“DIALLEL ANALYSIS IN OKRA [*Abelmoschus esculentus* (L.) Moench]”

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ABSTRACT

The present investigation on okra comprised of a half-diallel set of eight parents including standard check GAO 5 and their 28 crosses. The experiment was laid out in randomized block design with three replications at Main Vegetable Research Station, Anand Agricultural University, Anand during *kharif* 2014. Heterosis, combining ability, components of genetic variance and graphical analysis were studied for thirteen characters *viz.*, fruit yield per plant, days to 50% flowering, first fruiting node, days to first picking, fruit length, fruit girth, fruit weight, number of fruits per plant, plant height, number of nodes per plant, number of primary branches per plant, moisture content and ash content.

Analysis of variance revealed significant differences among the genotypes for all the traits studied. Several crosses exhibited significantly desirable relative heterosis, heterobeltiosis and standard heterosis for fruit yield per plant and other characters. On the basis of *per se* performance and estimates of heterosis, the crosses GO 2 x GPOK 123, AOL 10-22 x GPOK 578 and GAO 5 x GO 2 were found the most promising for fruit yield and other desirable traits; hence, could be evaluated further to exploit the heterosis or utilized in future breeding programme to obtain desirable segregates for the development of superior genotypes.

The general and specific combining ability variances were significant for all the traits except sca mean squares for number of first fruiting nodes. The potence ratio indicated that the non-additive gene action was predominant for the inheritance of all the traits. The estimates of general combining ability effects suggested that parents GAO 5, GO 2, Pusa Sawani and AOL 10-22 were good general combiners for fruit yield per plant and its related attributes. The estimates of specific combining ability effects indicated that cross combinations GO 2 x GPOK 123, AOL 10-22 x GPOK 578 and GPOK 123 x GPOK 349 were significant for fruit yield per plant. The hybrids depicted high heterosis and sca effects for fruit yield per plant explicated high heterosis and sca effects for fruit girth and number of primary branches per plant.

Assumptions basic to diallel fulfilled for fruit yield per plant, days to 50% flowering, days to first picking, fruit weight, number of fruits per plant, plant height, fruit girth, moisture and ash content. The components and graphical analysis revealed importance of both additive and non-additive genetic variance for inheritance of these traits.

Degree of dominance manifested over dominance for fruit yield per plant, fruit girth and primary branches per plant. Asymmetrical distribution of positive and negative alleles and unequal distribution of dominant and recessive genes found in parents for these traits. Low narrow sense heritability (<30.00%) were observed for number of nodes and primary branches per plant. The medium ranged heritability (between 30 and 60%) found in fruit yield, days to 50% flowering, first fruiting node, days to first picking, fruit girth, fruit weight, number of fruits per plant, plant height and ash content and higher narrow sense heritability (>60.00%) observed for moisture content and fruit length. The graphical analysis indicated that all the traits controlled by either over or partial dominance.

The parents had greater diversity as their array points scattered throughout the graph for the traits like fruit yield, fruit weight, number of fruits per plant, number of nodes per plant, number of primary branches per plant, moisture content and ash content.

The outcome of research has discussed in relation to its implications for okra improvement programme. Present outcome revealed that the parents GAO 5, GO 2 and AOL 10-22 exhibited high *per se* performance and good general combining ability for yield and its related characters. Likewise, the hybrids GO 2 x GPOK 123 and AOL 10-22 x GPOK 578 manifested high heterosis and specific combining ability may used for commercial exploitation of heterosis for further evaluation.

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CERTIFICATE

This is to certify that the thesis entitled **"Diallel Analysis in Okra** [*Abelmoschus esculentus* (L.) Moench]" submitted by **Mr. BUDHA RAM (Reg. No. 04- 2101- 2013)** in partial fulfillment of the requirements for the award of the degree of **Master of Science (Agriculture)** in the subject of **Genetics and Plant Breeding** of the Anand Agricultural University, Anand is a record of bonafide research work carried out by him under my personal guidance and supervision and the thesis has not previously formed the basis for the award of any degree, diploma or other similar title.

Place: Anand
Date: 01/07/2015

(R. R. Acharya)
Major Advisor

DECLARATION

This is to declare that whole of the research work reported herein the thesis for partial fulfillment of the requirement for the award of the degree of **Master of Science** (Agriculture) in the subject of **Genetics and Plant Breeding** is the result of investigation done by undersigned, under the direct guidance and supervision of **Dr. R. R. Acharya,** Associate Research Scientist (Pl. Br.), Main Vegetable Research Station, Anand Agricultural University, Anand. No part of the research work has submitted for any other degree so far.

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Place : Anand

Date: 01/07/2015 **(BUDHA RAM)**

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I. INTRODUCTION

Okra is also known as Lady's finger and it is a member of the *Malvaceae* family. Presently accepted binomial nomenclature of okra is ***Abelmoschus esculentus*** (L.) Moench, formerly it was referred as *Hibiscus esculentus* L. The genus *Abelmoschus* consists of nine different **species** *viz*., *Abelmoschus angulosus* Wall ex. W. & A. (2n=56), *A. tuberculatus* Pal and Singh (2n=58), *A. manihot* L. Medikus (2n=66), *A. moschatus* Medikus (2n=72), *A. ficulneus* L. (2n=72), *A. tetraphyllus* (Roxb. ex. Hormen) R. Graham var. *tetraphyllus* (2n=138), *A. crinitus Wall* (2n=138), *A. caillei* Sterv. (2n = 186-198) and *A. esculentus* (L.) Moench (2n =130) (Anon., 1991). It is a traditional vegetable crop commercially cultivated in India, West Africa, South-East Asia, Southern United States, Brazil, Turkey and Northern Australia. Okra has been cultivated in Africa for over 2000 years and domestication probably in Egypt, where records date back to Neolithic times (Charrier, 1984).

It is an important annual vegetable crop grown for its immature, green and non-fibrous edible fruits in the tropical and sub-tropical regions of the world. In addition to fruits, leaves are also consumed in some African countries. Okra is now commonly available as a boiled or fried vegetable dish at restaurants, salad bars and cafeterias. The roots and stems of okra are use for cleaning the cane juice from which *gur* or *jaggery* is prepared.

Okra provides an important source of vitamins, calcium, potassium and other minerals, which are often lacking in the diet of developing countries. The fruits of okra are rich source of vitamin A and C. The seeds of okra are good source of protein (20%) and gained much interest as a new source of vegetable oil (14%). The average nutritive value (ANV) of okra is 3.21%, which is higher than tomato, brinjal and cucurbitaceous vegetables (Sharma and Arora, 1993).

The nutritional value of 100g of edible okra is characterized 1.9 g protein, 0.2 g fat, 6.4 g carbohydrate, 0.7 g minerals and 1.2 g fibres.

In India, it was cultivated in the area of 5.31 lakh hectares with the annual production of 63.50 lakh tonnes with the productivity of 12.00 tonnes per ha during the year 2012-13. The important okra growing states are Andhra Pradesh, West Bengal, Bihar, Gujarat, Orissa, Jharkhand, Maharashtra, Uttar Pradesh, Haryana and Punjab in which it is cultivated as a *Kharif* as well as summer season crop. In Gujarat, its area, production and productivity was 0.66 lakh hectares, 7.23 lakh tonnes and 11.0 tonnes per ha, respectively (Anon., 2013). The main okra growing districts of Gujarat are Surat, Vadodara, Junagadh, Surendranagar, Gandhinagar, Banaskantha, Kheda and Anand.

India produced 73% of world production and secured ranked first. Okra has a good potential as a foreign exchange crop and accounts for 60% of the export of fresh vegetables. It is being export to Middle East countries, Western Europe and USA. Now a day there is a great demand of baby okra as well as frozen okra.

In India, a number of ICAR institutes, state agricultural universities and private seed companies are working on various aspects of genetic improvement of okra in order to develop high yielding and disease resistant varieties. Through intensive research, over 50 improved varieties and hybrids have released.

Exploitation of hybrid vigour has recognized as an important tool for increasing genetic yield ceiling. In okra, hand emasculation and hand pollination processes are easier due to its large flower and monoadelphous stamens. This has facilitated to the breeders for exploitation of hybrid vigour through manual hybridization.

To design an efficient breeding programme in vegetable crops, the breeders confronted with the problem of choosing parents, because many times the high yielding parents may not nick well to give desirable segregates. The parents or lines that produce good hybrids or progenies are of immense use to breeders. This necessitates the testing of parents for their combining ability, that in turn helps in identifying the best combiners, which may hybridized either to exploit heterosis or to accumulate fixable genes through selection.

The analysis of quantitative inheritance of fruit yield and its related traits was also an equally important objective to gain knowledge regarding the nature and magnitude of gene action, which has an important bearing on the choice of most appropriate and efficient breeding methodology. Clear-cut knowledge for the types of gene action, magnitude and composition of genetic variance are of fundamental importance to a plant breeder. Further, heterosis and combining ability studies are useful for the evaluation of newly developed lines for their performance as parents. The concept of combining ability, which is a landmark in the adoption of appropriate breeding methods, is of great use for the improvement of any crop varieties. It furnishes useful information on selection of suitable parents for hybridization and at the same time elucidates the nature and magnitude of different types of gene action involved in the expression of quantitative traits of economic importance.

In this context, the present investigation was undertaken to elucidate information on heterosis, combining ability and gene action for fruit yield and its component traits. Therefore, the investigation was carried out with following objectives;

Objectives

1. To ascertain the extent and magnitude of heterosis
2. To study the general combining ability of parents and specific combining ability of crosses
3. To estimate additive and non-additive components of genetic variation.

II. REVIEW OF LITERATURE

Present investigation planned to study the magnitude of heterosis, combining ability, components of genetic variance and graphical analysis for various characters in okra. The available literatures and information pertaining to heterosis, combining ability and gene action with reference to okra is reviewed and presented in this chapter.

Heterosis

The term 'Heterosis' was first coined by Shull (1914) but first reported in plants by Koelreuter long back in 1766. It refers to the phenomenon in which the F_1 population obtained by the crossing of the two genetically dissimilar gametes or individuals shows increased or decreased in size, vigour, yield, etc., over the mid or better parental value (Rai, 1979).

When heterosis of F_1 hybrid estimated over the mid parental value, it regarded as average heterosis and the heterosis estimated over the superior parent, such an estimate referred as heterobeltiosis. The term 'Heterobeltiosis' proposed by Fonseca and Paterson (1968) and used it to describe improvement of heterozygote in relation to better parent. Standard heterosis or economic heterosis is a recent phenomenon, which refers to superiority of F_1 in comparison to adapted variety or hybrid. According to Mather and Jinks (1971), heterosis means the amount by which average of F_1 family exceeds its better parent. Heterosis being a complex phenomenon, no single conclusive or clear-cut explanation is available to account for its manifestation. The recent literature for heterosis in okra reported for different characters by various workers presented below.

Kumbhani *et al.* (1993) conducted 8 x 8 half diallel crosses along with their parents in okra. Heterobeltiosis for yield per plant ranged from -16.09% to 43.53%.

For days to flowering, hybrid, Punjab Selection x KS 312 recorded the maximum heterobeltiosis (43.53%) and hybrid, GO 1 x Punjab Selection exhibited the lowest significant relative heterosis (-11.63%) and heterobeltiosis (-10.75%).

Poshiya and Vashi (1995) studied nine genetically diverse genotypes and their 36 F_1's of okra in a half diallel mating fashion. The cross combination of Parbhani Kranti x Gujarat Okra 1 registered the highest heterobeltiosis (27.32%) for fruit yield. The magnitude of heterobeltiosis was recorded the highest for number of fruits per plant (30.77%) followed by yield per plant (27.32%), plant height (22.67%), nodes per plant (18.01%), inter node length (17.90%), fruit girth (17.36%), fruit length (11.71%) and days to flowering (-4.34%). Out of thirty-six, fifteen crosses showed significant heterobeltiosis for fruit yield.

Dhankar *et al.* (1996) evaluated 51 hybrids of 17 lines and 3 pollen parents in okra. The cross combination Raj 12 x Parbhani Kranti exhibited the highest heterosis for fruit yield (166.66%) and number of fruits per plant (113.38%) over both standard check and better parent. It also showed significant heterosis for days to flowering and fruit length over both standard check and better parent.

Singh *et al.*(1996) studied 8 x 8 diallel crosses in okra, they found that Pusa Makhamali x Parbhani Kranti, Pusa Sawani x Parbhani Kranti, Pusa Makhamali x P 5 and Parbhani Kranti x P 7 were the best performing hybrids which exhibited 103.2, 88.1, 87.1 and 84.1% higher marketable yield than better parent, respectively.

Panda and Singh (1999) evaluated heterosis in twenty crosses of okra. The highest values of heterosis recorded for fruit yield followed by number of fruits per plant. The extent of heterosis was 45.62% for fruit yield and 28.32% for number of fruits per plant over mid parent.

Dhaduk *et al.* (2003) studied the extent of heterosis for fruit yield and yield contributing traits in okra using 10 x 10 diallel crosses. The experimental result revealed that heterosis over mid parent, better parent and standard check variety observed for traits like, fruit yield per plant, number of fruits per plant, number of branches per plant and 10 fruits weight. The cross HRB 9-2 x Arka Anamika exhibited significant and positive relative heterosis (70.82%), heterobeltiosis (62.53%) and standard heterosis (42.55%) along with the maximum mean performance for fruit yield per plant (402.0 g). Likewise, other crosses *viz.*, HRB 9-2 x VRO 4, HRB 55 x Arka Abhay, HRB 9-2 x Lorm 1 and Arka Abhay x KS 404 also expressed high heterobeltiosis as well as economic heterosis for fruit yield per plant.

Rawale *et al.* (2003) reported heterosis over mid and better parent in 63 F_1's for fruit yield and its contributing traits in okra. They developed these hybrids using nine lines and seven testers. The two crosses *viz.*, SOH 2 x Parbhani Kranti and SOH 2 x Gold Finger exhibited desirable negative and significant heterotic effects for days to first flower and days to first picking. The cross DVR 3 x Green Gold recorded significant heterobeltiosis for yield per plant (208.44%), fruits per plant (241.70%), nodes per plant (212.63%), branches per plant (121.21%) and plant height (129.38%). Crosses JNDO 5 x Parbhani Kranti (153.43%) and NOL 101 x Green Gold (147.79%) also showed higher magnitude of heterosis for fruit yield over better parent.

Ahlawat *et. al*. (2004) carried out an experiment of line x tester analysis using fifteen lines and four testers to study the extent of heterosis for yield and yield contributing characters in okra. The maximum heterobeltiosis and standard heterosis observed for number of primary branches per plant (12.50 and 50.00 %) followed by fruit yield per plant (23.49 and 43.75%), number of fruits per plant (15.00 and 32.18%), plant height (10.17 and 18.18%) and fruit weight (1.25 and 15.71%), respectively. For fruit yield per plant, hybrids AOL 95-37 x Parbhani Kranti and AOL 95-4 x Arka Abhay exhibited significant and positive heterosis over better parent.

