability, genetic advance and genetic advance as per cent of mean, character association and path coefficient analysis are discussed here under.

5.1 Evaluation of parents and crosses

Six lines and three testers and their 18 hybrids synthesised adopting the L x T mating design were evaluated for their mean performance. Mean performance is a realised value, hence it may be employed as the first criterion for selecting superior parents and hybrids. Among different lines Gourav surpassed the remaining lines in mean performance for plant height, branches per plant, fruits per plant, seeds per fruit, 100 seed weight and fruit yield per plant followed by CO-1 for fruit length, fruit weight and fruit yield per plant, Varsha Upahar for fruits per plant and fruit length, SK-403 for plant height, nodes on the main stem and fruit weight and Naveen for branches per plant and 100-seed weight (Table 3).

Among the testers, Arka Anamika exhibited significantly high mean performance for plant height, nodes on main stem, branches per plant, node of first flower appearance, fruit weight, seeds per fruit, 100 seed weight and fruit yield per plant. The next best tester was Jagdish-111 which also recorded significantly high mean performance for plant height, days to first flower, node of first flower appearance, fruits per plant, fruit length, fruit weight and fruit yield per plant Parbhani Kranti had shown considerable superiority in performance towards days to first flower, fruit length, seeds per fruit and 100 seed weight. Kalloo *et al.* (1974) emphasized the importance of mean expression in selecting parents. However, a high yielding genotype may not necessarily transmit its superiority in its cross combination. Therefore, this study of L x T proposed by Kempthrone (1957) was conducted as it appears to be the most useful technique for screening large number of lines with a reasonable confidence.

With regard to *per se* performance of the crosses, seven F_1 hybrids namely Gourav x Parbhani Kranti, Varsha Uphar x Jagdish-111, Pusa Makhmali x Parbhani Kranti, Pusa Makhmali x Jagdish-111, Gourav x Jagdish-111, Co1- x Parbhani Kranti and Varsha Uphar x Arka Anamika exhibited significantly high mean performance for yield and some of its economic components. Gourav x Jagdish-111 for fruits per plant, fruit length, girth and weight and seeds per fruit and even plant height, branches per plant, Pusa Makhmali x Jagdish-111 for days to first flower and Varsha Uphar x Jagdish-111 for node of first flower appearance and 100 seed weight were found superior. Among these seven F_1 hybrids, the highest *per se* performance for fruit yield was noted with Gourav x Parbhani Kranti (200.23 g / plant) followed by Varsha Uphar x Jagdish-111 (192.9 g/plant) and Pusa Makhmali x Parbhani Kranti (191.43 g/plant) and least with Varsha Uphar x Arka Anamika (171.98 g / plant) in that order.

The other hybrids Naveen x Jagdish-111, Naveen x Arka Anamika, Co-1 x Arka Anamika, Co-1 x Jagdish-111 and Varsha Uphar x Parbhani Kranti having involved high mean parents, failed to produce high fruit yield, but exhibited high mean performance for some of the yield attributes, suggesting that the parents involved had dominant gene action for fruit yield. This also indicates lack of interaction between dominant genes of the involved parents. The lines viz., Gourav, Pusa Makhmali, Varsha Uphar and testers viz., Parbhani Kranti and Jagdish-111 may be exploited for fruit yield improvement in Okra.

5.2 HETEROSIS

Estimation of the extent of heterosis in diverse cross combinations would always be useful in choosing the best performing crosses for commercial exploitation. The extent of heterosis has been estimated over mid parent or better parent with the objective of studying the nature of gene action involved in the parental combinations. The estimates of heterosis in 18 crosses over mid parent and better parent are presented in Table 5.

Yield is a complex trait and sum of functions of its component traits. Moreover it is under polygenic control and also influenced by the environment. The F_1 hybrids which exhibit heterosis more than 20 per cent over the standard check would be considered as economical. The relative merits of heterotic hybrids for yield and its components in the present study are discussed below.

Among the 18 F_1 hybrids, eight crosses viz., Pusa Makhmali x Parbhani Kranti, Gourav x Parbhani Kranti, Varsha Uphar x Jagdish-111, Co-1 x Parbhani Kranti, Varsha Uphar x Parbhani Kranti, Naveen x Parbhani Kranti, Pusa Makhmali x Jagdish-111 and Co-1 x Arka Anamika exhibited significantly high heterosis in the range of 5.22 to 34.43% and 0.84 to 29.31% over mid and better parents for yield respectively. The highest was exhibited with Pusa Makhmali x Parbhani Kranti and the lowest with Co-1 x Arka Anamika (Table 5). Joshi *et al.* (1959) reported hybrid vigour and 60 per cent increase in yield similar to the present findings in Okra. Dash *et al.* (2001) observed increased yield in the range of 3.54 to 15.26 q per ha and per cent increase over the standard check in the range of 1.21 to 294.18.

The F_1 hybrid Pusa Makhmali x Parbhani Kranti recorded significantly high positive heterosis over mid parent and better parent for fruit yield per plant (33.43% and 29.31%), fruits per plant (26.99% and 24.44%), fruit weight (14.40% over mid parent) and branches per plant (20.0% and 25.49%) besides registering high mean performance for number of fruits and fruit yield per plant (Table 5). Whereas the hybrid Gourav x Parbhani Kranti registered high mean performance for fruits per plant, fruit weight and fruit yield per plant and exhibited significantly high heterosis over mid parent and better parent for fruit yield per plant (24.09% and 14.48%), fruit weight (17.24% and 11.68%) and node of first flower appearance (-5.80% and -10.96%). The parents involved in these hybrids had significantly high mean performance for plant height, branches per plant, fruits per plant, fruit yield per plant (Gourav), seeds per fruit, 100 seed weight (Gourav and Parbhani Kranti), fruit girth (Pusa Makhmali), fruit length and days to first flower (Parbhani Kranti).

The other F_1 hybrids viz., Co1 x Parbhani Kranti, Varsha Uphar x Jagdish-111 and Varsha Uphar x Parbhani Kranti which showed significantly high mean performance for fruit length and fruit weight, seeds per fruit and 100 seed weight and fruit girth, fruit weight and fruit yield per plant respectively also expressed significantly high positive heterosis over mid and better parents for fruit yield per plant (11.94 and 3.31%, 11.25 and 3.94% and 5.22 and 0.84% respectively) next to Pusa Makhamali x Parbhani Kranti and Gourav x Parbhani Kranti. The parents involved in these hybrids were also significantly superior in *per se* performance for fruits per plant (Varsha Uphar), fruit length (Varsha Uphar, Co-1), fruit weight and fruit yield per pant (Co-1).

The cross combinations Naveen x Parbhani Kranti, Pusa Makhmali x Jagdish-111 and Co-1 x Arka Anamika which exhibited significant high mean performance for seeds per fruit and 100 seed weight, days to first flower, fruits and fruit yield per plant, and node of first flower appearance and seeds per fruit respectively, exhibited significantly high positive heterosis over mid parent for fruit yield per plant (17.72, 13.49 and 11.29% respectively). The parents involved in these hybrids also expressed significantly high mean performance for branches per plant (Naveen, Arka Anamika), days to first flower (Parbhani Kranti), node of first flower appearance (Arka Anamika, Jagdish-111), fruits per plant (Jagdish-111), fruit length (Co-1, Jagdish-111, Parbhani Kranti), fruit girth (Pusa Makhmali), fruit weight and fruit yield per plant (Co-1, Jagdish-111, Arka Anamika), seeds per fruit (Arka Anamika, Parbhani Kranti) and 100-seed weight (Naveen, Jagdish-111, Arka Anamika).