Bhalekar *et al.* (2004) have taken a set of 7 x 7 diallel crosses excluding reciprocals to evaluate the magnitude of heterosis. They reported that the highest heterosis over better parent for fruit yield manifested by hybrid A.A.D.F. 1 x Arka Anamika (19.29%). The range of heterosis for plant height was -10.33 to 8.96 per cent and for first fruiting node were -18.81 to 24.18 %.

Borgaonkar *et al.* (2006) estimated heterosis in 28 hybrids of okra obtained through 8x8 diallel mating design. The degree of heterosis was higher for fruit length, inter node length, leaf area and yield per plant; while, moderate for number of nodes on the main stem and plant height; and low for number of days to first picking and fruit girth. The hybrid Number 129 x JNDO 5 exhibited the highest heterobeltiosis (52.22%) for yield per plant followed by Number 74 x JNDO 5 (40.45%) and Number 114 x JNDO 5 (37.96%).

Singh *et al.* (2006) studied extent of heterosis over better parent in a half-diallel set of 12 parents. The result revealed that the highest heterosis over better parent to the extent 54.54% (Pusa Sawani x Punjab Padmini) for fruit yield per plant followed by 53.28% (IC 90177 x IC 90202) for the number of fruits per plant, 45.71% (Pusa Sawani x Punjab Padmini) for the number of primary branches per plant, 12.65% (Arka Abhay x BO 1) for individual fruit weight and 7.19% (Pusa Sawani x Arka Abhay) for plant height in okra.

Desai *et al.* (2007) evaluated twenty-eight hybrids of okra derived from 8 x 8 half-diallel crossing. For fruit yield per plant, they reported range of heterosis from 2.6 to 558.3% and -4.5 to 446.9% for mid parent and better parent, respectively.

Parbhani Kranti x Gold Finger recorded the highest heterobeltiosis for fruit yield per plant (446.9%) followed by fruits per plant (243.8%), nodes per plant (226.1%), plant height (78.8%) and fruit weight (76.2%).

Khanpara *et al.* (2009) studied heterosis for fruit yield and its components in a set of 32 crosses developed from eight lines and four testers. Out of 32 crosses studied, two and twenty-eight crosses manifested significant and positive heterobeltiosis and standard heterosis for fruit yield per plant, respectively. The hybrid (Pant Bhindi x JOL 1) showed the maximum standard heterosis (60.18%) and hybrid (BO 13 x GO 2) exhibited the highest heterobeltiosis (15.72%) for fruit yield per plant.

A diallel analysis using eight pure lines of okra was done at three sites in Cameroon (Dibang,Yaounde and Yagoua) to estimate the heterosis by Dabandata *et al.* (2010). The heterosis over mid-parent was significant for all the traits studied. Reciprocal effects of crosses on heterosis observed for all traits, except for the day to 50 % flowering. The highest value of heterosis was recorded from P_5 x P_4 for number of seeds per fruit (54.78%) followed by P_1 x P_3 for plant height (40.89%) and P_1 x P_4 for stem diameter (34.94%). Among hybrids, the P_3 x P_4 exhibited the highest significant positive reciprocal effects (18.51%) for the number of seeds per fruit.

Ramya and Senthil (2010) evaluated 42 F_1's developed in a diallel mating of seven parents including reciprocals and reported the highest standard heterosis in Pusa A 4 x Punjab Padmini (55.95%) followed by Punjab Padmini x Pusa A 4 (53.59%), Punjab Padmini x Varsh Uphar (51.38%) and Parbhani Kranti x Punjab Padmini (46.99%) for fruit yield per plant in okra.

Wammanda *et al.* (2010) developed 36 F_1's from nine parents by half diallel in okra. They observed that heterosis for yield per plant was the greatest in crosses where the high yielding parent such as Mothol- AE2, Mothol- AE3, Mothol- AE1 and Gerio- AE1 were involved. Thus, the hybrid, Mothol- AE2 x Mothol- AE3 had the highest heterotic effect of 23.8% over the higher parent, followed by Mothol- AE1 x Mothol- AE3, Mothol- AE5 x Gerio- AE1, Mothol- AE2 x Gerio- AE1, Mothol- AE2 x Mothol- AE1 and Mothol- AE1 x Gerio- AE1 for yield per plant. Likewise, seven crosses expressed positive heterosis for number of fruits per plant. The highest heterosis were expressed by Mothol- AE1 x Gerio- AE1 (17.23%) followed by Pella- AE1 x Gerio- AE1 (11.8%), Mothol- AE5 x Mothol- AE1 (9.96%), Mothol- AE5 x Mothol-AE3 (8.69%), Pella- AE2 x Mothol- AE3 (7.24%) and Mothol- AE5 x Pella- AE2 (6.98%) for number of fruits per plant.

Bhatt (2011) studied extent of heterosis over better parent and standard check (JOH 2) in a half-diallel set of eight parents. The result revealed that the highest heterosis over better parent to the extent 88.89% (AOL 08-10 x AOL 08-02) followed by 74.14% (AOL 08-10 x AOL 09-24) and 21.52% (GO 2 x AOL 09-28) and standard heterosis observed maximum in hybrid AOL 08-10 x AOL 09-24 (53.32%) followed by AOL 08-10 x AOL 08-02 (36.59%) for ash content in okra.

Solankey *et al.* (2013) conducted the trial in okra during summer and rainy seasons of years 2006 to 2008 at the Institute of Agricultural Sciences, BHU, Varanasi. They recorded appreciable heterosis over better parents for various horticultural traits and quality traits over both the seasons. The highest better parent and standard heterosis for number of fruits per plant observed in IIVR 198 x Parbhani Kranti (67.27 and 12.25%, respectively) during rainy season. However, the maximum heterobeltiosis manifested by EC 305612 x Pusa Sawani (26.10%) in summer season. It was confounded that the rainy seasons was more yield productive seasons than summer.

Medagam *et al.* (2013) selected ten elite, optimally divergent and nearly homozygous lines of okra from the germplasm and crossed in all possible combinations excluding reciprocals to produced 45 hybrids and tested during *kharif* at the Vegetable Research Station, Hyderabad. Heterosis over mid parent, better parent and standard check were studied for seventeen quantitative characters pertaining to fruit yield and its associated characters. For total yield per plant, the crosses as a whole manifested 7.17 and -15.22% average relative and standard heterosis, respectively. For marketable yield per plant, the crosses as a group manifested 6.77 and -22.64% average relative and standard heterosis, respectively. The hybrid P_5 (IC 45732) x P_7 (IC 89976) exhibited good performance and found heterotic for pod yield.

Ashwani *et al.* (2013) conducted experiment at Vegetable Research Farm, BHU, Varanasi using five lines and three testers by making 15 cross combinations. They found significant and negative heterosis for days to first flowering over mid parent ranged from -4.88% (Hisar Unnat x Parbhani Kranti) to -26.67 % (Arka Abhay x Arka Anamika). Likewise, the range of standard and significant heterosis for plant height varied from 4.49% (VRO 5 x Parbhani Kranti) to 36.18% (Hisar Unnat x Punjab Padmini). Out of 15 crosses, eleven crosses exhibit significant and positive standard heterosis for the number of primary branches and thirteen crosses represent highly significant and negative standard heterosis for days to 50% flowering. Out of 15 crosses, 13 crosses showed highly significant and positive standard heterosis for total number of fruits per plant. The hybrids Arka Abhay x Punjab Padmini (50.68%) exhibited the highest standard heterosis followed by VRO 6 x Parbhani Kranti (25.32%) and Arka Abhay x Punjab Padmini (23.40%) for number of fruits per plant.

Combining ability and gene action

Ability of a parent to combine well and to produce promising segregates in succeeding generations is an important criterion in selecting parents for a successful hybridization programme. The analysis of diallel crosses data to partition total genotypic variance into additive and non-additive components outlined by Fisher (1918). However, the concept of general and specific combining ability, which provided, first by Sprague and Tatum (1942) as a measure of gene effect has become very important to plant breeders. According to them, general combining ability (gca) measures the average performance of a line in hybrid combinations; while, specific combining ability (sca) measures the deviation of certain expected combinations on the basis of average performance of the line involved.

Jinks (1954) explained gca as the result of additive effect and sca of non-allelic interaction effects. Griffing (1956) presented statistical concept of general and specific combining ability. The general combining ability involve additive x additive interaction; whereas, specific combining ability measures dominance, dominance x dominance and additive x dominance interactions. Griffing (1956) described two models; each with four methods, for working out the general and specific combining ability estimates in a set of diallel crosses and showed the relationship of diallel crossing methods to Fisher's method of covariance between relatives as expressed in terms of additive and non-additive genetic variance.

The literature pertaining to the combining ability and gene action obtained for various characters pertinent to the present study presented below:

Kulkarni *et al.* (1991) studied combining ability through 10 x 10 diallel excluding reciprocals in okra. The results indicated that GCA variance was higher in magnitude than respective SCA variance for fruit girth and yield per plant. These suggested the preponderance of additive gene action.

Shrivastava (1991) evaluated 10 x 10 diallel set including reciprocals in okra for combining ability and gene action. He found that the characters *viz.*, days to 50% flowering and plant height predominantly governed by additive type of gene action.

Sundhari *et al.* (1992) estimated combining ability in six inbreds and their F_1s using diallel mating including reciprocals. The variance associated with general combining ability found to be significant for number of fruits per plant, plant height, yield per plant and crude fibre content. The variance due to SCA for the direct and reciprocal crosses was significant for all the characters. The variances ratio of GCA and SCA revealed preponderance of non-additive gene action for inheritance of all the characters except crude fibre content. The parent Arka Abhay found as the best general combiner for yield and number of fruits per plant, while, the hybrid Arka Abhay x Arka Anamika had high sca effect for number of fruits and yield per plant.

Arora (1993) studied diallel crosses in okra and found that non-additive component was more important for yield. However, preponderance of additive component observed for fruit length, number of nodes and plant height. The parents Pusa Sawani, Vaishali Vadhu and Foam Bareilly were good general combiners for yield per plant, fruit length, number of nodes and plant height.

Shinde *et al.* (1995) conducted an experiment to estimate combining ability through 7 x 7 diallel crosses in okra. They reported that both general and specific combining ability variances were significant for fruit yield, plant height, number of nodes on main stem and fruit length. The hybrids Japan Okra x Parbhani Tillu and Parbhani Tillu x Number 168 found the most promising.

Poshiya and Vashi (1995) evaluated combining ability for fruit yield and its eight contributing characters with 9 x 9 parental diallel F_1 progenies in okra. The mean squares due to gca and sca were highly significant for all the characters. Higher magnitude of GCA and SCA variances ratio indicated greater role of additive genetic variance for the inheritance of number of pods per plant and number of nodes on main stem. The parent Parbhani Kranti, Gujarat Okra 1 and Punjab Padmini found good general combiners for yield, number of branches per plant and plant height. The crosses Parbhani Kranti x Gujarat Okra 1 and Parbhani Kranti x Punjab Padmini showed high sca effects for fruit yield.

Singh *et al.* (1996) studied gene effects through combining ability analysis through 8 x 8 diallel in okra. The results revealed that non-additive gene action was predominant for plant height. The best specific combinations were Punjab Padmini x Punjab 7, Punjab 7 x Punjab 5 and Punjab Padmini x Punjab 5 for fruit yield.

Pawar *et al.* (1999) performed combining ability analysis in ten promising lines of okra by crossing in all possible combinations excluding reciprocals. The comparison of components of variance due to GCA and SCA revealed preponderance of additive gene effect for all the characters. Parents HRB 55, Pusa Sawani, DL 1-87-5 and JO 5 were good general combiners for yield per plant, fruit girth and number of nodes per plant. The cross combination Kheda 11 x Pusa Sawani showed the highest sca effects for number of fruits per plant, fruit girth and yield per plant.

Sood and Kalia (2001) carried out combining ability study for yield and its contributing characters in okra. The gene action was additive for all the characters except fruit yield, fruits per plant and plant height for which non-additive gene action was prominent. Parent IC 9856 was good general combiners for early flowering, maturity, dwarfness and shorter inter nodal length. The best specific combiner was Punjab 7 x Arka Abhay followed by Punjab 7 x Arka Anamika for fruit yield.

Rajani *et al.* (2001) estimated the combining ability of six genetically diverse parental lines of okra in a half-diallel fashion. Parent NBPGR/TCR 861 was the best general combiner for individual fruit weight and fruit length. Among hybrids, NBPGR/TCR 893 x NBPGR/TCR 861 exhibited the highest sca effect for yield.

Ahlawat *et. al.* (2004) carried out combining ability analysis using fifteen lines and five testers. Lines, AOL 95-37, AOL 95-4, Sel. 2 and D 1-87-5 identified as high yielders and good general combiners for fruit yield. Similarly, pollinating parent, Parbhani Kranti found better performer and good general combiner for fruit yield. The hybrids Lorm 1 x HRB 55, KS 312 x Parbhani Kranti, HRB 9-2 x GO 2, AOL 95-37 x Parbhani Kranti and AOL 95-4 x Arka Abhay were found potentially high yielders with desirable sca effects.

Jindal and Ghai (2005) carried out combining ability study of yield and related traits in okra during 2004 and 2005 with 66 hybrids produced in a diallel mating excluding reciprocals. The estimates of gca effects indicated that HRB 107-4 was a good combiner for days to first picking in both years. Parents VRO 4 and S 2 were good general combiners for fruit weight in 2004 and 2005, respectively. For fruit diameter, the parents IIVR 11 and NDO 10 were the best general combiners in both seasons, whereas, HBR 108-2 and S 2 were good general combiners for average fruit length.

Kumar *et al.* (2006) made diallel crosses including reciprocals in okra. The experiment involved six parents *viz.*, Arka Anamika, Parbhani Kranti, Punjab Padmini, Pusa Sawani, MDU 1 and Mohanur Local and their 30 crosses. The analysis of variance for combining ability revealed the importance of both additive and non-additive gene actions in the inheritance of traits. They observed significant GCA and SCA variances for fruit yield, plant height, number of branches, internodal length, individual fruit weight and fruit diameter. They found that the parents, who recorded high fruit yield per plant *viz.*, Arka Anamika and Punjab Padmini were good general combiners. The parent Arka Anamika exhibited significant and positive gca effects for number of nodes, number of fruits, fruit yield, total green matter production and harvest index. It also exhibited negative gca effects for days to first flowering.