It is also evident from the results (Table 5) that the F_1 hybrids Varsha Uphar x Arka Anamika for fruit length (6.83 and 5.80%), fruit girth (10.04 and 10.04%), seeds per fruit (17.0 and 6.86) and 100 seed weight (17.1 and 7.44%) showed significantly highest heterosis over mid and better parent which registered significantly high mean performance for these traits. However, this cross failed to manifest heterosis, but exhibited significantly superior mean performance for fruit yield per plant. These findings thus indicate the establishment of relationship between the *per se* performance of parents and hybrids and heterosis of hybrids as was observed earlier by Sharma and Mahajan (1979) and Elangovan *et al.* (1979) in Okra.

Similarly, the parents Co-1 and Arka Anamika which had significantly high mean performance for fruit length (Co-1) fruit weight and fruit yield per plant (Co-1, Arka Anamika), seeds per fruit and 100 seed weight (Arka Anamika) when involved in hybrid combinations could manifest significant positive heterosis over mid parent for fruit yield per plant indicating existence of dominant genes in these parents for this trait. Singh and Sonia Sood (1999) also observed the importance of dominant genes in expression of heterotic effects through recombination breeding in Okra.

The F_1 hybrids which involved the parents especially the lines SK 403 and Naveen with low mean performance, for fruits per plant, fruit length and girth, seeds per fruit, 100 seed weight and fruit yield per plant exhibited significant negative heterosis for fruit yield per plant, fruit length and fruit weight, indicating that the parents lack dominant genes for these traits. Low or negative heterosis may also be due to reduction in intra and interallelic non-additive gene action (Mather and Jinks, 1982). These findings further confirm the results reported by Sharma and Mahajan (1979) and Elangovan *et al.* (1979) who stated that heterosis can be manifested in the F_1s when the parents of high x high or high x medium or low x low mean performance are involved.

A range of heterosis observed in Okra over mid parent and better parent for fruit yield per plant (5.22 - 34.43% and 0.84-29.31%), fruits per plant (13.78-26.99% and 11.84-24.44%), fruit length (5.04-6.83% and 5.80%), fruit girth (3.52-10.64% and 2.62-10.04%), fruit weight (7.90-

17.24% and 1.36-11.68%) seeds per fruit (9.65-19.84% and 5.43-14.48%) and 100-seed weight (5.75-18.40% and 1.181-17.72%) in the present investigation in okra is corroborating the results reported by Joshi *et al.* (1959) and Singh (1979) for fruits and fruit yield per plant, Raman and Ramu (1963) and Raman (1965) for fruit weight and fruit yield, Poshiya and Shukla (1986) for fruits per plant and fruit weight, Sharma (1965) and Babu *et al.* (1994) for fruits per plant, fruit weight and fruit yield per plant, Lal and Srivastava (1973) for fruits per plant, fruit length, fruit thickness and fruit yield per plant. Sharma and Mahajan (1978) for fruits per plant, fruit length, fruit weight and fruit yield per plant.

High heterobeltiosis for fruits per plant (74.77%), fruit weight (62.50%), branches per plant (52.5%), moderate for height of first fruiting (44.83%), fruit yield per plant (36.42%), plant height (26.75) and low for fruit length and fruit girth (1.12%) observed by Ahmed *et al.* (1999) in Okra are some what in agreement with the findings of the present study and suggest the possibility of exploiting the hybrid vigour in Okra.

With regards to days to first flowering and node of first flower appearance which reckoned as early flowering, the hybrid combinations SK-403 x Arka Anamika followed by Co-1 x Arka Anamika and Pusa Makhmali x Jagdish-111 which being involved the parents of poor mean performance for days to first flower except Jagdish-111 exhibited significantly high negative heterosis over mid and better parents (-10.29% and -13.48%, -9.96% and -12.86% and -6.72% and -11.94% respectively) for this trait. The other hybrids which also showed significant negative heterosis for this trait were Gourav x Arka Anamika and Naveen x Arka Anamika (-7.58% and -8.27%; -6.42% and -7.42% respectively). But these hybrids exhibited poor mean performance as the parents involved in these crosses were being of low mean performers for this trait (Table 3).

On contrary the F_1 hybrid Pusa Makhmali x Jagdish-111 alone showed significantly high mean performance for days to early flowering as one of the parents (Jagdish-111) involved was being high mean performer for this trait. Heterosis for early flowering was also reported by Ramu and Ramu (1963), Sharma (1965), Raman (1965), Sharma and Mahajan (1978) and Dhillon and Sharma (1982) in Okra. Singh and Sonia Sood (1999) reported that for days to 50 per cent flowering negative heterosis is desirable because the early maturing genotypes resulted in better yield in okra.

With regard to node of first flower appearance, negative heterosis being considered desirable for early flowering and it ranged from -3.70 to -7.58% and -8.96 to -11.43% over mid and better parents respectively. The highest heterosis was noticed with Naveen x Arka Anamika and the lowest with Co-1 x Arka Anamika. All these hybrids except Gourav x Parbhani Kranti involved either both or at least one of the parents (Co-1, Jagdish-111, Arka Anamika) with high mean performance for this trait, exhibited not only high mean performance but also significantly high heterosis in desirable direction for node of first flower appearance. All these F_1 hybrids except Gourav x Arka Anamika and Naveen x Arka Anamika also showed significantly high heterosis for fruit yield per plant, while the hybrids Gourav x Arka Anamika and Naveen x Arka Anamika were found to show significant heterosis for days to early flowering. Similarly Shukla and Gautam (1990) have reported moderate heterosis (44.83%) for node of first flowering in the desirable direction in Okra.

Regarding the vigour of plant expressed in terms of plant height, nodes on the main stem and branches per plant, the lines SK 403, Naveen and the testers Arka Anamika, Jagdish-111 exhibited high mean performance for these traits. These parents when involved in the hybrid combinations SK-403 x Parbhani Kranti (73.5% and 109.67% ; 9.21% and 29.74%; 22.22% and 26.92% respectively) and Naveen x Jagdish-111 (26.80 and 36.80%, 9.24% and 13.68% respectively) have showed significantly high heterosis over mid and better parent as well as significantly high mean performance for these traits except Naveen x Jagdish-111 for branches per plant.

The hybrid Naveen x Arka Anamika for plant height (48.87% and 15.30%), Co-1 x Arka Anamika for plant height (51.27% and 17.0%), branches per plant (0 and 31.82%) and Varsha Uphar x Parbhani Kranti for nodes on the main stem (8.10% and 8.19%) and branches per plant (40.74% and 46.15%) showed significantly high positive heterosis over mid and better parent, being involved the parents of higher *per se* performance for these traits. The cross combination, Co-1 x Arka Anamika besides registering high heterosis for vegetative vigour also exhibited heterosis for early flowering in terms of days to first flower and node of first flower appearance and also for seeds per fruit, 100 seed weight and fruit yield per plant indicating the importance of vegetative vigour in manifesting early fruiting and better yield as reported by Singh and Sonia Sood (1999) in Okra. Medium vigour may be considered desirable to contribute adequate fruit yield as reported by Chadha and Kalloo (1993) in Okra. This is true in view of lesser competition for nutrients and photosynthates between vegetative growth and fruit sink resulting in better yield.

The other F_1 hybrids which also exhibited significantly high heterosis over mid and better parents were Co-1 x Jagdish-111 (30.61% and

43.45%), Gourav x Jagdish-111 (14.75% and 29.63%), Pusa Makhmali x Jagdish-111 (24.49% and 33.3%) and Pusa Makhmali x Parbhani Kranti (20.0% and 25.0%) which all (except Gourav x Jagdish-111) involved the parents with poor mean performance (except Gourav). These hybrids except Co-1 x Jagdish-111 however failed to express high mean performance for this trait. Similar to the present findings, heterosis was also reported by Sharma (1965), Lal and Srivastava (1973) and Poshiya and Shukla (1986) for plant height, Dhillon and Sharma (1982) and Shukla and Gautam (1990) for plant height (26.75%) and branches per plant (52.50%).

5.3 COMBINING ABILITY ANALYSIS AND GENE ACTION

The combining ability analysis is a powerful tool for selection of appropriate parental lines for hybridsation programmes as well as for identifying superior crosses having high heterotic effect for further development of high yielding crosses. The knowledge and nature of gene action is also useful for planning a sound and efficient breeding programme for identifying promising lines in segregating progenies. The estimation of general combining ability of the parents is important as it attributes to fixable gene effects including additive and additive x additive interaction. On the other hand, specific combining ability (sca) is non-fixable and caused by non-additive gene action including dominance and epistatic interaction.

Estimates of variances due to gca and sca provide an appropriate diagnosis of the predominant role of additive and non-additive gene effects respectively. Higher magnitude of component due to gca further reveals the predominance of additive gene action.

Among the attributes of ideal plant type early flowering is one of the important trait. Hence parents showing negative and significant gca effects should be selected for improving this trait. Component variance due to sca was larger than the component variance due to gca suggests the predominance of non-additive gene action.

5.3.1 Analysis of variance

The analysis of variance for parents and crosses revealed the existence of significant differences for all the characters studied (Table 6). The mean sum of squares of the lines and testers provides a measure of their general combining ability, while the interaction between line x tester provides a measure of specific combining ability. In the present study, the mean squares for lines were non-significant for all the characters except number of fruits per plant and fruit yield per plant. The mean squares for testers were non-significant for all the characters. Whereas line x tester interaction were highly significant indicating that lines as well as testers used in the present study represented wide genetic divergence. Significant line x tester interactions indicated that non-additive gene effects were important rather than additive gene effects for all the characters. The lines, however, expressed greater magnitude of mean squares than testers for all the characters except fruit yield per plant and line x tester interactions for all the characters except number of branches per plant, 100 seed weight and fruit yield per plant. The testers had also registered greater mean squares than lines and line x tester interactions for fruit yield per plant. It suggests that the performance of crosses would be expected on the basis of specific combining ability (Table 7).

Estimates of the relative contribution of general and specific combining ability within the genetic variability present in a population are of interest to plant breeders. The variances due to general and specific combining ability effects (table 7) showed that the variances due to SCA were predominant for all the 12 characters studied. The ratios of variance due to general and specific combining ability were also lesser than using indicated the predominance of non-additive gene action for all the characters.

Predominance of non-additive gene actions were reported earlier by Kulakarni *et al.* (1976) for days to flowering, Rao and Ramu (1977) for plant height, seeds per fruit, Singh and Singh (1979b) for plant height, branches per plant and fruit yield per plant, Elangovan *et al.* (1979) for all the characters, Patel *et al.* (1994) for number and weight of seeds per fruit and 100 seed weight, Shinde *et al.* (1995) for all characters, Rajani and Manju (1999) for fruits per plant, fruit length, fruit girth and fruit weight. However, considerable amount of additive gene action was also observed in the present investigation for plant height, nodes on the main stem, days to first flower, node of first flower appearance, fruits per plant, fruit length, girth and weight, number of seeds per fruit and fruit yield per plant due to greater mean squares of lines than the mean squares of L x T interactions.

Similar to the present findings, Singh and Singh (1979b) reported additive gene action for days to flowering and fruit yield per plant based on gca/sca ratio and suggested pedigree breeding for improvement of these traits. Additive gene action was also reported by Rao and Satyavathi (1971) for plant height, days to flowering. Singh (1979) for fruit length, girth and weight, ridges on the fruit and inter nodal length, Pratap and Dhankar (1980) for fruit girth, length and weight and fruit yield, Chaudhary (1991) for all characters, Siva Kumar *et al.* (1995) for plant height, days to flowering and Shinde *et al.* (1995) for fruit weight.

Under such situation where both additive and non-additive gene actions governing the traits of Okra as observed in the present investigation, it is suggested that few cycles of recurrent selection could be adopted for handling such population. Biparental mating design may also give fruitful results by exploiting both additive and non-additive variances for yield improvement in Okra since this method increase the frequencies of genetic recombinations and hasten the rate of genetic improvement (Jensen, 1970). Sharma and Mahajan (1979) also observed the importance of both additive and non-additive gene actions for plant height, marketable fruit maturity, fruit length, fruit girth, fruit weight and fruit yield per plant in okra and suggested population breeding in the form of biparental mating between the genotypes in selected cross combinations to exploit both types of gene action. Similar results were also reported by Arumugam and Muthukrishnan (1979) for plant height, branches per plant and days to flowering, Kulkarni *et al.* (1976) for plant height and days to flowering Kulkarni and Thimmappaiah (1977) for fruits per plant, Veeraraghavathathan and Irulappan (1990) for plant height, fruits per plant, fruit length and fruit girth in Okra.

5.3.2 General combining ability effects

Several workers while evaluating the ability of parents to transmit desirable characters to their off springs have used the gca effects of parents. It was difficult to choose good combiners for all the characters together. In the present study, the gca effects of parents revealed that the tester Jagdish-111 was found to be a good general combiner for five traits viz plant height, number of fruits per plant, fruit length, fruit weight and fruit yield per plant, while Parbhani Kranti was a good general combiner for fruit length, fruit girth, fruit weight and fruit yield per plant and Arka Anamika for number of nodes on main stem, number of branches per plant and 100 seed weight (Table 8).

Among the lines, Gourav was found to be a good general combiner as it exhibited high gca effects for days to first flower, number of fruits per plant, fruit length, fruit weight and fruit yield per plant, while Varsha Uphar was found to be good general combiner for number of branches per plant, number of fruits per plant, fruit length, fruit girth, fruit weight, number of seeds per fruit and fruit yield per plant. Pusa Makhmali was a good combiner for economic characters viz., fruits per plant, fruit weight and fruit yield. The next good general combiner among lines was observed to be Co-1 for node at which first flower appear, fruit length, number of seeds per fruit and 100 seed weight followed by Naveen for plant height, nodes on the main stem, branches per plant, seeds per fruit and 100 seed weight for plant height and number of nodes on main stem and 100 seed weight.