Mehta *et al.* (2007) evaluated 42 hybrids developed by crossing three testers with fourteen lines. The GCA variances for fruit weight, fruit length and plant height were higher than SCA variances indicated preponderance of additive gene action. They found that the parents Harsha and Kaveri Selection found good general combiners for fruit yield. Cross VRO 6 x Parbhani Kranti showed significant sca effect for fruit yield per plant.

Weerasekara *et al.* (2008) studied 24 hybrids developed from eight lines and three testers. Results showed that the non-additive gene action was an integral component of the genetic architecture of individual fruit weight and fruit length. Parents and hybrids differed significantly for gca and sca effects, respectively. Among the lines, KAO 25 and KAO 61 found good general combiners for days to 50% flowering. The testers KAO 23 and KAO-AA depicted negative and significant gca effects for number of seeds per fruit. The cross combinations KAO 52 x KAO 23, KAO 16 x KAO-AA, KAO 61 x KAO 18, KAO 16 x KAO 23, KAO 10 x KAO 18 and KAO 53 x KAO 18 manifested the highest sca effects for number of branches per plant, plant height, fruit length, fruit diameter, fruit weight and fruit yield per plant, respectively.

Pal and Sabesan (2009) estimated combining ability through 12 x 12 diallel mating excluding reciprocals. They reported preponderance of additive gene action for primary branches per plant and fruit diameter and non-additive gene action for plant height, number of nodes on main stem, days to first flowering, number of fruits per plant, fruit length, fruit weight and fruit yield per plant. The parents Satdhari, Ratna 78, VRO 5 and Varsha Uphar found good general combiners for fruit yield. The cross combinations Satdhari x Ratna 78, VRO 5 x Sagun and Ratna 78 x Punjab 8 showed significant sca effects for fruit yield per plant, individual fruit weight and fruit length.

Wammanda *et al.* (2010) developed 36 F_1's from nine parents by half diallel in okra. The non-additive gene effect found prominent as the GCA and SCA variances ratio was less than unity for days to 50% flowering and internode distance. Parents Mothol-AE 2, Mothol-AE 3, Gerio-AE 1 and Mothol-AE 1 showed good general combining ability effects for plant height and internodal length. The estimates of sca effect identified that the crosses Mothol-AE 2 x Mothol-AE 3, Mothol-AE 1 x Mothol-AE 3, Mothol-AE 2 x Gerio-AE 1 and Mothol-AE 2 x Mothol-AE 1 were good specific combiners for yield per plant and number of fruits per plant.

Bhatt (2011) carried out combining ability study for yield and related traits in okra with 28 hybrids produced in a diallel mating excluding reciprocals. Parents AOL 08-02, AOL 09-24 and AOL 08-10 were observed good general combiners as they depicted significant and positive gca effects. Out of 28 hybrids, ten cross combinations manifested significant and positive sca effects. Among them, the best was AOL 08-10 x AOL 09-24 followed by AOL 08-10 x AOL 08-2 and GO 2 x AOL 09-28 for ash content in okra.

Raghuvanshi *et al.* (2011) performed combining ability analysis for yield and its components by lines x testers crosses using six lines and four testers. They found that parents VRO 6, HRB 9-2 and VRO 5 were the best general combiners for fruit yield, first flowering node, internodal length, number of primary branches, number of fruits per plant, single fruit weight, fruit length and fruit diameter. The study revealed that the cross combination VRO 6 x Arka Anamika exhibited the highest sca effect followed by HRB 9-2 x P 7, VRO 6 x Arka Abhay, Pusa Kranti x IIVR 11, HRB 9-2 x Arka Abhay, VRO 5 x IIVR 11 and HRB 55 x Arka Abhay for yield per plant.

Prakash *et. al.* (2012) accomplished full diallel analysis involving six genotypes of okra to study the combining ability for fruit yield and its component characters. The result revealed that the parent Hissar Unnat exhibited good general combining ability for number of branches per plant, number of fruits per plant, fruit weight and fruit yield per plant. The hybrid Kamini x Bakra manifested the maximum sca effect for fruit yield per plant followed by PB 7 x P 7, P 7 x Kamini, Hissar Unnat x PB 7, P 7 x PB 266, P 7 x Hissar Unnat and Kamini x PB 266.

Reddy *et al.* (2012) evaluated 45 hybrids derived from 10 nearly homozygous germplasm lines using half diallel. Analysis of variance for combining ability revealed that the variances due to GCA and SCA were highly significant for number of branches per plant, internodal length, days to 50% flowering, first flowering node, first fruiting node, fruit length, fruit width, fruit weight and number of fruits per plant. Significance of GCA and SCA variances implied that both additive and non-additive components of heritable variance were responsible for variation observed. However, the ratio of GCA variance to SCA variance was lower than unity for fruit weight (0.927), fruit length (0.481), plant height (0.413), days to 50% flowering (0.413), first flowering node (0.366), first fruiting node (0.366), internodal length (0.315), fruit yield per plant (0.289) and number of fruits per plant (0.059) suggested the predominance of the non-additive gene action. The parents IC 45732, IC 89819 and IC 89976 were good general combiners for fruit yield per plant. The crosses IC 29119-B x IC 99716, IC 27826-A x IC 111443 and IC 89976 x IC 111443 were superior specific combiners for yield per plant.

Ashwani *et al*. (2013) carried out combining ability analysis using five lines and three testers at Vegetable Research Farm, BHU, Varanasi during summer and *kharif* seasons of the year 2009. Based on gca effects across nine characters, Arka Abhay, VRO 6, Hisar Unnat and Punjab Padmini were identified as promising parents for improving number of fruits per plant, fruit girth and days to 50% flowering. The high yielding crosses Arka Abhay x Parbhani Kranti, Hisar Unnat x Punjab Padmini, VRO 6 x Parbhani Kranti and VRO 6 x Arka Anamika depicted significant and positive sca effects for fruit yield.

Two Egyptian and four exotic parental genotypes of okra were self pollinated for one generation and crossed in half diallel manner to study combining ability for earliness, vegetative and yield components traits by Hazem *et al.* (2013). The general combining ability and specific combining ability mean squares were highly significant for fruit yield per plant, number of fruits per plant, fruit length, fruit girth and plant height. Pusa Sawani was the excellent general combiners for all studied traits except average fruit weight per plant. The results revealed that the cross combination Escandarany x Clemson Spineless, which resulted from crossing between poor x poor general combiner parents, showed desirable negative and significant sca effect for earliness. The Balady x Pusa Sawani showed desirable sca effects for all studied traits except number of branches per plant.

Kumar *et al.* (2013) crossed eight elite diverse lines of okra in half diallel fashion and evaluated these hybrids along with parents. The results revealed that the parents KS 404, KS 7218, VRO 54 and BO 2 were good general combiners for days to 50% flowering; Parbhani Kranti, KS 404 and KS 7109 for plant height; KS 7109, VRO 54 and BO 2 for number of branches per plant; Parbhani Kranti for fruit length; Parbhani Kranti and KS 7109 for fruit diameter and KS 404 and Parbhani Kranti for number of fruits per plant. Significant and positive sca effect for yield per plant was found in 12 cross combinations. The crosses Parbhani Kranti x KS 404, Parbhani Kranti x P 7, KS 404 x BO 2 and KS 7218 x VRO 54 manifested good sca effects for yield per plant. Cross combination KS 404 x BO 2 showed good x poor gca status; while, KS 7218 x VRO 54 involved poor x poor parents of gca combination.

III. MATERIALS AND METHODS

The present investigation was carried out to elicit information on heterosis, combining ability and gene action for fruit yield and its contributing characters in okra. The experiment was conducted at Main Vegetable Research Station, Anand Agricultural University, Anand during *kharif* season of the year 2014.

3.1 Geographic and adaphic details

Anand is situated on 22^o-35' North latitude and 72^o-55' East longitude, at an elevation of 45.1 meters above mean sea level. The soil of experimental site is sandy loam in texture, well drained and has average moisture holding capacity. The meteorological data were recorded at the observatory, B. A. College of Agriculture, Anand Agricultural University, Anand during the period of experimentation are given in Appendix-I.

3.2 Experimental material

The basic parental material for this study was obtained from Research Scientist (Veg.), Main Vegetable Research Station, Anand Agricultural University, Anand. Twenty-eight hybrids developed in a diallel mating design excluding reciprocals using eight parents. The seeds of 28 hybrids and eight parents were produced by hand emasculation-hand pollination and selfing, respectively, during *kharif* 2013. The detailed description of parental lines used in crossing programme is given in Table 3.1.

3.3 Selfing and crossing technique

The day before anthesis selfing was done by tying the closed flower buds with a thread (Parthsarathy and Sambandan, 1976). Anthesis in okra occurs between 6 to 10 a.m. (Sulikiri and Rao, 1972). A simple emasculation technique evolved by Giriraj and Rao (1973) was used. The well developed greenish yellow flower buds about to open in the next morning were emasculated in the evening hours in between 4.00 to 6.00 p.m. A circular cut was made around the fused calyx at about 1-3 mm near to the base of buds and then the corolla and anthers removed gently without injuring the gynoecium. The emasculated buds were covered with red butter paper bag to prevent undesirable out crossing. Next morning in between 7.00 to 9.30 a.m., the emasculated buds were pollinated using pollens from flowers of the appropriate male parent and covered with white butter paper bag.

Table 3.1 The detailed description of parental lines used in crossing programme

Sr. No.	Parents	Origin/Source	Pedigree	Important characters
1.	GAO 5 (check)	AAU, Anand	Selected from cross VRO 6 x AOL 00-06	Fruits have attractive shape, small in size and deep green in colour. The plants are tall and resistance to YVMV
2.	GO 2	JAU, Junagadh	Selection from the back cross of (S 81-20 x Manihot) x S 81-20	Small sized and light green colour fruits, tall plant height with more branches
3.	Pusa Sawani	IARI, New Delhi	Selected from cross IC 1542 x Pusa Makhmali	Presence of a purple patch at the base of the yellow petal on both the sides
4.	AOL 10-22	AAU, Anand	Selected from the germplasm number 127	Medium sized and dark green colour fruits, dwarf plant height, less branching habit
5.	GPOK 123	AAU, Anand	Selection from the germplasm number 123 (Purple red fruit)	Stem, leaf petiole and veins are red in colour. Baby fruits are initially green then after become red
6.	GPOK 349	AAU, Anand	Selection from the germplasm number 349 (Collected from Amreli)	Leaves are shallow lobed. Fruits have 7-8 ridges and thick in diameter.
7.	GPOK 573	AAU, Anand	Selection from the germplasm number 573 (EC 305741)	Fruits have small spine and heavy in weight, tall plant height
8.	GPOK 578	AAU, Anand	Selection from the germplasm number 578 (IC 090262)	Fruits are small and pale yellow in colour, more spines on plants and short plant stature.

3.4 Experimental details

A total thirty-six entries (Table 3.2) comprised of eight parents including standard check Gujarat Anand Okra 5 (GAO 5) and their 28 hybrids were grown in a randomized block design replicated thrice during *kharif* season on July 2, 2014 at Main Vegetable Research Station, Anand Agricultural University, Anand.

The planting distance of 60 x 30 cm was adopted for evaluation of the entries. Each parent and hybrid were planted in a single row plot of 2.4 m length accommodating eight plants per plot. The recommended packages of practices were followed to raise the good crop.

Table 3.2 Diallel crosses excluding reciprocals: 28 Hybrids + 8 Parents

		Male Parents							
Female Parents		**P_1**	**P_2**	**P_3**	**P_4**	**P_5**	**P_6**	**P_7**	**P_8**
	P_1	1x1	1x2	1x3	1x4	1x5	1x6	1x7	1x8
	P_2		2x2	2x3	2x4	2x5	2x6	2x7	2x8
	P_3			3x3	3x4	3x5	3x6	3x7	3x8
	P_4				4x4	4x5	4x6	4x7	4x8
	P_5					5x5	5x6	5x7	5x8
	P_6						6x6	6x7	6x8
	P_7							7x7	7x8
	P_8								8x8

3.5 Characters studied

The observations were recorded on five competitive plants in each plot leaving border ones except days to 50% flowering, which recorded on plot basis. The detailed procedure adopted for recording observations is given as under.

3.5.1 Fruit yield per plant (g)

It was recorded by weighing the pods harvested picking wise from individual sampled plants in grams and mean values were computed.

3.5.2 Days to 50% flowering

The phenological observation was recorded on population basis. The number of days taken from date of sowing to the opening of flower in 50% plants in each plot were recorded.

3.5.3 First fruiting node

Number of nodes on main stem counting from the first node at ground level to first fruiting node.

3.5.4 Days to first picking

It was recorded by counting of days for the first picking of fruits from the date of sowing.

3.5.5 Fruit length (cm)

The length of five fruits were measured in centimeter from the stem end to the blossom end tip of the fruit and mean length of fruit worked out for each genotype and recorded separately. The fruits from the randomly selected and tagged five plants used for measuring length.

3.5.6 Fruit girth (cm)

The fruits used for measuring fruit length were used to measure the girth of fruit. It was in centimeters. Ordinary measuring tape used for measurement of fruit girth. The tape wrapped around the middle portion of the fruit and the length of tape, which utilized noted as fruit girth. By this method, girth of five fruits of each selected plant was determined and mean was worked out and recorded separately for each entry.

3.5.7 Fruit weight (g)

It was recorded by weighing five fruits, which used for measuring of fruit girth and fruit length and mean values were computed. It measured in grams.

3.5.8 Number of fruits per plant

Number of fruits were recorded picking wise by counting the fruits on individual tagged plant, total values obtained after last picking and mean values were computed.

3.5.9 Plant height (cm)

The height of randomly selected five competitive plants measured in centimeters from first node of stem at ground level to end of the apical tip after last picking. The mean height per plant worked out and recorded separately for each test entry.

3.5.10 Number of nodes per plant

Total number of nodes on main stem (leaving top one fit height) of the selected plants counted after last picking and mean values were computed.

3.5.11 Number of primary branches per plant

It was recorded by counting branches of individual selected plant emerged on main stem after last picking and mean values were computed.

Fruit quality characters

3.5.12 Moisture content (%)

Moisture content of fresh fruit was determined by oven dry method. The 5 g sample was taken from the bulk of fresh marketable fruits harvested from each replication and heated at 105°C for five hours in oven. The final fruit weight obtained after oven drying was used to compute the moisture content percent in fresh fruit. This observation was recorded replication wise.

$$\text{Moisture (\%)} = \frac{\text{Fresh fruit weight - Oven dried fruit weight}}{\text{Fresh fruit weight}} \times 100$$

3.5.13 Ash content (%)

The ash content in the fruit determined by a method described in A.O.A.C. (Anon., 1980).

$$\text{Ash (\%)} = \frac{\text{Weight of ash}}{\text{Oven dry weight of fruit sample}} \times 100$$

3.6 Statistical analysis

The mean data generated for the various characters used for statistical analysis under the following sub heads.

i. Analysis of variance
ii. Estimation of heterosis
iii. Combining ability analysis and
iv. Estimation of components of genetic variation and graphical analysis

3.6.1 Analysis of variance

Analysis of variance technique suggested by Snedecor and Cocherham (1967) and reviewed by Panse and Sukhatme (1978) was followed to test the significant differences between the genotypes for all the characters. The statistical model for randomized block design is:

$$Y_{ij} = \mu + \beta_i + \tau_j + \varepsilon_{ij}$$

Where,

Y_{ij} = Phenotypic value of j^{th} genotype in i^{th} replication

μ = General mean

β_i = Effect due to i^{th} replication

τ_j = Effect due to j^{th} genotype

ε_{ij} = Uncontrolled variation associated with i^{th} replication and j^{th} genotype

The source of variance and expectation of mean squares are given in Table 3.3.