The lines Gourav and Co-1 observed to be good general combiners for early flowering while none of the testers registered early flowering than parental mean (Table 3). A close relationship between the *per se* performance and the gca effect was noted in SK 403 for plant height and nodes on the main stem, Naveen for branches per plant, Gourav for fruits per plant, Co-1 for fruits per plant and 100 seed weight, Varsha Uphar for fruits per plant and fruit length among lines. Among testers, Jagdish-111 for plant height, fruits per plant, fruit weight, fruit yield per plant, Arka Anamika for nodes on main stem, branches per plant and 100-seed weight and Parbhani Kranti for fruit weight had similar relationship between *per se* performance and gca effect. However, such relationship was not established in Pusa Makhmali (line) and Parbhani Kranti (tester). From this it is evident that combining ability of parents cannot always be judged accurately by their *per se* performance. Therefore gca estimates and *per se* performance of breeding lines should be taken together for assessing their breeding potentiality.

An overall ranking of lines for all characters indicated that good combiner for yield gave either average or good *per se* performance for the yield components as in case of the above matched lines and testers. These findings are inconfirmity with the results of Sharma and Mahajan (1979) and Elangovan *et al.* (1979). Contrary to the present findings, Anitha Vasline and Ganesan (1995) reported that the combining ability showed absence of relationship between the parental *per se* performance and gca and sca effects.

Among the crosses, Co-1 x Parbhani Kranti recorded high sca effects for most of the economic characters namely days to first flower, fruits per plant, fruit weight and fruit yield per plant followed by Naveen x Arka Anamika for fruits per plant, fruit girth, seeds per fruit and fruit yield, Gourav x Parbhani Kranti for branches per plant, fruits per plant, seeds per fruit and fruit yield per plant, Co-1 x Arka Anamika for plant height, nodes on main stem, branches per plant, days to first flower, fruits per plant, fruit weight, seeds per fruit and 100 seed weight and Varsha Uphar x Arka Anamika for fruit length, fruit girth, fruit weight, seeds per fruit and 100 seed weight and were adjudged as best specific combiners for fruit yield and its components (Table 14).

These F_1 hybrids namely Co-1 x Parbhani Kranti also recorded high mean performance for node of first flower appearance, fruit length, fruit weight and fruit yield and heterotic vigour for node of first flower appearance and seeds per fruit. Naveen x Arka Anamika recorded high *per se* performance for plant height, nodes on the main stem, branches per plant, node of first flower appearance, fruits per plant, fruit girth and seeds per fruit and heterosis for node of first flower appearance and fruit girth; Gourav x Parbhani Kranti registered higher *per se* performance for fruits per plant and fruit yield and heterosis and fruit weigh and fruit yield.

The cross Co-1 x Arka Anamika recorded high *per se* performance for plant height, nodes on the main stem, days to first flower and seeds per fruit while the cross Varsha Uphar x Arka Anamika registered high mean performance for fruit length, fruit girth, seeds per fruit, 100 seed weight and fruit yield and heterosis for fruit length, fruit girth and 100 seed weight (Table 14). All these F_1 hybrids expressed high sca effects for economic yield components involving the parents of high / medium x medium general combiners with high *per se* performance for fruit yield and atleast two or three yield component characters.

The other F_1 hybrids which also exhibited high sca effects and or heterosis for fruits per plant and seeds per fruit and or fruit yield per plant were Varsha Uphar x Jagdish-111 and Pusa Makhmali x Jagdish-111 which involved the parents of high x high general combiners with high mean performance. The F_1 hybrid Co-1 x Jagdish-111 involved the parents of medium x high general combiners for node at which first flower appearance, fruits per plant and fruit length, fruit weight, seeds per fruit and fruit yield and high *per se* performance for fruit yield and most of its components, expressed high sca effects for fruit length and fruit girth. This supports the findings of Singh and Singh (1979b) and Elangovan *et al.* (1979) who reported that in general the crosses involving high x high, high x medium and low x low general combiners appeared to be potential material for exploiting hybrid vigour in developing high yielding lines through pedigree breeding.

Though the cross combinations Co1 x Arka Anamika, Varsha Uphar x Arka Anamika, Co1 x Jagdish-111 and Pusa Makhmali x Arka Anamika involved both the parents or one of the parents of poor general combiners with good *per se* performance for fruit yield, but exhibited negative heterosis because of high sca effects due to non-additive component of variance. These findings confirm the opinion put forth by Anitha Vasline and Ganesan (1995) that there was no relationship between the parental *per se* performance, gca and sca effects in okra.

Both additive and non-additive genetic effects were involved in inheritance of all the traits under the study. Rapid improvement in fruit yield may be achieved through conventional breeding programme. Recurrent random mating of parents in a selected cross or biparental mating followed by mass selection could be perspective breeding procedure for improving yield potentiality in Okra.

The lines Gourav and Varsha Uphar, Pusa Makhmali and Co 1 and the testers Jagdish-111, Parbhani Kranti and Arka Anamika could be exploited through heterosis breeding for developing high yielding hybrids. Intermating between these lines and testers followed by selection may be useful in exploitation of these crosses for high fruit yield with better size and heavy fruits and good seed yielding fruits. This method of breeding provides opportunity for breaking the undesirable linkages if present and produce broad base genetic back ground against which the gene arrangement may be expressed. The best crosses namely Co-1 x Parbhani Kranti, Naveen x Arka Anamika, Gourav x Pusa Makhmali, Co1 x Arka Anamika, Varsha Uphar x Arka Anamika and Pusa Makhmali x Jagdish-111 could be advanced in further generations for selecting superior transgressive segregants.

5.4 VARIABILITY, HERITABILITY, GENETIC ADVANCE AND GENETIC ADVANCE AS PER CENT OF MEAN

Improvement in any crop species depends upon the amount of variation present in a given breeding material and its mode of utilization in the breeding programmes. The measure of transmission of a character from parent to offspring is termed as heritability and the consistency of performance of selected material in succeeding generations depends on the magnitude of heritable variation present in relation to the observed variation. The estimates of genotypic variation alone cold not provide the necessary heritable variance that could be required for selection. Hence, information on heritability is a pre-requisite for planning a sound breeding programme for selection. This would also provide the information to predict the genetic gain obtained by selections. The genetic advance is commonly predicted as a product of heritability, phenotypic standard deviation and selection differential. High estimates of heritability accompanied by high expectation of genetic advance indicates that additive gene effects governing the characters. High heritability accompanied by a low genetic advance indicates the presence of non-additive (epistasis and dominance) component. Therefore, the estimates of heritability and expected genetic gain is important to have an idea about effectiveness of selection.

High heritability values have been found to be useful in selection of superior genotypes on the basis of phenotypic performance and low heritability estimates suggests that they were highly influenced by environment.

Heritability with genetic advance was of more value than the former alone in estimating the influence of environment. If the heritability was mainly due to non-additive gene effects, the expected genetic gain would be low and if it is additive genetic effects alone, a high genetic advance may be expected. Therefore, the availability of rich source of variants and the ability of expression of a particular character of the desiderate in successive generations are vested in efficient selections.