Table 3.3 Analysis of variance and expected mean squares

Source	d. f.	Mean squares	Expectation of mean squares
Replications	(r-1)	Mr	$\sigma^2 e + g\,\sigma^2 r$
Genotypes	(g-1)	Mg	$\sigma^2 e + r\,\sigma^2 g$
Parents	(p-1)	M_p	-
Hybrids	(h-1)	M_h	-
Parents *vs* hybrids	1	M_p vs. M_h	-
Checks *vs* hybrids	1	M_c vs M_h	-
Error	(r-1) (g-1)	M_e	σ^2_e

Where,

r = Number of replications

g = Number of genotypes

p = Number of parents

h = Number of hybrids

c = Number of checks

Test of Significance

Test of significance for various components carried out by F- test. The 'F' values calculated as under:

$$\text{Genotypes} = \frac{M_g}{M_e}$$

$$\text{Parents} = \frac{M_p}{M_e}$$

$$\text{Hybrids} = \frac{M_h}{M_e}$$

$$\text{Parents vs Hybrids } = \frac{M_p \text{ vs } M_h}{M_e}$$

$$\text{Check vs Hybrids} = \frac{M_c \text{ vs } M_h}{M_e}$$

Critical difference of the estimates

To test the significance of differences of the estimates, critical difference calculated as:

$$\text{Standard Error of difference (S. Ed.)} = \sqrt{\frac{2M_e}{r}}$$

Critical Difference (C.D.) = S. Ed. x t

Where,

t = Table ‘t’ value for error degree of freedom at 0.05 and 0.01 levels of probability.

Co-efficient of variance

The co-efficient of variance for each character calculated as under:

$$\text{Co-efficient of Variance (C.V.) \%} = \frac{\sqrt{M_e}}{\overline{X}} \text{x100}$$

Where,

M_e = Error mean square

$\overline{X}$ = General mean for the character

3.6.2 Estimation of heterosis

Heterosis expressed as per cent increase or decrease in hybrid vigour over its better parent (BP), mid parent (MP) and standard check (SC) values in the desirable direction estimated in terms of three parameters.

(i) Relative heterosis (RH) expressed as per cent deviation of mean performance of F_1 from mid parents value, *i.e.* average value of female and male parents involved. It estimated as formula suggested by Turner (1953).

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

Where,

$\overline{MP}$ = Mean value of the parents for respective hybrid $\left[= \frac{P1 + P2}{2}\right]$

$\overline{F_1}$ = Mean performance of the hybrid (F_1).

(ii) Heterobeltiosis (HB) expressed as per cent deviation of mean performance of F_1 towards better parent in respect to desired direction. It estimated as formula suggested by Fonseca and Patterson (1968).

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

Where,

$\overline{BP}$ = Mean value of better parent.

$\overline{F_1}$ = Mean value of the hybrid (F_1).

(iii) Standard heterosis (SH) expressed as per cent deviation of mean performance of F_1 towards standard check in respect to desired direction. It estimated as formula suggested by Meredith and Bridge (1972).

$$\text{Standard heterosis (SH) \%} = \frac{\overline{F_1} - \overline{SC}}{\overline{SC}} \times 100$$

Where,

$\overline{SC}$ = Mean value of standard check

$\overline{F_1}$ = Mean value of the hybrid (F_1)

Test of significance

The standard errors were estimated using following formula for relative heterosis.

$$\text{Standard error (S.E.)} = \sqrt{\frac{3\,M_e}{2r}}$$

$$\text{Critical Difference (C.D.)} = \text{S.E. x t}$$

Where,

M_e = Error mean square

r = Number of replications

t = Table ‘t’ value at 0.05 and 0.01 levels of significance for error degree of freedom.

The standard errors were estimated using following formula for heterobeltiosis and standard heterosis:

$$\text{Standard error (S.E.)} = \sqrt{\frac{2\,M_e}{r}}$$

$$\text{Critical Difference (C.D.)} = \text{S.E. x t}$$

Where,

M_e = Error mean square

r = Number of replications

t = Table ‘t’ value at 0.05 and 0.01 levels of significance for error degree of freedom.

3.6.3 Combining ability analysis

Combining ability analysis was performed with the data obtained for parents and hybrids according to Model-I, Method-II proposed by Griffing (1956). This includes partitioning of variation among sources attributable to general combining ability (gca) and specific combining ability (sca) components. The analysis of variances for the combining ability is based on the following statistical model:

$$Y_{ijk} = \mu + g_i + g_j + s_{ij} + (1/b)\, e_{ijk}$$

Where,

Y_{ijk} = Mean value of hybrid involving i^{th} and j^{th} parent in k^{th} replication

μ = General mean

g_i = gca effect of i^{th} parent

g_j = gca effect of j^{th} parent

s_{ij} = sca effect for the cross between i^{th} and j^{th} parents

e_{ijk} = Uncontrolled variation associated with ijk^{th} observation

i, j = 1, 2…p (p = number of parents)

k = 1, 2 …b (b = number of blocks)

The analysis of variance for combining ability and expectation of mean squares are given in Table 3.4.

Table 3.4 Analysis of variance for combining ability analysis

Source	d. f.	S. S.	M. S.	Expectation of mean squares
gca	(P-1)	S_g	M_g	$\sigma^2 e + \frac{(P+2)}{(P-1)} \sum_i g^2{}_i$
sca	$\frac{P(P-1)}{2}$	S_s	M_s	$\sigma^2 e + \frac{2}{P(P-1)} \sum_i \sum_j s^2{}_{ij}$
Error	(r-1)(g-1)	S_e	M'_e	$\sigma^2{}_e$

Sum of squares due to gca were calculated as follow:

$$S_g = \frac{1}{(P+2)}\left[\left(\sum_i (Y_{i.} + Y_{ii})^2\right) - \frac{4}{P} Y^2 \cdot\cdot\right]$$

Sum of squares due to sca were calculated as follow:

$$\mathrm{S_s} = \sum_i \sum_j Y^2{}_{ij} - \frac{1}{(P+2)} \sum (Y_{i.} + Y_{ii})^2 + \frac{2}{(P+1)(P+2)} Y^2{}_{..}$$

Where,

S_g = S.S. due to general combining ability

S_s = S.S. due to specific combining ability

P = Number of parents

$Y_{i.}$= Total value of i^{th} parent

$Y_{..}$= Grand total of all the progenies and parental mean values

M'_e = Error mean square (M_e/r)

Further, the components of genetic variance determining the additive and non-additive gene actions computed using the following formulae:

$$\hat{\sigma}^2 gca = \frac{\mathrm{M_g} - \mathrm{M'e}}{\mathrm{P}+2}$$

$$\hat{\sigma}^2\mathrm{sca} = \mathrm{M_s} - \mathrm{M'e}$$

Where,

M_g = Mean sum of square due to gca effect

Ms = Mean sum of square due to sca effect

M'_e = M_e/b = Error mean square

The magnitude of components of genetic variance estimated by potence ratio, which was suggested by Hebert and Gallais, 1986

$$\text{Potence ratio} = \frac{\hat{\sigma}^2\ \mathrm{gca/d.f.}}{\hat{\sigma}^2\ \mathrm{sca/d.f.}}$$

Test of significance of combining ability

The error mean square for combining ability (M'_e) obtained by dividing error mean square (M_e) in Table 3.3 by number of replications.

Estimation of general and specific combining ability effects

The general combining ability and specific combining ability effects estimated as under:

$$\text{Population mean}(\mu) = \frac{2}{P(P+1)} Y..$$

$$\text{gca effect } (\hat{g}_i) = \frac{1}{p+2} [\Sigma(Y_{i.} + Y_{ii}) - \frac{2}{p} Y..]$$

$$\text{sca effect} = (\hat{s}_{ij}) = Yij - \frac{1}{(P+2)}(Y_{i.} + Y_{ii} + Y._j + Y_{jj}) + \frac{2}{(P+1)(P+2)} Y..$$

Where,

P = Number of parents

g_i = General combining ability effect of ith parent

s_{ij} = Specific combining ability effect of the cross involving ith and jth parents

Y_i = Total of array involving ith parent

$Y._j$ = Total of array involving jth parent

Y_{ii} = Parental value of the ith parent

Y_{jj} = Parental value of the jth parent

$$Y.. = \text{Total of all } \frac{P(P+1)}{2} \text{ items of the diallel table}$$

Various standard errors required testing the significance of gca and sca effects and differences between them are calculated as:

$$S.E.(\hat{g}_i) = \sqrt{\frac{(P-1)}{P(P+2)} M'_e}$$

$$S.E.(\hat{s}_{ij}) = \sqrt{\frac{(P^2+P+2)}{(P+1)(P+2)} M'_e}$$

Test of Significance

The ‘t’ test was used to test the significance of individual gca and sca effects as under:

$$\text{To test } \hat{g}_i : t = \frac{\hat{g}_i - 0}{S.E.(\hat{g}_i)}$$

$$\text{To test } \hat{s}_{ij} : t = \frac{\hat{s}_{ij} - 0}{S.E.(\hat{s}_{ij})}$$

To test the significance differences of two estimates, critical differences (CD) was calculated as product of the ‘t’ for error degree of freedom and the standard error of difference of two estimates.

3.6.4 Components of genetic variation and graphical analysis

Besides combining ability analysis, the components of genetic variance were also determined. The diallel cross method given by Hayman (1954a) was used for computing the components of genetic variance for the F_1 data where additive-dominance model is adequate.

The analyses of gene action by this method following assumptions are there:

i. Homozygous parents
ii. Diploid segregation
iii. No maternal effects
iv. Absence of multiple alleles
v. Absence of linkage
vi. Absence of lethal genes
vii. No genotype x environment interaction

The following parameters, which derived from the analysis of diallel table, utilized in the equations for components of variance.

$V_0L_0 = V_p$ = Variance of paternal array

V_r = Variance of one array (r^{th} array)

V_1L_1 = Mean variance of all progenies in an array of each parent

V_0L_1 = Variance of the mean of arrays

Wr = Covariance between parents and their off-springs in one array (r^{th} array)

W_0L_{01} = Mean covariance between parents and their offsprings of the arrays.

M_e = The expected environment component of variation for parents and F_1s data

M_{L1}-M_{L0} = The difference between mean of parents and mean of their n^2 progenies.

The expected values of components of genetic variance computed as follows:

$D = VoLo - E$

$H_1 = Vo\ Lo - 4\ W_0Lo_1 - 4V_1\ L_1 - (3n-2)\ E/n$

$H_2 = 4V_1L_1 - 4Vo\ L_1 - 2\ E$

$F = 2Vo\ Lo - 4W_0Lo_1 - 2\ (n-2)\ E/n$

$h^2 = 4\ [(ML_1 - MLo)^2 - (n-1)\ E/n^2\ ]$

$F = 2[VoLo - WoLo_1 + V_1\ L_1 - (Wr + Vr) - 2(n-2)]$

E = Error

Where,

D = Component of genetic variance due to additive gene effect

H_1 = Component of genetic variance due to the dominance gene effect

H_2= H1 $[1 - (u - v)^2]$ = Proportion of dominance variance due to the positive (u) and negative (v) effects of the genes in the parents, where u + v =1

h^2 = Dominance effects summed over all loci in heterozygous phase in all crosses

F = The covariance of additive and non-additive effects in all arrays. It may be positive or negative.

E = M_e (As mentioned above)

By utilizing the above genetic parameters, following proportions of genetic component were calculated.

[1] Degree of dominance: The mean degree of dominance was calculated with formula suggested by Hayman (1954a): $(H_1/D)^{1/2}$

[2] Proportion of dominant and recessive genes in the parents calculated as given by Hayman (1954a): $K_D/K_R = [(4DH_1)^{1/2} + F] / [(4DH_1)^{1/2} - F]$

[3] Number of group of genes, which control the character and exhibit dominance: It calculated as the ratio of h^2/H_2 suggested by Singh and Choudhary (1977).

[4] Proportion of genes with positive and negative effects in the parents: It calculated by the ratio of $(H_2/4H_1)$ given by Hayman (1954a).

[5] Heritability in narrow sense: $[¼ D/(1/4D + 1/4\, H_1 - 1/4\, F + E)]$

Graphical analysis

The graphical analysis was done according to Hayman (1954b). The V_r, W_r points for the parents depicted along the V_r, W_r axis. The regression line 'b' = Cov (V_r, W_r)/ Var V_r was fitted to those points. The limiting parabola drawn by depicting limits (PL_i) for i^th parent obtained by the formula:

$$PLi = (Vri \times V_0L_0)^{1/2}$$

Where: Vri = variance of the r^th array

V_0L_0 = variance of the parental values.

The point of interception (a) on Wr ordinate by the regression line obtained by the formula:

$$a = Wr - b\ Vr$$

The point of interception and the position of Vr, Wr points for the different parents along the regression line would lead to draw the conclusions regarding degree of dominance and type of gene action.

IV. EXPERIMENTAL RESULTS

The present investigation was carried out to study the magnitude of heterosis, combining ability, components of genetic variance and graphical analysis for various quantitative traits in okra [*Abelmoschus esculentus* (L.) Moench]. The character wise results obtained presented under the following heads:

4.1 Analysis of variance

4.2 Estimation of heterosis

4.3 Combining ability analysis

4.4 Estimation of components of genetic variance and graphical analysis

4.1 ANALYSIS OF VARIANCE

The character wise mean data of parents and F_1's subjected to analysis of variance for green fruit yield per plant and other characters are presented in Appendix-II. The results of analysis of variance of parents and their hybrids for various traits are given in Table 4.1.

Mean squares due to genotypic differences found significant for all the traits studied. This indicated that the experimental material under study had sufficient genetic diversity for different traits. Further, partitioning of sum of squares due to genotypes indicated that the differences among parents were significant for all the characters under study. In case of hybrids, significant differences obtained for all the traits studied. While, mean squares due to parents vs. hybrids were significant for fruit yield per plant, days to 50% flowering, first fruiting node, fruit length, fruit girth, number of nodes per plant, number of primary branches per plant, moisture and ash content per cent. The mean squares due to check vs. hybrids were significant for fruit yield per plant, first fruiting node, fruit weight, number of fruits per plant and ash content.

Table 4.1 Analysis of variance for various characters in okra

Sources of variation	d. f.	Fruit yield per plant	Days to 50% flowering	First fruiting node	Days to first picking	Fruit length	Fruit girth	Fruit weight
Replications	2	1550.11	2.06	0.59	2.00	0.58	0.31*	2.06
Genotypes	36	6737.44**	24.74**	2.75*	22.58**	10.38**	0.43*	6.05**
Parents	7	11463.04**	36.23**	4.38*	33.52**	20.93**	0.81**	8.74**
Hybrids	27	5865.95*	23.40**	2.07*	21.39**	8.22**	0.33*	5.79*
Parents vs hybrids	1	3924.66*	5.23*	12.23**	0.68	5.01*	0.84**	0.21
Check vs hybrids	1	5439.08*	12.71	4.96**	9.48	0.17	0.051	8.57**
Error	72	1121.66	1.53	1.01	2.45	0.88	0.73	1.29

Table 4.1 Contd...

Sources of variation	d. f.	Number of fruits per plant	Plant height	Number of nodes per plant	Number of primary branches per plant	Moisture content	Ash content
Replications	2	4.17	581.48*	0.25	0.37	7.89*	0.07
Genotypes	36	37.58**	600.68**	6.55**	0.85**	8.72**	1.31**
Parents	7	46.75**	800.27**	3.04*	0.59**	26.47**	2.10**
Hybrids	27	37.94**	592.23*	7.11*	0.90**	4.29*	1.20**
Parents vs hybrids	1	1.19	32.30	22.14**	2.04**	12.44**	0.01**
Check vs hybrids	1	90.60**	161.89	0.39	0.08	1.06	3.57**
Error	72	2.27	130.47	1.30	0.59	1.25	0.08

*,** Significant at 5 and 1% levels, respectively.

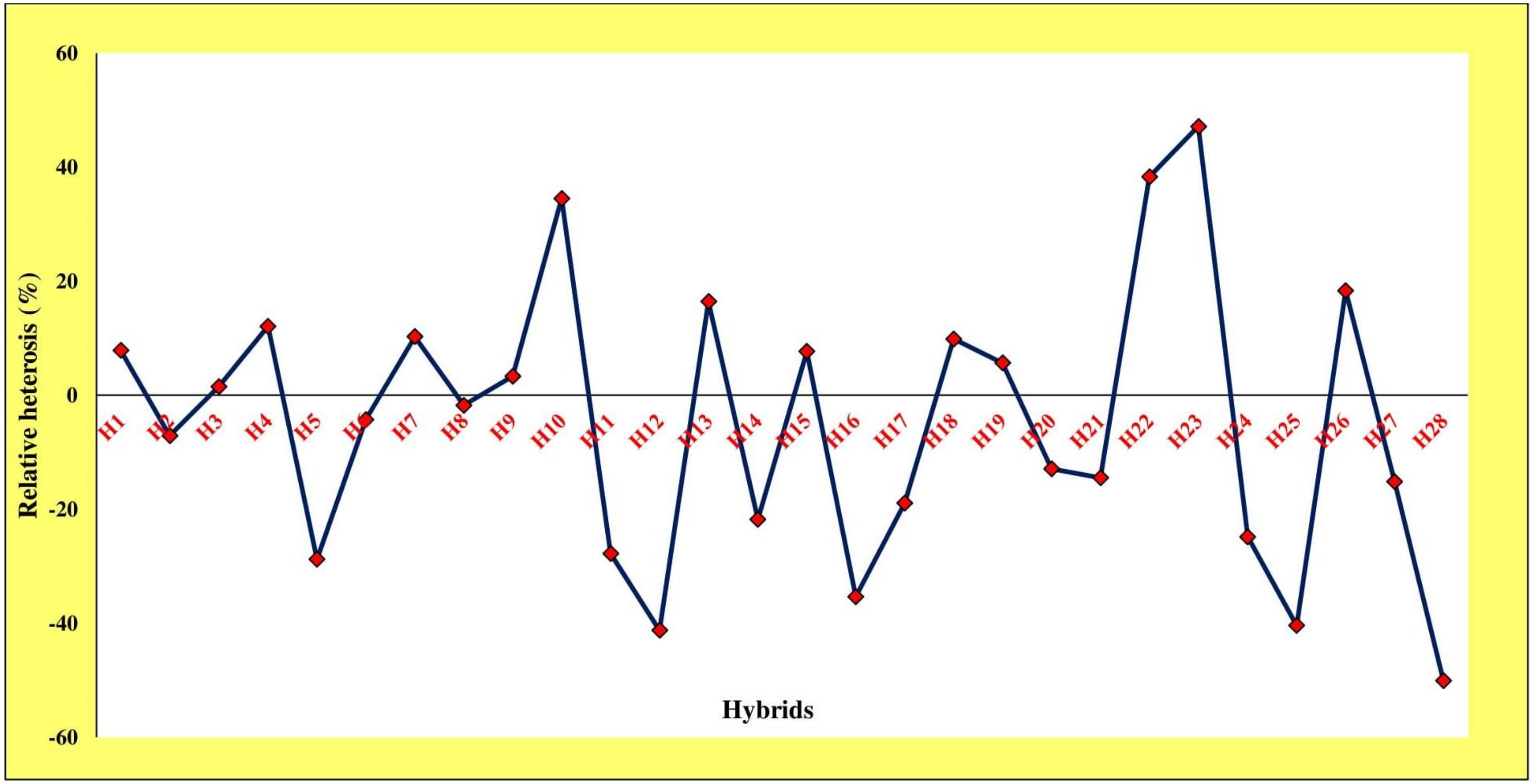

Fig. 1 Phenogram of per cent relative heterosis for fruit yield per plant

4.2 ESTIMATION OF HETEROSIS

The findings of heterosis over mid parent, better parent and standard check (GAO 5) are presented in Table 4.2.1 to 4.2.4. While interpreting the results of heterosis, the positive effects considered favourable for all the characters except days to 50% flowering, first fruiting node, days to first picking and moisture content for which negative effects were considered favourable. The character wise results are summarised as under.

4.2.1 Fruit yield per plant

The estimate of heterosis over mid parent was ranged from -50.12 to 47.09 per cent. Significant and positive mid parent heterosis was manifested by thirteen crosses, top ranked hybrids were *viz.*; GPOK 123 x GPOK 349 (47.09%), AOL 10-22 x GPOK 578 (38.27%), GO 2 x GPOK 123 (34.46%) and GPOK 349 x GPOK 573 (18.29%). On the other hand, fifteen crosses exhibited significant negative relative heterosis for fruit yield per plant. The estimates of heterobeltiosis ranged from -66.04 to 47.09 per cent. Total four hybrids depicted significant positive heterosis over better parent. Cross GPOK 123 x GPOK 349 (47.09%) depicted the highest significant positive heterobeltiosis followed by GO 2 x GPOK 123 (11.48%), AOL 10-22 x GPOK 578 (5.48%) and GAO 5 x GO 2 (5.36%). It was interested to note that out of 28 hybrids, 24 hybrids depicted significant negative heterobeltiosis. The maximum standard heterosis was observed with GO 2 x GPOK 123 (16.84%), while the minimum standard heterosis was revealed with GPOK 573 x GPOK 578 (–59.09%).

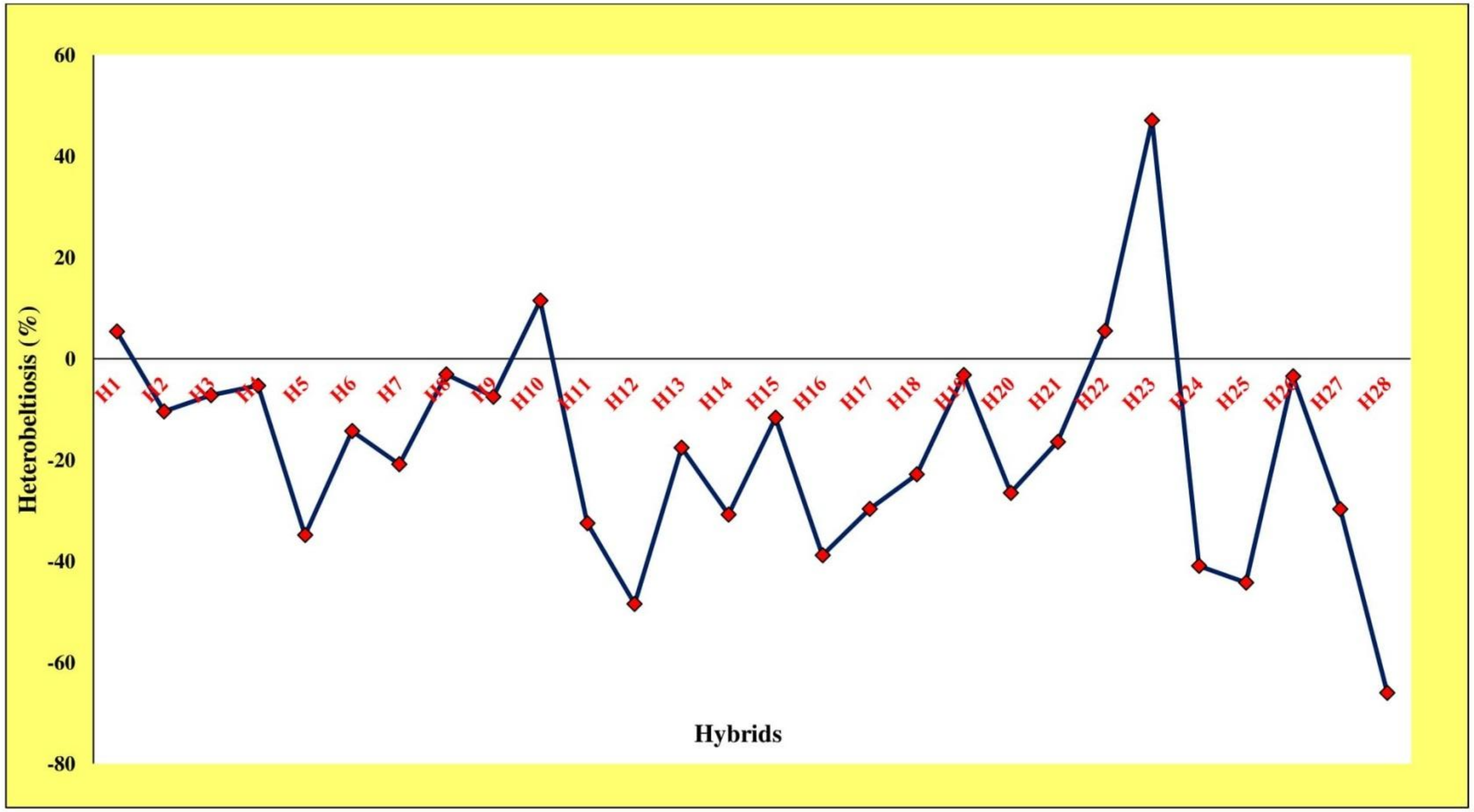

Fig. 2 Phenogram of per cent heterobeltiosis for fruit yield per plant

4.2.2 Days to 50% flowering

Heterosis over mid parent for days to 50% flowering ranged from -7.83 to 16.51 per cent. Among the crosses, twelve hybrids were depicted negative and significant heterosis over mid parent value. The highest heterosis estimated for GPOK 349 x GPOK 573 (-7.83%) followed by Pusa Sawani x GPOK 578 (-7.32%), AOL 10-22 x GPOK 578 (-7.32%), GAO 5 x GPOK 578 (-5.81%), AOL 10-22 x GPOK 573 (-5.36%) and GAO 5 x GPOK 573 (-4.43%). On the other hand, six hybrids show positive and significant heterosis. Heterosis over better parent ranged from -14.61 to 11.98 per cent. Fifteen crosses showed significant and negative heterobeltiosis, of these top ranking crosses were Pusa Sawani x GPOK 578 (-14.61%), AOL 10-22 x GPOK 578 (-14.61%), GPOK 349 x GPOK 573 (-14.04%), GAO 5 x GPOK 578 (-13.48%) and AOL 10-22 x GPOK 573 (-10.18%) as well as four crosses exhibited positive significant heterobeltiosis. The value of standard heterosis varied from -0.67 to 25.50 per cent. None of the hybrid showed negative heterosis over standard check, but eighteen crosses had positive and significant standard heterosis.

4.2.3 First fruiting node

For this trait, mid parent heterosis varied from -11.11 to 36.00%. Among the 28 hybrids, GO 2 x GPOK 573 (-11.11%) and GPOK 123 x GPOK 578 (-8.20%) were manifested negative and significant heterosis, while, 15 crosses depicted positive and significant heterosis. The heterobeltiosis ranged from -18.18 to 30.77 per cent with six crosses were negative significant and 9 were positive significant. Top three hybrids for this important trait were AOL 10-22 x GPOK 573 (-18.18%), GAO 5 x GPOK 573 (-15.15%) and GO 2 x GPOK 573 (-15.15%). In case of heterosis over standard check, all the crosses exhibited positive value range from zero to 40.00 per cent.