In the present study variability analysis, heritability and genetic advance estimates were carried out for the nine parents and 18 crosses separately and the results are discussed below.

Most of the characters studied exhibited low genetic variability in terms of range except for plant height (36.53 - 51.77 cm), seeds per fruit (28.20 - 38.07), fruits per plant (15.73 - 20.41), and fruit yield per plant (138.67 - 185.62) in parents. In crosses, the genetic variability was low for branches per plant, node of first flower appearance and fruit girth and 100 seed weight where as it was moderate for days to first flower (39.33 - 45.33 days), weight of fruit (6.87 - 10.47 g), fruit length (10.48 - 15.34 cm) and high for nodes on the main stem (14.07-20.07), fruits per plant (15.40-22.40), seeds per fruit (26.80-40.67) and fruit yield per plant (126.61-227.0 g). The genotypic coefficient of variations were high in parents compared to crosses for branches per plant (24.12), days to first flower (5.36), node of first flower appearance (5.63) and length of fruit (12.06) whereas these were high in crosses compared to parents for plant height (19.51), nodes on the main stem (8.34), fruits per plant (9.83), fruit girth (4.86), seeds per fruit (12.92), 100 seed weight (9.79) and fruit yield per plant (12.16), similar situation was also observed with regard to phenotypic coefficients of variation in parents and crosses. In general the phenotypic coefficients of variations were higher than genotypic coefficients of variation in both parents and crosses indicating little environmental influence in expression of all the traits studied in the present investigation.

Both genotypic and phenotypic coefficients were found to be high for branches per plant (24.12 and 24.54) in parents and plant height (19.51 and 19.59) in crosses and lending scope for selection in these traits. Moderate

GCV and PCV were noticed for plant height, fruit length, fruit weight, seeds per fruit and fruit yield per plant in parents, for branches per plant, fruits per plant, fruit length, fruit weight, seeds per fruit, and fruit yield per plant in crosses and low GCV and PCV for rest of the characters were observed in both parents and crosses. These findings are in agreement with the results reported by Agarwal *et al.* (1984) for fruit length and fruit weight while on the contrary to the high GCV and PCV observed by Pathak and Singh (1999) and Gandhi *et al.* (2001) for fruits and fruit yield per plant in Okra.

With regard to heritability and genetic advance as percentage of mean, both the parents and crosses exhibited high heritability in expression of all the characters, whereas high genetic advance for plant height, branches per plant, fruit length, fruit weight, seeds per fruit and fruit yield per plant, moderate genetic advance for nodes on the main stem , fruits per plant and 100 seed weight and low genetic advance for days to first flower, node of first flower appearance and fruit girth were observed in both parents and crosses. These results indicating the importance of additive gene actions for plant height, branches per plant, fruit length, fruit weight, seeds per fruit and fruit yield per plant while both additive and non-additive gene actions were found important for rest of the characters in both the parents and crosses. These findings are corroborating with the results reported by Malik (1968) for fruit length, Padda *et al.*, (1970) for plant height, 100 seed weight and fruit yield per plant, Rao (1972) for plant height, Rao (1977) for fruits per plant, Rao and Ramu (1977) for seeds per fruit but contrary to the findings of Malik (1968) for fruit girth, Rao and Ramu (1977) for days to flowering, fruits per plant, fruit yield per plant, and plant height.

Additive gene action as established due to high heritability coupled with high genetic advance in plant height (99.09 - 99.64% and 23.60 - 40.13%), branches per plant (96.6-89.12% and 48.85 - 26.69%), fruit length (98.56-96.64% and 24.68-20.41%), fruit weight (97.40-96.74% and 22.76-22.97%), seeds per fruit (98.1-99.85% and 19.81-26.50%) and fruit yield per plant (99.81% and 8.5-25.03%) lend scope for improvement of these traits through mass selection procedure. Similar findings of high heritability coupled with high genetic advance were also reported for fruit yield and seed yield per plant by Agarwal *et al.* (1984), for plant height and fruit yield per plant by Siva Kumar *et al.* (1996), for plant height, fruit weight and fruit yield per plant by Ramesh Pathak and Arun Kumar Singh (1999). Hence, for yield improvement, the characters viz., plant height, fruit length, fruit weight, seeds per fruit and fruit yield per plant which exhibited moderate to high phenotypic and genotypic coefficients of variation along with high heritability and genetic advance would have scope for selection.

5.5 CHARACTER ASSOCIATION AND PATH COEFFICIENT ANALYSIS

The aim of correlation studies is primarily to know the suitability of various characters for indirect selection because selection on any particular trait may induce desirable or undesirable changes in other associated characters. Generally, direct selection for yield is not aimed at, as it is a complex and quantitatively inherited character and is highly influenced by environment. As such, high genotypic and environmental interactions are likely to restrict the improvement, if selection is based on yield as a simple trait. Therefore correlation between yield and yield components are of considerable importance in selection programmes.

The component characters of yield show different associations among themselves and with yield. Unfavorable associations between the desired attributes under selection may limit genetic advance. Hence, a knowledge of association between the yield and yield components and also among the yield components themselves is essential for planning a sound selection programme. Though correlations provide information about the component characters associated with yield they could not provide direct and indirect contribution of the component characters. Thus, correlations in combination with path analysis would give better insight into the cause and effect of the relationship between different pairs of characters. Information on the interrelationship of different characters besides the nature of gene action would aid in a selection programme useful in crops like bhendi, where selection has to be exercised simultaneously for more than one character.

In the present study, phenotypic and genotypic correlations of fruit yield with its components and inter-se associations among the components were computed separately by utilizing nine parents and 18 crosses (Table 10 and 11). Similarly the path coefficient analysis of different characters on yield based on phenotypic and genotypic correlations in parents and crosses were computed and presented in Table 12 and 13 respectively.

In general, the genotypic correlations were higher than the corresponding phenotypic correlations both in parents and crosses indicating that strong inherent associations were some what masked at phenotypic level due to environmental effects.

A perusal of the results in the present study indicated that in parents, the fruit yield was positively correlated with plant height (r_p = 0.5688 ; r_g = 0.5725), node on the main stem (0.2743 and 0.2798), branches per plant (0.2158; 0.2189), fruits per plant (0.6182, 0.6335), fruit length (0.2664; 02.695), fruit weight (0.6454; 0.6546) and 100 seed weight (0.4404; 0.4428) while it was positively and significantly correlated with seeds per fruit (0.8334 ; 0.8518) both at phenotypic and genotypic level. High correlation coefficients were noticed for seeds per fruit followed by fruit weight, fruits per plant and plant height.

Similar results of significant positive correlations have been reported by Kaul *et al.* (1978) for plant height, branches per plant and seed yield per plant, Agarwal *et al.* (1984) for plant height, branches and fruits per plant, seeds per fruit at phenotypic level, Mishra and Singh (1985) for plant height, nodes on the main stem, fruits per plant, fruit weight and length, 100 seed weight with fruit yield per plant. Similar to the present findings Elangovan *et al.* (1980) reported positive association of fruits per plant, fruit length, fruit width and branches per plant with fruit yield, Arumugam and Muthurkrishnan (1981) for plant height, fruits per plant, fruit length, and seeds per fruit with fruit yield, Sivagamasundari *et al.* (1992b) for fruits per plant, fruit length and fruit weight with fruit yield and were considered as functional factors of yield in okra.