Table 4.2.1 Heterosis (%) over mid parent (RH), better parent (HB) and standard check (SH) for fruit yield per plant, days to 50% flowering and first fruiting node in okra

Crosses	Fruit yield per plant			Days to 50% flowering			First fruiting node		
	RH	HB	SH	RH	HB	SH	RH	HB	SH
GAO 5 X GO 2	7.83**	5.36**	10.43**	1.00	0.67	1.34	12.73**	3.33	24.00**
GAO 5 X Pusa Sawani	-7.15**	-10.43**	-3.61**	3.01**	2.67**	3.36**	26.53**	24.00**	24.00**
GAO 5 X AOL 10-22	1.46**	-7.22**	-7.22**	-0.33	-0.67	0.00	6.38	0.00	0.00
GAO 5 X GPOK 123	12.03**	-5.35**	-5.35**	-0.33	-1.95*	1.34	-5.66	-10.71*	0.00
GAO 5 X GPOK 349	-28.81**	-34.85**	-21.52**	1.96**	-0.64	4.70**	-1.96	-3.85	0.00
GAO 5 X GPOK 573	-4.33**	-14.30**	-14.30**	-4.43**	-9.58**	1.34	-3.45	-15.15**	12.00*
GAO 5 X GPOK 578	10.24**	-20.86**	-20.86**	-5.81**	-13.48**	3.36**	14.29**	12.00*	12.00*
GO 2 X Pusa Sawani	-1.83**	-3.11**	4.28**	-1.33	-1.33	-0.67	7.41	-3.33	16.00**
GO 2 X AOL 10-22	3.28**	-7.53**	-3.07**	0.67	0.67	1.34	15.38**	0.00	20.00**
GO 2 X GPOK 123	34.46**	11.48**	16.84**	0.00	-1.30	2.01*	6.90	3.33	24.00**
GO 2 X GPOK 349	-27.83**	-32.52**	-18.72**	0.98	-1.27	4.03**	17.86**	10.00*	32.00**
GO 2 X GPOK 573	-41.28**	-48.47**	-45.99**	8.52**	2.99**	15.44**	-11.11**	-15.15**	12.00*
GO 2 X GPOK 578	16.40**	-17.60**	-13.64**	2.44**	-5.62**	12.75**	29.63**	16.67**	40.00**
Pusa Sawani X AOL 10-22	-21.82**	-30.81**	-25.53**	2.67**	2.67**	3.36**	17.39**	12.50*	8.00
Pusa Sawani X GPOK 123	7.65**	-11.68**	-4.95**	-1.97**	-3.25**	0.00	3.85	-3.57	8.00
Pusa Sawani X GPOK 349	-35.40**	-38.85**	-26.34**	0.98	-1.27	4.03**	12.00**	7.69	12.00*
Pusa Sawani X GPOK 573	-18.97**	-29.69**	-24.33**	-0.95	-5.99**	5.37**	5.26	-9.09*	20.00**
Pusa Sawani X GPOK 578	9.81**	-22.86**	-16.98**	-7.32**	-14.61**	2.01*	20.83**	20.83**	16.00**
AOL 10-22 X GPOK 123	5.63**	-3.23**	-19.79**	-1.97**	-3.25**	0.00	12.00**	0.00	12.00*
AOL 10-22 X GPOK 349	-12.95**	-26.53**	-11.50**	-2.93**	-5.10**	0.00	12.50**	3.85	8.00
AOL 10-22 X GPOK 573	-14.52**	-16.45**	-30.75**	-5.36**	-10.18**	0.67	-1.82	-18.18**	8.00
AOL 10-22 X GPOK 578	38.27**	5.48**	-12.57**	-7.32**	-14.61**	2.01*	21.74**	16.67**	12.00*
GPOK 123 X GPOK 349	47.09**	47.09**	1.47**	0.00	0.00	3.36**	3.57	3.57	16.00**
GPOK 123 X GPOK 573	-24.91**	-40.95**	-28.88**	-1.61*	-2.55**	2.68**	14.81**	10.71*	24.00**
GPOK 123 X GPOK 578	-40.43**	-44.26**	-55.88**	16.51**	11.98**	25.50**	-8.20*	-15.15**	12.00*
GPOK 349 X GPOK 573	18.29**	-3.49**	-33.42**	-7.83**	-14.04**	2.68**	15.38**	7.14	20.00**
GPOK 349 X GPOK 578	-15.20**	-29.74**	-15.37**	-2.47**	-5.39**	6.04**	-5.08	-15.15**	12.00*
GPOK 573 X GPOK 578	-50.12**	-66.04**	-59.09**	-2.09**	-7.87**	10.07**	36.00**	30.77**	36.00**
S. E. (±)	23.32	27.05	-	0.88	0.98	-	0.67	0.79	-
No. of positive significant crosses	13	4	4	6	4	18	15	9	21
No. of negative significant crosses	15	24	24	12	15	-	2	6	-
Range	-50.12 to 47.09	-66.04 to 47.09	-59.09 to 16.84	-7.83 to 16.51	-14.61 to 11.98	-0.67 to 25.50	-11.11 to 36.00	-18.18 to 30.77	0.00 to 40.00

*,** Significant at 5 and 1% levels, respectively

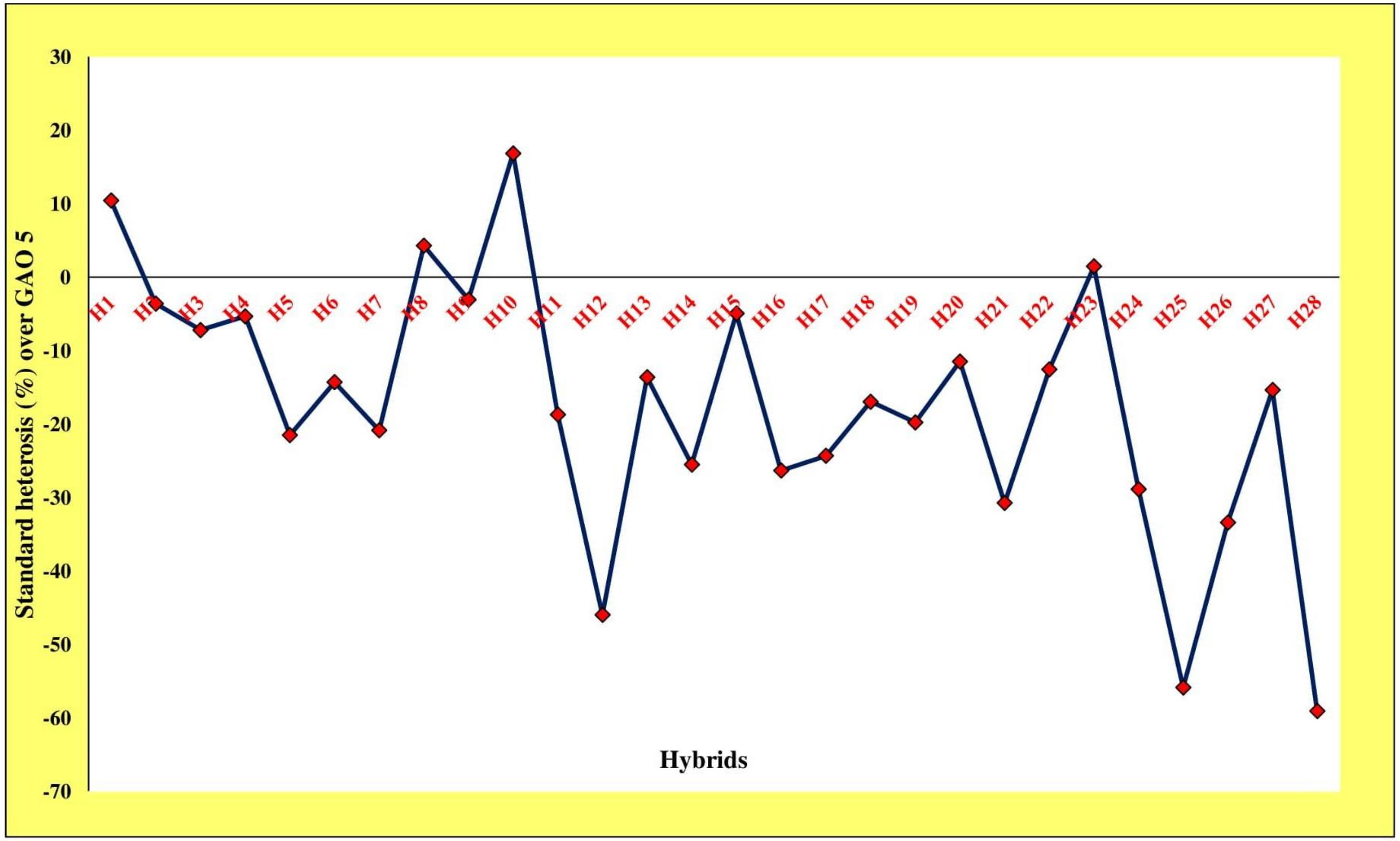

Fig. 3 Phenogram of per cent standard heterosis over GAO 5 for fruit yield per plant

4.2.4 Days to first picking

The range of heterosis over mid parent for days to first picking was -6.59 to 13.17 per cent. Among the 28 hybrids, eleven hybrids expressed significant negative heterosis. The top ranked crosses were AOL 10-22 x GPOK 578 (-6.59%), AOL 10-22 x GPOK 573 (-5.52%), GPOK 349 x GPOK 573 (-5.26%) and GAO 5 x GPOK 573 (-3.66%). The range of heterobeltiosis lied between -13.33 and 9.88%. Seventeen crosses expressed significant negative heterobeltiosis. Among those some top hybrids were AOL 10-22 x GPOK 578 (-13.33%), Pusa Sawani x GPOK 578 (-11.11%) and AOL 10-22 x GPOK 573 (-10.47%). The value of standard heterosis for days to first picking ranged from -1.28 to 21.15 per cent. None of the hybrid recorded significant and negative heterotic effect over standard check GAO 5.

4.2.5 Fruit length

The estimation of heterosis over mid parent for fruit length ranged from -41.51 to 33.68 per cent. Among the crosses, twelve hybrids were depicted significant positive heterosis. The best crosses were GO 2 x GPOK 578 (33.68%), GPOK 349 x GPOK 573 (27.55%), GAO 5 x GPOK 578 (22.55%), Pusa Sawani x GPOK 578 (21.90%) and GO 2 x GPOK 123 (21.52%) and six crosses were showed significant and negative heterotic effects over mid parent. The estimate of heterobeltiosis for fruit length varied between -47.31 and 19.22 per cent. Six crosses showed positive heterobeltiosis. The top three hybrids were GO 2 x GPOK 123 (19.22%), GO 2 x Pusa Sawani (9.85%) and GAO 5 x GPOK 123 (8.69%). On the contrary, 14 crosses exhibited negative heterobeltiosis. The estimates of standard heterosis varied from -47.74 to 22.91 per cent. Nine crosses showed significant and positive standard heterosis. Among these, top three hybrids were GO 2 x GPOK 123 (22.91%), GO 2 x Pusa Sawani (16.95%) and GAO 5 x AOL 10-22 (12.05%).

4.2.6 Fruit girth

Heterosis for fruit girth over mid parent ranged between -16.91 and 11.83 per cent. Hybrid GPOK 349 x GPOK 573 (11.83%) showed positively significant heterotic effect over mid parent and three other hybrids exhibited significantly negative heterosis. Heterosis over better parent was in between -25.13 and 9.92 per cent. None of cross showed positive and significant heterosis, on the other hand, eight crosses exhibited significantly negative heterobeltiosis for fruit girth. The estimates of standard heterosis ranged from -7.59 to 14.45 per cent. Positive and significant heterosis over standard check was reported for GPOK 349 x GPOK 573 (14.45%).

4.2.7 Fruit weight

The estimated heterosis over mid parent lied between -26.85 and 33.33 per cent. The hybrid GPOK 123 x GPOK 578 (33.33%) exhibited the highest heterotic effect followed by GO 2 x GPOK 578 (16.09%), AOL 10-22 x GPOK 578 (12.90%), GAO 5 x GO 2 (11.41%), Pusa Sawani x GPOK 578 (10.35%), GAO 5 x GPOK 123 (8.06%), GAO 5 x GPOK 578 (7.97%), Pusa Sawani x GPOK 573 (7.22%) and GO 2 x Pusa Sawani (6.55%). On the other hand, eight crosses manifested significant and negative heterosis. The value of heterobeltiotic effect for fruit weight was in between -39.76 and 29.93 per cent. Two crosses GPOK 123 x GPOK 578 (29.93%) and Pusa Sawani x GPOK 573 (6.67%) showed positively significant heterobeltiosis. On the opposite, eleven crosses showed negative and significant heterobeltiosis. The range for standard heterosis was from -14.16 to 54.34 per cent. Twenty-four crosses exhibited positive and significant standard heterosis. Out of these, top crosses were GPOK 123 x GPOK 578 (54.34%), GO 2 x GPOK 349 (27.17%), GPOK 123 x GPOK 349 (25.72%), GO 2 x Pusa Sawani (22.25%), GO 2 x GPOK 578 (21.97%) and Pusa Sawani x GPOK 123 (21.39%).

Table 4.2.2 **Heterosis (%) over mid parent (RH), better parent (HB) and standard check (SH) for days to first picking, fruit length and fruit girth in okra**

Crosses	Days to first picking			Fruit length			Fruit girth		
	RH	HB	SH	RH	HB	SH	RH	HB	SH
GAO 5 X GO 2	3.23**	2.56**	2.56**	8.12**	6.49	9.79**	-0.56	-1.06	-1.06
GAO 5 X Pusa Sawani	1.30	0.00	0.00	-1.56	-4.54	1.62	-5.07	-7.85	-2.12
GAO 5 X AOL 10-22	-0.65	-1.28	-1.28	3.91	-3.13	12.05**	-2.72	-4.17	-1.22
GAO 5 X GPOK 123	-1.89**	-3.70**	0.00	9.13**	8.69*	8.69*	0.92	-0.64	-0.64
GAO5 X GPOK 349	-0.62	-3.61**	2.56**	-11.95**	-12.26**	-11.65**	-10.20	-13.41*	-6.74
GAO 5 X GPOK 573	-3.66**	-8.14**	1.28	20.57**	8.23*	8.23*	-11.96*	-20.31**	-1.65
GAO 5 X GPOK 578	-3.57**	-10.00**	3.85**	22.55**	-12.78**	-12.78**	-1.89	-5.42	1.91
GO 2 X Pusa Sawani	1.96**	1.30	0.00	11.61**	9.85**	16.95**	-3.36	-6.65	-0.85
GO2 X AOL 10-22	0.00	0.00	-1.28	0.34	-5.11	9.76**	-3.50	-5.41	-2.50
GO 2 X GPOK 123	1.27	-1.23	2.56**	21.52**	19.22**	22.91**	6.75	5.63	4.57
GO 2 X GPOK 349	1.25	-2.41**	3.85**	9.31**	8.04*	11.38**	0.62	-3.45	3.98
GO 2 X GPOK 573	8.59**	2.91**	13.46**	4.70	-7.28*	-4.40	-16.91**	-25.13**	-7.59
GO 2 X GPOK 578	4.19**	-3.33**	11.54**	33.68**	-5.70	-2.78	6.09	1.77	9.67
Pusa Sawani X AOL 10-22	1.96**	1.30	0.00	-14.68**	-18.08**	-5.24	-6.93	-8.30	-2.60
Pusa Sawani X GPOK 123	-1.91**	-4.94**	-1.28	-0.32	-3.73	2.49	-1.28	-5.60	0.27
Pusa Sawani X GPOK 349	0.63	-3.61**	2.56**	-1.36	-4.03	2.17	-3.97	-4.64	2.71
Pusa Sawani X GPOK 573	1.23	-4.65**	5.13**	-10.93**	-22.20**	-17.18**	-8.37	-14.76**	5.20
Pusa Sawani X GPOK 578	-3.61**	-11.11**	2.56**	21.90**	-14.80**	-9.30**	-2.95	-3.65	3.82
AOL 10-22 X GPOK 123	-1.27	-3.70**	0.00	3.25	-4.11	10.92**	-0.90	-3.86	-0.90
AOL 10-22 X GPOK 349	-2.50**	-6.02**	0.00	-4.57	-10.74**	3.24	-1.13	-3.25	4.20
AOL 10-22 X GPOK 573	-5.52**	-10.47**	-1.28	-7.18*	-21.69**	-9.41**	-5.89	-13.64**	6.59
AOL 10-22 X GPOK 578	-6.59**	-13.33**	0.00	14.76**	-21.61**	-9.33**	2.07	-0.15	7.59
GPOK 123 X GPOK 349	0.00	0.00	3.85**	7.36*	7.36*	6.49	9.92	9.92	6.53
GPOK 123 X GPOK 573	1.22	0.00	6.41**	-8.46**	-9.15**	-8.52*	-8.12	-12.72*	-6.00
GPOK 123 X GPOK 578	13.17**	9.88**	21.15**	-41.51**	-47.31**	-47.74**	-3.35	-13.73**	6.48
GPOK 349 X GPOK 573	-5.26**	-10.00**	3.85**	27.55**	-9.00*	-9.73**	11.83*	6.21	14.45*
GPOK 349 X GPOK 578	-1.78**	-3.49**	6.41**	-6.12	-16.00**	-15.41**	-9.74*	-15.49**	4.30
GPOK 573 X GPOK 578	-1.73**	-5.56**	8.97**	8.10	-23.22**	-22.68**	2.83	2.81	10.78
S. E. (±)	1.09	1.19	-	0.72	0.88	-	0.20	0.23	-
No. of positive significant crosses	6	3	16	12	6	9	1	-	1
No. of negative significant crosses	11	17	-	7	14	11	3	8	-
Range	-6.59 to 13.17	-13.33 to 9.88	-1.28 to 21.15	-41.51 to 33.68	-47.31 to 19.22	-47.74 to 22.91	-16.91 to 11.83	-25.13 to 9.92	-7.59 to 14.45

*,** Significant at 5 and 1% levels, respectively.

4.2.8 Number of fruits per plant

The estimated heterosis over mid parent varied from -51.69 to 62.73 per cent. Among the all crosses, fourteen hybrids were depicted significant and positive heterosis. The hybrid GPOK 123 x GPOK 349 (62.73%) showed the highest heterosis followed by GO 2 x GPOK 123 (58.81%), AOL 10-22 x GPOK 578 (26.74%), GPOK 349 x GPOK 573 (20.63%) and Pusa Sawani x GPOK 123 (19.59%). On the other hand, nine hybrids exhibited significant negative heterosis. The estimates of heterosis over better parent varied from -58.48 to 62.73 per cent. Out of 28 cross combinations, five were registered significant and positive heterobeltiosis. Of these, three top ranking were GPOK 123 x GPOK 349 (62.73%), GO 2 x GPOK 123 (25.72%) and GPOK 349 x GPOK 573 (18.01%). The minimum and the maximum values of standard heterosis for number of fruits per plant were -71.38 and 6.77 per cent, respectively. Only one cross combination GO 2 x GPOK 123 (6.77%) was registered significant and positive standard heterosis. On the contrary, twenty-five hybrids were depicted significant negative heterosis for this important yield-attributing trait.

4.2.9 Plant height

The heterosis for plant height over mid parent lied between -27.88 and 35.09 per cent. The top three hybrids were GO 2 x GPOK 578 (35.09%), GPOK 123 x GPOK 573 (21.65%) and GAO 5 x Pusa Sawani (11.61%). Among the crosses, twelve cross combinations showed significant and negative heterosis. The range of heterosis over better parent was -29.02 to 16.09%, respectively. Out of twenty-eight hybrids, three hybrids showed positive and significant heterobeltiosis. The highest value of heterobeltiosis was observed for the cross GPOK 123 x GPOK 573 (16.09%) followed by GAO 5 x Pusa Sawani (6.13%) and GO 2 x GPOK 578 (3.49%). The value of standard heterosis ranged from -30.98 to 18.10 per cent. Eight cross combinations GO 2 x GPOK 578 (18.10%), GPOK 123 x GPOK 573 (12.88%), GO 2 x GPOK 573 (11.66%), GAO 5 x GO 2 (9.20%), GO 2 x AOL 10-22 (8.28%), GAO 5 x Pusa Sawani (6.13%), GO 2 x GPOK 123 (4.91%) and GO 2 x Pusa Sawani (2.45%) showed significant and positive heterosis over standard check.

4.2.10 Number of nodes per plant

The estimate of heterosis for nodes per plant over mid parent varied between -15.46 and 25.00 per cent. Twenty-two crosses manifested positive and significant heterosis; of these three top ranking crosses were GPOK 123 x GPOK 349 (25.00%), GAO 5 x GPOK 349 (17.17%) and Pusa Sawani x GPOK 578 (16.13%). The heterosis over better parent lied between -18.00 to 25.00 per cent. The hybrid GPOK 123 x GPOK 349 (25.00%) exhibited the highest heterobeltiosis followed by GO 2 x Pusa Sawani (14.00%), GPOK 349 x GPOK 573 (13.64%), Pusa Sawani x GPOK 573 (12.00%), GAO 5 x GPOK 349 (11.54%) and AOL 10-22 x GPOK 349 (8.51%). On the other, five hybrids showed significant and negative heterobeltiosis. The standard heterosis ranged from -21.15 to 11.54 per cent. The crosses GAO 5 x GPOK 349 (11.54%), GO 2 x Pusa Sawani (9.62%), GAO 5 x AOL 10-22 (7.69%), Pusa Sawani x GPOK 573 (7.69%), GAO 5 x GPOK 123 (5.77%) were manifested positive and significant standard heterosis.

Table 4.2.3 Heterosis (%) over mid parent (RH), better parent (HB) and standard check (SH) for fruit weight, number of fruits per plant and plant height in okra

Crosses	Fruit weight			Number of fruits per plant			Plant height		
	RH	HB	SH	RH	HB	SH	RH	HB	SH
GAO 5 X GO 2	11.41**	2.94	21.39**	5.82**	-2.15	-2.15	2.01**	-4.30**	9.20**
GAO 5 X Pusa Sawani	4.37	-1.04	10.40**	-2.08	-9.54**	-9.54**	11.61**	6.13**	6.13**
GAO 5 X AOL 10-22	-9.63**	-15.92**	-2.31	16.88**	-2.00	-2.00	3.70**	-1.23**	-1.23**
GAO 5 X GPOK 123	8.06**	-0.49	18.21**	13.58**	-15.08**	-15.08**	-6.69**	-7.98**	-7.98**
GAO5 X GPOK 349	-20.14**	-32.05**	-3.18	-10.20**	-18.77**	-18.77**	4.89**	-1.23**	-1.23**
GAO 5 X GPOK 573	4.62	-1.28	11.27**	10.75**	-6.46**	-6.46**	0.79*	-2.15**	-2.15**
GAO 5 X GPOK 578	7.97*	3.76	3.76	1.25	-25.38**	-25.38**	5.73**	-15.03**	-15.03**
GO 2 X Pusa Sawani	6.55*	3.68	22.25**	0.82	0.72	-14.46**	0.30	-10.22**	2.45**
GO 2 X AOL 10-22	-0.49	-1.23	16.47**	9.27**	-1.81	-16.62**	5.85**	-5.11**	8.28**
GO 2 X GPOK 123	0.61	0.24	19.08**	58.81**	25.72**	6.77**	-0.73*	-8.06**	4.91**
GO 2 X GPOK 349	-2.33	-10.75**	27.17**	-24.68**	-26.45**	-37.54**	-3.64**	-14.52**	-2.45**
GO 2 X GPOK 573	-4.01	-6.13*	10.69**	-34.4**	-40.58**	-49.54**	7.22**	-2.15**	11.66**
GO 2 X GPOK 578	16.09**	3.43	21.97**	0.47	-21.74**	-33.54**	35.09**	3.49**	18.10**
Pusa Sawani X AOL 10-22	-4.57	-6.47*	8.67*	-7.77**	-17.06**	-29.69**	-13.07**	-13.22**	-21.47**
Pusa Sawani X GPOK 123	5.40*	2.19	21.39**	19.59**	-5.26*	-19.69**	3.11**	-0.63	-3.37**
Pusa Sawani X GPOK 349	-8.30**	-18.26**	16.47**	-20.15**	-21.96**	-33.85**	-11.34**	-12.24**	-20.86**
Pusa Sawani X GPOK 573	7.22**	6.67*	20.23**	-17.12**	-24.86**	-36.31**	-10.15**	-12.05**	-17.18**
Pusa Sawani X GPOK 578	10.35**	0.78	12.43**	13.39**	-11.62**	-25.08**	11.38**	-6.80**	-15.95**
AOL 10-22 X GPOK 123	-4.31	-5.35	12.43**	13.39**	-1.82	-33.54**	1.63**	-1.89**	-4.60**
AOL 10-22 X GPOK 349	-9.94**	-18.26**	16.47**	6.21**	-2.47	-21.08**	-5.32**	-6.44**	-15.34**
AOL 10-22 X GPOK 573	-5.30*	-6.72*	8.38*	6.53**	5.58*	-27.23**	-8.97**	-10.75**	-15.95**
AOL 10-22 X GPOK 578	12.90**	1.24	17.63**	26.74**	7.73**	-27.08**	13.18**	-5.42**	-14.42**
GPOK 123 X GPOK 349	5.84*	5.84	25.72**	62.73**	62.73**	-19.38**	-7.89**	-7.89**	-10.43**
GPOK 123 X GPOK 573	-17.70**	-24.54**	7.51*	3.77	-16.35**	-32.31**	21.65**	16.09**	12.88**
GPOK 123 X GPOK 578	33.33**	29.93**	54.34**	-51.69**	-58.48**	-71.38**	-27.88**	-29.02**	-30.98**
GPOK 349 X GPOK 573	6.03*	-5.84	11.85**	20.63**	18.01**	-41.54**	-2.91**	-21.14**	-23.31**
GPOK 349 X GPOK 578	-5.10*	-15.01**	21.10**	-7.60**	-14.45**	-30.77**	-14.62**	-17.26**	-22.09**
GPOK 573 X GPOK 578	-26.85**	-39.76**	-14.16**	-21.34**	-37.64**	-49.54**	7.00**	-9.72**	-20.25**
S. E. (±)	0.83	1.01	-	1.01	1.15	-	7.44	8.48	-
No. of positive significant crosses	12	2	24	14	5	1	15	3	8
No. of negative significant crosses	8	11	1	9	17	25	12	24	19
Range	-26.85 to 33.33	-39.76 to 29.93	-14.16 to 54.34	-51.69 to 62.73	-58.48 to 62.73	-71.38 to 6.77	-27.88 to 35.09	-29.02 to 16.09	-30.98 to 18.10

*,** Significant at 5 and 1% levels, respectively.

4.2.11 Number of primary branches per plant

The minimum and the maximum values of heterosis over mid parent were -58.54 and 113.70 per cent, respectively. The cross combinations AOL 10-22 x GPOK 578 (113.70%), GO 2 x AOL 10-22 (95.12%), GO 2 x GPOK 123 (83.53%), GAO 5 x GO 2 (78.95%) and GAO 5 x AOL 10-22 (49.53%) depicted the significant and positive relative heterosis. The range of heterobeltiotic effect for number of primary branches per plant was between -66.00 and 70.21 per cent. Four crosses exhibited significant and positive heterobeltiosis, of which three top ranking were GO 2 x AOL 10-22 (70.21%), AOL 10-22 x GPOK 578 (65.96%) and GO 2 x GPOK 123 (56.00%). The value of standard heterosis ranged from -71.67 to 41.67 per cent. Cross GAO 5 x GO 2 (41.67%) showed positive and significant standard heterosis.

4.2.12 Moisture content

The values of heterosis for moisture content over mid parent ranged from -6.05 to 2.53 per cent. The hybrid GO 2 x Pusa Sawani (-6.05%) exhibited the highest heterosis followed by Pusa Sawani x GPOK 578 (-5.20%), GO 2 x GPOK 123 (-4.88%), GO 2 x GPOK 578 (-4.01%), GPOK 349 x GPOK 573 (-3.47%) and GAO 5 x Pusa Sawani (-2.62%). The eight cross combinations showed significant and positive heterosis. The minimum and the maximum values for heterobeltiosis were -8.66 and 3.70 per cent, respectively. Nineteen crosses manifested significantly negative heterobeltiosis, which was considered favourable because low moisture content prevents the growth of microbes that may spoil it within a few days and deteriorate the quality during storage conditions. Among these crosses, GO 2 x Pusa Sawani (-8.66%) exhibited the highest negative effect followed by GO 2 x GPOK 123 (-7.45%), Pusa Sawani x GPOK 578 (-6.22%) and GO 2 x GPOK 573 (-5.95%). The estimates of standard heterosis were in between -2.09 and 3.70 per cent. The cross combinations Pusa Sawani x GPOK 578 (-2.09%), GAO 5 x Pusa Sawani (-1.57%), GO 2 x Pusa Sawani (-1.20%) and GAO 5 x GPOK 123 (-0.95%) exhibited significant and negative heterosis over standard check. On the other hand, eleven crosses registered significant and positive effect, which may not desirable for quality improvement.

4.2.13 Ash content

As ash content in fruits contribute the mineral contents, therefore, positive estimate of heterosis might be desirable. The magnitude of heterosis over mid parent ranged from -18.69 to 36.96 per cent. The four crosses GAO 5 x AOL 10-22 (36.96%), AOL 10-22 x GPOK 123 (28.76%), Pusa Sawani x GPOK 123 (17.00%) and GAO 5 x GPOK 578 (15.62%) showed significant and positive effects for relative heterosis. Likewise, the former two hybrids GAO 5 x AOL 10-22 (32.57%) and AOL 10-22 x GPOK 123 (25.29%) exhibited significant and positive heterobeltiosis effects. The estimates of heterotic effect over check were observed between -2.81 and 44.09 per cent. Interestingly, nineteen crosses exhibited significant positive heterosis. The most superior hybrids as far as standard heterosis is concerned were GPOK 573 x GPOK 578 (44.09%), GAO 5 x AOL 10-22 (41.64%), Pusa Sawani x GPOK 123 (41.57%), Pusa Sawani x GPOK 349 (41.14%), GAO 5 x GPOK 578 (37.82%) and GO 2 x Pusa Sawani (37.54%).