In the present investigation the inter-correlations between plant height, nodes on the main stem, branches per plant, fruits per plant, fruit length, fruit girth, fruit weight, seeds per fruit and 100 seed weight were also positive both at phenotypic and genotypic level in parents. These findings are in agreement with the results reported by Kirthi Singh *et al.* (1974) who observed significant positive inter-correlations between fruit yield and its contributing characters plant height, branches per plant, fruits per plant. Similar inter-correlations between fruits per plant, fruit length, fruit girth and internodal length, fruit length with fruit girth and fruit weight with fruits per plant, fruit length, fruit girth and internodal length were reported by Sivagamasundari *et al.* (1992b) in okra.

The characters branches per plant, fruit length and fruit weight also recorded moderate to high PCV and GCV while high heritability and genetic advance as percentage of mean were noticed for plant height, fruit length, fruit weight and seeds per fruit and 100 seed weight in both parents and crosses. More over all the component characters except fruit girth, 100 seed weight at both levels and fruit weight at phenotypic level had direct positive effects on fruit yield per plant. These characters also had positive indirect effects on fruit yield through each other in both parents as well as crosses. Therefore, simultaneous selection of these characters must be adopted to achieve substantial improvement of yield in Okra.

Non-significant negative correlations between days to first flower, node of first flower appearance and fruit yield at both phenotypic and genotypic level in parents observed in the present investigation are corroborating with the findings of Kirthi Singh *et al.* (1974) and Sivagama Sundari *et al.* (1992b) while these are contrary to the findings of Kaul *et al.* (1992) and Arumugam and Muthukrishnan (1981). The positive inter-correlations were found to exist between days to first flower, plant height, nodes on the main stem, branches per plant, node of first flower appearance, fruit girth and fruit weight. Similarly, positive inter-correlations between node of first flower appearance, plant height, days to first flower, fruits per plant, fruit girth and seeds per fruit also existed. Thus indicating that simultaneous selection for these traits would result in improvement for obtaining early fruiting genotypes in okra.

Fruit girth at both phenotypic and genotypic levels had non-significant negative correlation with yield but exhibited positive inter-correlations with days to first flower, node of first flower appearance and fruit length. Path analysis in parents also revealed that the trait fruit girth had direct non-significant negative effect on fruit yield and indirect negative and non-significant effect through most of the characters except days to flower, node of first flower appearance, fruit length and 100 seed weight. Almost similar results of direct positive effects of fruit weight, fruits and branches per plant on fruit yield and the resultant over all positive correlation between fruits per plant and fruit yield per plant from indirect positive effects of fruits per plant through plant height, nodes on the main stem, branches per plant, node of first flower appearance, fruit girth, fruit weight (at genotypic level) and seeds per fruit have also been reported by Agarwal *et al* (1984).

With regard to crosses, the association analysis revealed significant positive correlation of fruits per plant, fruit length, fruit girth and fruit weight with fruit yield. The *inter se* correlations among fruits per plant, fruit length, fruit girth and fruit weight showed significant positive association, thus indicated that simultaneous selection of these traits would result in improvement of fruit yield in Okra. The *inter se* correlations of these characters with branches per plant, days to first flowering and node of first flower appearance were also found positive. Fruit weight also had significant positive association with seeds per fruit. More over the direct effects of fruits per plant, fruit length, girth and weight on fruit yield per plant were also positive though not significant. Their indirect effects on fruit yield through plant height, nodes on the main stem, branches per plant, days to first flower, seeds per fruit and 100 seed weight were also positive.

Non-significant negative association of plant height, branches per plant, days to first flower, node of first flower appearance, seeds per fruit and 100 seed weight with fruit yield were observed, while significant negative correlation was existed between nodes on the main stem, and fruit yield per plant although the inter-correlations among these attributes were positive.

Moreover, the attributes plant height, branches per plant, at both phenotypic and genotypic level and nodes on the main stem at genotypic level had direct negative effects on fruit yield and also had high indirect negative effects, through fruits per plant, fruit length, fruit weight and seeds per fruit. Seeds per fruit at both levels and 100 seed weight at genotypic level also exerted non-significant negative direct effects on fruit yield and high indirect negative effects through fruits per plant and fruit weight.

The association analysis of parents when compared with the association analysis of crosses, the positive association of plant height, nodes on the main stem, branches per plant, seeds per fruit and 100 seed weight and negative association of fruit girth existed with fruit yield in parents had broken down in crosses whereas the negative correlations of days to first flower, node of first flower appearance and positive association of fruits per plant, fruit length, fruit weight with fruit yield established in parents were maintained or retained in the crosses. This may be due to interaction of parents in the cross combination at coupling stage which resulted in break down or retention of association of characters in the crosses. This can also be attributed to the dominant gene action of parents for these characters.

The present study indicated that fruits per plant, fruit length, and fruit weight, exhibited significant association with fruit yield per plant in parents and crosses could be employed judiciously in selection programme. Besides plant height, branches per plant, seeds per fruit and 100 seed weight which exhibited high GCV and PCV coupled with high heritability and genetic advance for improvement of the fruit yield in okra. Since fruit weight had negative association with fruits per plant in parents, selection programe based on medium fruit weight is likely to have a balanced the number of fruits resulting in yield improvement. Grafius (1964) also advocated that selection pressure should operate simultaneously for such characters. The association of days to first flower and node of first flower appearance with fruit yield had a negative association both in parents and crosses. Earlier workers also observed negative association between these characters in okra. The association of lateness with yield would result when linkages are considerable between these traits. Such a situation restricts the scope of selection for combining days to flowering with yield. It is expected that such linkages are broken in the F_2's resulting in wide recombinations.

Table 14 : Evaluation of parents (lines and testers) based on *per se* and gca, hybrids based on *per se*, sca and mid and better parent heterosis

Sl. No	Characters	Lines		Testers		Crosses			
		Per se	**gca**	***per se***	**gca**	***per se***	***sca***	**Mid parent heterosis**	**Better parent heterosis**
1.	Plant height	Gourav, SK 403	SK 403 Naveen	Arka Anamika, Jagdish-111	Jagdish-111	SK 403 x Parbhani Kranti Naveen x Jagdish-111 SK 403 x Jagdish-111 Naveen x Arka Anamika Co1 x Arka Anamika Gourav x Jagdish-111 Gourav x Arka Anamika	SK 403 x Parbhani Kranti Co1 x Arka Anamika Naveen x Jagdish	SK 40 3 x Parbhani Kranti Naveen x Jagdish-111 Naveen x Arka Anamika Co-1 x Arka Anamika	SK 403 x Parbhani Kranti Naveen x Jagdish 111 Varsha Uphar x Arka Anamika Naveen x Arka Anamika Co1- x Arka Anamika
2.	Number of node son main stem	SK 403	SK 403 Naveen	Arka Anamika	Arka Anamika Parbhani Kranti	SK 403 x Parbhani Kranti Co-1 x Arka Anamika SK-403 x Jagdish-111 Naveen x Arka Anamika Naveen x Jagdish-111	SK 403 x Parbhani Kranti Co1 x Arka Anamika Varsha Uphar x Parbhani Kranti	SK 403 x Parbhani Kranti Jagdish-111 Naveen x Jagdish-111 Varsha Uphar x Parbhani Kranti	SK 403 x Parbhani Kranti Co1 x Arka Anamika Naveen x Arka Anamika Naveen x Jagdish-111 Varsha Uphar x Parbhani Kranti
3.	Number of branches per plant	Naveen, Gourav	Naveen Varsha Uphar	Arka Anamika	Arka Anamika	Varsha Uphar x Parbhani Kranti Naveen x Arka Anamika Gourav x Jagdish-111 SK-403 x Parbhani Kranti	Varsha Uphar x Parbhani Kranti Gourav x Parbhani Kranti	Varsha Uphar x Parbhani Kranti Co1 x Jagdish-111 SK-403 x Parbhani Kranti Gourav x Jagdish-111 Pusa Makhmali x Jagdish-111 Pusa Makhmali x Parbhani Kranti	Varsha Uphar x Parbhani Kranti Co-1 x Jagdish-111 SK 403 x Parbhani Kranti Gourav x Jagdish-111 Parbhani Kranti x Jagdish-111 Pusa Makhmali x Jagdish-111 Pusa Makhmali x Parbhani Kranti Co1 x Arka Anamika
4.	Days to first flower	-	Gourav	Jagdish-111 Parbhani Kranti	-	Pusa Makhmali x Jagdish-111	Co1 x Arka Anamika Pusa Makhmali x Jagdish-111	SK 403 x Arka Anamika Co1 x Arka Anamika Pusa Makhmali x Jagdish-111 Gourav x Arka Anamika Naveen x Arka Anamika	SK-403 x Arka Anamika Co-1 x Arka Anamika Pusa Makhmali x Jagdish-11 Gourav x Arka Anamika Naveen x Arka Anamika
5.	Node of first flower appearance	Nil	Co-1	Jagdish-111 Arka Anamika	-	Co-1 x Arka Anamika Co-1 x Parbhani Kranti Co-1 x Jagdish-111 Naveen x Arka Anamika Varsha Uphar x Jagdish-111	Varsha Uphar x Jagdish-111 Naveen x Arka Anamika	Varsha Uphar x Jagdish-111 Naveen x Arka Anamika Gourav x Parbhani Kranti Gourav x Arka Anamika Co-1x Parbhani Kranti Co-1 x Arka Anamika	Varsha Uphar x Jagdish-111 Naveen x Arka Anamika Gourav x Parbhani Kranti Gourav x Arka Anamika Co-1 x Parbhani Kranti Co-1 x Arka Anamika
6.	Fruits per plant	Gourav, Varsha Uphar	Pusa Makhmali Gourav Varsha Uphar	Jagdish-111	Jagdish-111	Pusa Makhmali x Jagdish-111 Pusa Makhmali x Parbhani Kranti Naveen x Arka Anamika Gourav x Parbhani Kranti Gourav x Jagadish-111	Naveen x Arka Anamika Pusa Makhmali x Jagdish-111 Gourav x Parbhani Kranti Co-1 x Parbhani Kranti Varsha Uphar x Jagdish-111	Pusa Makhmali x Parbhani Kranti Pusa Makhmali x Jagdish-111 Naveen x Arka Anamika	Pusa Makhmali x Parbhani Kranti Pusa Makhmali x Jagdish-111 Naveen x Arka Anamika

7.	Fruit length	Co-1, Varsha Uphar	Gourav Co Varsha Uphar	Jagdish-111 Parbhani Kranti	Parbhani Kranti Jadish-111	Co-1 x Jagdish-111 Co-1 x Parbhani Kranti Varsha Uphar Arka Anamika Gourav x Jagdish-111 Varsha Uphar x Parbhani Kranti Varsha Uphar x jagdish-111	Varsha Uphar x Arka Anamika Co1 x Jagdish-111 Pusa Makhmali x Arka Anamika	Varsha Uphar x Arka Anamika Gourav x Jagdish-111	Varsha Uphar x Arka Anamika
8.	Fruit girth	Pusa Makhmali	Varsha Uphar	-	Parbhani Kranti	Varsha Uphar x Arka Anamika Naveen x Arka Anamika Pusa Makhmali x Parbhani Kranti Varsha Uphar x Parbhani Kranti	Naveen x Arka Anamika Co1 x Jagdish-111 Varsha Uphar x Arka Anamika	Varsha Uphar x Arka Anamika Naveen x Arka Anamika Varsha Uphar x Jagdish-111	Varsha Uphar x Arka Anamika Naveen x Arka Anamika Varsha Uphar x Jagdish-111
9.	Fruit weight	Co1, SK 403	Gourav Varsha Uphar	Arka Anamika Jagdish-111	Parbhani Kranti Jagdish-111	Varsha Uphar x Jagdish-111 Co-1 x Parbhani Kranti Gourav x Parbhani Kranti Varsha Uphar x Arka Anamika Gourav x Jagdish-111 Co-1 x Jagdish-111	Co-1 x Parbhani Kranti Varsha Uphar x Arka Anamika	Gourav x Parbhani Kranti Pusa Makhmali x Parbhani Kranti Co-1 x Parbhani Kranti Varsha Uphar x Jagdish-111	Gourav x Parbhani Kranti Pusa Makhmali x Parbhani Kranti Co-1 x Parbhani Kranti Varsha Uphar x Jagdish-111
10.	Seeds per fruit	Gourav	Co-1, Naveen Varsha Uphar	Arka Anamika Parbhani Kranti	Jagdish-111	Co-1 x Jagdihs-111 Co-1 x Arka Anamika Gourav x Jagdish-111 Naveen x Arka Anamika Varsha Uphar x Jagdish-111 Varsha Uphar x Arka Anamika Naveen x Parbhani Kranti	Gourav x Jagdish-111 Naveen x Parbhani Kranti Naveen x Arka Anamika Varsha Uphar x Arka Anamika Gourav x Parbhani Kranti Co-1 x Arka Anamika Pusa Makhmali x Jagdish-111 Varsha Uphar x Jagdish-111	Co1 x Arka Anamika Co1 x Parbhani Kranti Co 1 x Jagdish-111 Naveen x Parbhani Kranti Varsha Uphar x Arka Anamika Naveen x Arka Anamika Naveen x Parbhani Kranti Varsha Uphar x Arka Anamika Gourav x Jagdish-111	Co-1 x Arka Anamika Co-1 x Parbhani Kranti Co-1 x Jagdish-111 Naveen x Parbhani Kranti Varsha Uphar x Arka Anamika Co1 x Arka Anamika Naveen x Parbhani Kranti Naveen x Arka Anamika Gourav x Jagdish-111
11.	100 Seed weight	Gourav, Naveen	Co-1 Naveen	Arka Anamika Parbhani Kranti	Arka Anamika	Naveen x Parbhani Kranti Co-1 x Arka Anamika Varsha Uphar x Arka Anamika SK-403 x Parbhani Kranti Varsha Uphar x Jagdish-111	Naveen x Parbhani Kranti Co1- x Arka Anamika Varsha Uphar Arka Anamika	Naveen x Parbhani Kranti Varsha Uphar x Arka Anamika SK-403 x Pusa Makhmali Co-1 x Arka Anamika Pusa Makhmali x Parbhani Kranti	Naveen x Parbhani Kranti Varsha Uphar x Arka Anamika SK-403 x Parbhani Kranti Co-1 x Arka Anamika Pusa Makhmali x Parbhani Kranti
12.	Fruit yield per plant	Gourav, Co-1	Pusa Makhmali Varsha Uphar	Arka Anamika Jagdish-111	Parbhani Kranti Jagdish-111	Gourav x Parbhani Kranti, Varsha Uphar x Jagdish-11 Pusa Makhmali x Parbhani Kranti Pusa Makhmali x Jagdish-111 Gourav x Jagdish-111 Co-1 x Parbhani Kranti Varsha Uphar x Arka Anamika	Naveen x Arka Anamika Co-1 x Parbhani Kranti Gourav x Parbhani Kranti	Pusa Makhmali x Parbhani Kranti Gourav x Parbhani Kranti Co-1 x Parbhani Kranti Varsha Uphar x Jagdish-111 Varsha Uphar x Parbhani Kranti Naveen x Parbhani Kranti Pusa Makhmali x Jagdish-111 Co-1 x Arka Anamika	Pusa Makhmali x Parbhani Kranti Gourav x Parbhani Kranti Co-1 x Parbhani Kranti Varsha Uphar x Jagdish-111 Varsha Uphar x Parbhani Kranti

CHAPTER - VI

SUMMARY

The present investigation on "Genetic analysis of yield and yield attributes in a Line x Tester analysis of Okra (*Abelmoschus esculentus* (L.) Moench)" was carried out at wet land farm, S.V.Agricultural College, Tirupati during spring summer 2003-2004 with nine parents namely Pusa Makhmali, Gourav, Co-1, SK 403, Naveen, Varsha Upahar as lines, Arka Anamika, Parbhani Kranti and Jagdish-111as testers. Nine parents and 18 crosses were raised in a Randomised block design with three replications. Data on 12 quantitative characters namely plant height, nodes on the main stem, branches per plant, days to first flower, node at which first flower appear, fruits per plant, fruit length, girth and weight, seeds per fruit, 100-seed weight and fruit yield per plant were collected on five randomly selected plants in each entry. The general and specific combining ability, heterosis and other genetic parameters were estimated for yield and its attributes.

The lines Gourav, Co1, Naveen, Varsha Upahar and testers Arka Anamika and Jagdish-111 were found to be superior for fruit yield, fruit and seed characters.

The crosses Gourav x Parbhani Kranti, Varsha Upahar x Jagdish-111, Pusa Makhmali x Jagdish-111, Gourav x Jagdish-111 and Co-1 x Parhani Kranti showed significantly high *per se* performance for fruit yield and its contributing characters. The other F_1 hybrids Co1 x Arka Anamika and SK-403 x Parbhani Kranti were found to be superior for vegetative characters viz., plant height, nodes on main stem and branches per plant.

Heterosis over the better parent ranged from 1.81 to 109.67% in different metric traits. Maximum heterosis was noticed for plant height, branches per plant, fruit yield per plant and fruits per plant.

The crosses Pusa Makhmali x Parbhani Kranti, Gourav x Parbhani Kranti, Co-1 x Parbhani Kranti , Varsha Upahar x Jagdish-111 and Varsha Upahar x Parbhani Kranti revealed high degree of hybrid vigour for fruit yield and its component characters.

Combining ability studies revealed predominance of non-additive gene effects for all the characters due to highly significant mean squares for Line x Tester interactions as well as predominance of *sca* variances than *gca* variance coupled with low (< 1) ratios of *gca : sca.*

Considerable amount of additive gene action was also observed for all characters except branches per plant and 100 seed weight due to greater mean squares of lines than to Line x Tester interactions.

The lines Gourav, Varsha Upahar, Co-1 for fruit yield, fruit characters and days to first flower, branches per plant and seed characters, Naveen and SK-403 for vegetative vigour and seed characters, the testers Parbhani Kranti and Jagdish-111 for fruit yield, fruit characters and plant height and Arka Anamika for vegetative vigour and 100 seed weight were found to be good general combiners. These can be exploited through heterosis breeding for developing high yielding hybrids.

The cross combinations Co1 x Parbhani Kranti, Naveen x Arka Anamika, Co1 x Arka Anamika for fruit yield and its contributing attributes, Gourav x Parbhani Kranti and Varsha Upahar x Arka Anamika for fruits per plant and seed characters were adjudged to be good specific combiners. These hybrids also expressed high *per se* performance as well as high heterotic vigour for fruit yield and yield contributing characters and could be advanced in further generations for selecting superior transgressive segregants.

The parents expressed moderate to high genetic variability for plant height, seeds per fruit, fruits per plant and fruit yield per plant whereas the crosses exhibited moderate variability for days to flowering, fruit length and high variability for seeds per fruit and fruit yield per plant.

High phenotypic coefficient of variation than genotypic coefficient of variation observed in both parents and crosses indicated little environmental influence in expression of all the traits.

Both PCV and GCV were high for branches per plant in parents and for plant height in crosses leading scope for selection.

Both parents and crosses exhibited high heritability for all the characters and high genetic advance as percentage of mean for plant height, branches per plant, fruit length, fruit weight, seeds per fruit and fruit yield indicating the importance of additive gene actions, whereas moderate genetic advance for nodes on the main stem, fruits per plant, 100 seed weight and low genetic advance for days to first flowering, node of first flower appearance and fruit girth indicated the presence of both additive and non-additive gene actions.

For yield improvement, the characters plant height, fruit length, fruit weight, seeds per fruit and fruit yield per plant have scope for selection.

Association analysis revealed that in parents fruit yield per plant was positively correlated with plant height, nodes on the main stem, branches per plant, fruits per plant, fruit length, fruit weight, seeds per fruit and 100 seed weight. The inter-correlations between these yield contributing attributes were also positive. All these characters except fruit girth and 100 seed weight also had direct positive effects on fruit yield.

In crosses, significant positive correlations were established between fruits per plant, fruit girth, fruit weight and fruit yield. The inter-correlations between these traits were also positive besides having direct positive effects on fruit yield per plant.

The positive associations between plant height, nodes on the main stem, branches per plant, seeds per fruit and 100 seed weight and fruit yield and the negative association of fruit girth with fruit yield per plant established in parents were however broken in crosses, whereas the negative associations of days to first flower, node of first flower appearance and positive associations of fruits per plant, fruit length and fruit weight with fruit yield existed in parents were maintained even in the crosses. The characters fruits per plant, fruit length, fruit weight which established positive association with fruit yield could be employed in selection programme.

Few cycles of recurrent selection or biparental mating could be adopted for handling the present experimental populations in order to exploit both additive and non-additive gene actions governing all the traits in okra.

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