Table 4.2.4 Heterosis (%) over mid parent (RH), better parent (HB) and standard check (SH) for number of nodes per plant, number of primary branches per plant, moisture content and ash content in okra

Crosses	Number of nodes per plant			Number of primary branches per plant			Moisture content			Ash content		
	RH	HB	SH	RH	HB	SH	RH	HB	SH	RH	HB	SH
GAO 5 X GO 2	-2.97	-5.77*	-5.77*	78.95**	41.67*	41.67*	-1.87**	-5.57**	2.14**	-18.69**	-30.10**	-2.81
GAO 5 X Pusa Sawani	7.84**	5.77*	5.77*	0.00	-3.12	3.33	-2.62**	-3.64**	-1.57**	-4.90	-18.71**	14.55
GAO 5 X AOL 10-22	13.13**	7.69**	7.69**	49.53*	33.33	33.33	0.84*	-0.38	-0.38	36.96**	32.57**	41.64**
GAO 5 X GPOK 123	14.58**	5.77*	5.77*	-23.64	-30.00	-30.00	-2.09**	-3.20**	-0.95*	7.42	6.84	8.00
GAO5 X GPOK 349	17.17**	11.54**	11.54**	31.48	18.33	18.33	3.82**	3.70**	3.70**	8.98	-4.89	27.59**
GAO 5 X GPOK 573	6.93**	3.85	3.85	-8.70	-30.00	-30.00	0.43	-0.20	-0.20	10.33	-3.31	28.46**
GAO 5 X GPOK 578	7.37**	-1.92	-1.92	32.56	-5.00	-5.00	-0.93*	-3.02**	1.26**	15.62*	-0.42	37.82**
GO 2 X Pusa Sawani	15.15**	14.00**	9.62**	21.21	-6.25	0.00	-6.05**	-8.66**	-1.20*	-1.75	-2.40	37.54**
GO 2 X AOL 10-22	10.42**	8.16**	1.92	95.12**	70.21**	33.33	-0.96*	-5.80**	1.89**	-17.67**	-27.20**	1.22
GO 2 X GPOK 123	5.38*	0.00	-5.77*	83.53**	56.00*	30.00	-4.88**	-7.45**	0.11	0.09	-13.58*	20.17*
GO 2 X GPOK 349	-12.50**	-14.29**	-19.23**	22.89	6.25	-15.00	-1.99**	-5.79**	1.90**	-12.76*	-14.30*	19.16*
GO 2 X GPOK 573	6.12**	6.12*	0.00	7.46	2.86	-40.00	-1.66**	-5.95**	1.73**	-12.98*	-14.92*	18.30*
GO 2 X GPOK 578	10.87**	4.08	-1.92	18.03	2.86	-40.00	-4.01**	-5.68**	2.02**	-4.54	-4.77	32.42**
Pusa Sawani X AOL 10-22	-15.46**	-18.00**	-21.15**	-4.50	-17.19	-11.67	2.53**	0.24	2.39**	4.39	-8.23	29.32**
Pusa Sawani X GPOK 123	6.38**	0.00	-3.85	19.30	6.25	13.33	-0.91*	-1.00*	1.31**	17.00**	0.46	41.57**
Pusa Sawani X GPOK 349	5.15*	2.00	-1.92	-35.71	-43.75*	-40.00	-0.45	-1.61**	0.50	2.62	0.15	41.14**
Pusa Sawani X GPOK 573	13.13**	12.00**	7.69**	16.67	-12.50	-6.67	1.47**	-0.23	1.92**	0.37	-2.51	37.39**
Pusa Sawani X GPOK 578	16.13**	8.00**	3.85	37.78	-3.13	3.33	-5.20**	-6.22**	-2.09**	-16.64**	-17.38**	16.43
AOL 10-22 X GPOK 123	7.69**	4.26	-5.77*	-5.15	-8.00	-23.33	-0.67	-2.97**	-0.71	28.76**	25.29**	33.86**
AOL 10-22 X GPOK 349	8.51**	8.51**	-1.92	38.95	37.50	10.00	1.99**	0.87	0.64	5.11	-5.59	26.66**
AOL 10-22 X GPOK 573	10.42**	8.16**	1.92	13.92	-4.26	-25.00	2.48**	1.89**	0.60	-0.15	-9.92	19.67*
AOL 10-22 X GPOK 578	-6.67**	-10.64**	-19.23**	113.7**	65.96*	30.00	-1.65**	-4.86**	-0.67	11.05	-1.61	36.17**
GPOK 123 X GPOK 349	25.00**	25.00**	5.77*	-12.00	-12.00	-26.67	-1.57**	-1.57**	0.71	0.78	0.78	1.87
GPOK 123 X GPOK 573	1.10	-2.13	-11.54**	6.12	4.00	-13.33	-0.46	-1.70**	0.59	-12.10	-22.93**	3.39
GPOK 123 X GPOK 578	11.83**	6.12*	0.00	-58.54*	-66.00**	-71.67**	1.92**	0.13	2.46**	-0.34	-12.26	16.57
GPOK 349 X GPOK 573	14.94**	13.64**	-3.85	15.79	-12.00	-26.67	-3.47**	-4.44**	-0.22	-5.54	-18.27**	13.11
GPOK 349 X GPOK 578	-10.42**	-12.24**	-17.31**	37.5	14.58	-8.33	1.59**	1.06*	0.83	-5.13	-5.59	26.66**
GPOK 573 X GPOK 578	11.11**	6.38*	-3.85	16.22	-10.42	-28.33	-1.19**	-3.38**	0.88	5.74	4.11	44.09**
S. E. (±)	0.82	0.94	-	0.16	0.17	-	0.76	0.84	-	0.21	0.24	-
No. of +ive significant crosses	22	15	7	4	4	1	8	3	11	4	2	19
No. of -ive significant crosses	4	5	8	1	2	1	15	19	4	5	9	-
Range	-15.46 to 25.00	-18.00 to 25.00	-21.15 to 11.54	-58.54 to 113.70	-66.00 to 70.21	-71.67 to 41.67	-6.05 to 2.53	-8.66 to 3.70	-2.09 to 3.70	-18.69 to 36.96	-30.10 to 32.57	-2.81 to 44.09

*,** Significant at 5 and 1% levels, respectively.

4.3 COMBINING ABILITY ANALYSIS

4.3.1 ANALYSIS OF VARIANCE FOR COMBINING ABILITY

The mean squares due to general combining ability and specific combining ability for different traits are presented in Table 4.3. The gca and sca mean squares were observed significant for all the traits except sca mean square for first fruiting node. This indicated that both additive and non-additive gene actions played important role for the inheritance of these traits. Whereas, the importance of additive gene action for expression of first fruiting node was noticed owing to the significant mean square of general combining ability. The SCA variance component was observed higher than the respective GCA variance component and below unit potence ratio for all the traits indicated that the predominance of non-additive gene action for the inheritance of the traits.

4.3.2 GENERAL COMBINING ABILITY EFFECTS

The character wise estimates of general combining ability effects for each parent is presented in Table 4.4. The salient features of general combining ability effects of different characters are given below.

4.3.2.1 Fruit yield per plant

Five parents *viz.,* GAO 5, GO 2, Pusa Sawani, AOL 10-22 and GPOK 349 recorded significant gca effects in desired direction for this trait. While, parents GPOK 123, GPOK 573 and GPOK 578 were observed poor general combiners owing to significant and negative gca effect.

Table 4.3 Mean square due to general and specific combining ability for different characters in okra

Sources of variation	d. f.	Fruit yield per plant	Days to 50% flowering	First fruiting node	Days to first picking	Fruit length	Fruit girth	Fruit weight
gca	7	6190.850**	22.001**	2.225**	24.780**	12.711**	0.327**	3.781**
sca	28	1339.750**	5.101**	0.621	3.481**	1.260**	0.104**	1.640**
error	70	384.570	0.522	0.346	0.841	0.301	0.025	0.442
σ^2 gca	-	33.640	0.046	0.030	0.073	0.026	0.002	0.039
σ^2 sca	-	316.200	0.433	0.291	0.710	0.251	0.020	0.363
Potence ratio	-	0.424	0.424	0.412	0.408	0.416	0.420	0.428

Table 4.3 Contd…

Sources of variation	d. f.	Number of fruits per plant	Plant height	Number of nodes per plant	Number of primary branches per plant	Moisture content	Ash content
gca	7	36.351**	695.370**	3.040**	0.470**	4.821**	0.741**
sca	28	7.011**	83.601**	2.041**	0.241**	2.520**	0.380**
error	70	0.780	44.730	0.445	2.022	0.431	2.841
σ^2 gca	-	0.071	3.911	0.039	0.002	0.038	0.003
σ^2 sca	-	0.642	36.781	0.371	0.017	0.352	0.023
Potence ratio	-	0.436	0.424	0.420	0.424	0.432	0.520

*,** Significant at 5 and 1% levels, respectively.

4.3.2.2 Days to 50% flowering

The parents GAO 5, GO 2, Pusa Sawani, AOL 10-22 and GPOK 349 exhibited significant and negative gca effects, hence these parents were consider as good general combiner for early flowering in okra. On the other, parents GPOK 123, GPOK 573 and GPOK 578 were found poor combiners.

4.3.2.3 First fruiting node

The parents GAO 5, Pusa Sawani, GPOK 123 and GPOK 349 depicted significant and negative gca effects, which were showed good general combining ability effects for first fruiting node. While, parents GO 2, GPOK 573 and GPOK 578 manifested significant and positive gca effects.

4.3.2.4 Days to first picking

The parents GAO 5, GO 2, Pusa Sawani and AOL 10-22 expressed negative and significant gca effects. Hence, theses four parents were consider as good general combiners for this trait. On the contrary, parents GPOK123, GPOK349, GPOK573 and GPOK578 were observed poor combiners for earliness.

4.3.2.5 Fruit length

All the parents except GPOK 573 and GPOK 578 have significant and positive gca effects were consider as good general combiner for fruit length. However, the parent GPOK 578 was poor combiner for increasing the length of fruit. In contrast to this, the genotype GPOK 578 may useful for breeding baby okra.

4.3.2.6 Fruit girth

Parents GPOK 349, GPOK 573 and GPOK 578 showed significant and positive gca effects. While, significant and negative gca effects were observed for GAO 5, GO 2, Pusa Sawani, AOL 10-22 and GPOK 123 parents.

4.3.2.7 Fruit weight

Significant and positive gca effects were observed for GO 2, Pusa Sawani, GPOK 123 and GPOK 349 parent and were considered as good general combiners. Whereas, parents GAO 5, AOL 10-22, GPOK 573 and GPOK 578 had significant and negative gca effects.

4.3.2.8 Number of fruits per plant

For this trait, parents GAO 5, GO 2, Pusa Sawani and AOL 10-22 manifested positive and significant gca effects and hence, considered as good general combiners. On the opposite, GPOK 349 and GPOK 578 depicted as poor combiners for number of fruits per plant.

4.3.2.9 Plant height

Parents GAO 5, GO 2 and GPOK 123 manifested significant and positive gca effects. On the other hand, parents Pusa Sawani, AOL 10-22 and GPOK 573 were observed poor combiners as they showed significant and negative gca effects.

4.3.2.10 Number of nodes per plant

Three parent *viz.*, GAO 5, Pusa Sawani and GPOK 573 had significant and positive gca effects and were identified as good general combiners. On the opposite, parents GO 2, AOL 10-22, GPOK 123, GPOK 349 and GPOK 578 recorded significant and negative gca effects.

4.3.2.11 Number of primary branches per plant

The parents GAO 5, GO 2, Pusa Sawani and AOL 10-22 exhibited significant and positive gca effects and identified as good combiners. While, parents GPOK 349 and GPOK 573 had significant and negative gca effects.

Table 4.4 General combining ability effects for different characters in okra

Parents	Fruit yield per plant	Days to 50% flowering	First fruiting node	Days to first picking	Fruit length	Fruit girth	Fruit weight
GAO 5	20.53**	-1.22**	-0.42**	-1.20**	0.51**	-0.23**	-0.84*
GO 2	26.07**	-0.12**	0.72**	-0.10**	1.13**	-0.14**	0.49**
Pusa Sawani	15.60**	-1.06**	-0.22**	-1.47**	0.37**	-0.04**	0.03**
AOL 10-22	0.03**	-1.56**	0.05	-2.00**	0.82**	-0.05**	-0.26**
GPOK 123	-3.43**	0.08**	-0.02**	0.43**	0.25**	-0.14**	0.74**
GPOK 349	15.03**	-0.22**	-0.12**	0.20**	0.18**	0.12**	0.79**
GPOK 573	-33.33**	1.11**	0.62**	1.37**	-0.88	0.27**	-0.59**
GPOK 578	-40.50**	3.01**	0.08**	2.77**	-2.38**	0.22**	-0.36**
S. E. (gi) ±	11.118	0.411	0.334	0.520	0.311	0.090	0.377

Table 4.4 Contd…

Parents	Number of fruits per plant	Plant height	Number of nodes per plant	Number of primary branches per plant	Moisture content	Ash content
GAO 5	3.36**	5.66**	1.02**	0.27**	-0.36**	-0.28**
GO 2	1.24**	15.72**	-0.02**	0.06**	1.45**	-0.06**
Pusa Sawani	0.77**	-2.78**	0.42**	0.16**	-0.23**	0.39**
AOL 10-22	0.28**	-2.11**	-0.42**	0.22**	-0.80**	-0.07**
GPOK 123	-1.10	2.09**	-0.25**	-0.10	0.00	-0.41**
GPOK 349	-0.14**	-5.94	-0.25**	-0.05**	-0.05**	0.04**
GPOK 573	-1.53	-0.17**	0.25**	-0.32**	-0.47**	0.06**
GPOK 578	-2.89**	-12.47	-0.75**	-0.26	0.46**	0.33**
S. E. (gi) ±	0.501	3.792	0.378	0.081	0.372	0.096

*,** Significant at 5 and 1% levels, respectively.

4.3.2.12 Moisture content

Parents GAO 5, Pusa Sawani, AOL 10-22, GPOK 349 and GPOK 573 showed significant and negative gca effects. Whereas, parents GO 2 and GPOK 578 observed to be poor general combiner as they showed significant and positive gca effects for moisture content.

4.3.2.13 Ash content

Four parents *viz.*, Pusa Sawani, GPOK 349, GPOK 573 and GPOK 578 were observed good general combiners as they depicted significant and positive gca effects for ash content. The rest of parents *viz.*, GAO5, GO2, AOL 10-22 and GPOK 123 showed significant and negative gca effects.

4.3.3 SPECIFIC COMBINING ABILITY EFFECTS

The character wise estimates of specific combining ability effects are presented in Table 4.5.1 to 4.5.3. The salient features of specific combining ability of different characters are given below.

4.3.3.1 Fruit yield per plant

The sca effects observed significant and positive for three crosses. These were GO 2 x GPOK 123, AOL 10-22 x GPOK 578 and GPOK 123 x GPOK 349. The hybrids showed good sca effects involved good x poor, good x poor and poor x good gca effects of parents, respectively. Opposite to that, six crosses manifested significant and negative sca effects.

4.3.2.2 Days to 50% flowering

Total nine crosses manifested significant sca effects. Out of these the cross combinations Pusa Sawani x GPOK 578 and AOL 10-22 x GPOK 578 depicted negative and significant sca effects for days to 50% flowering.

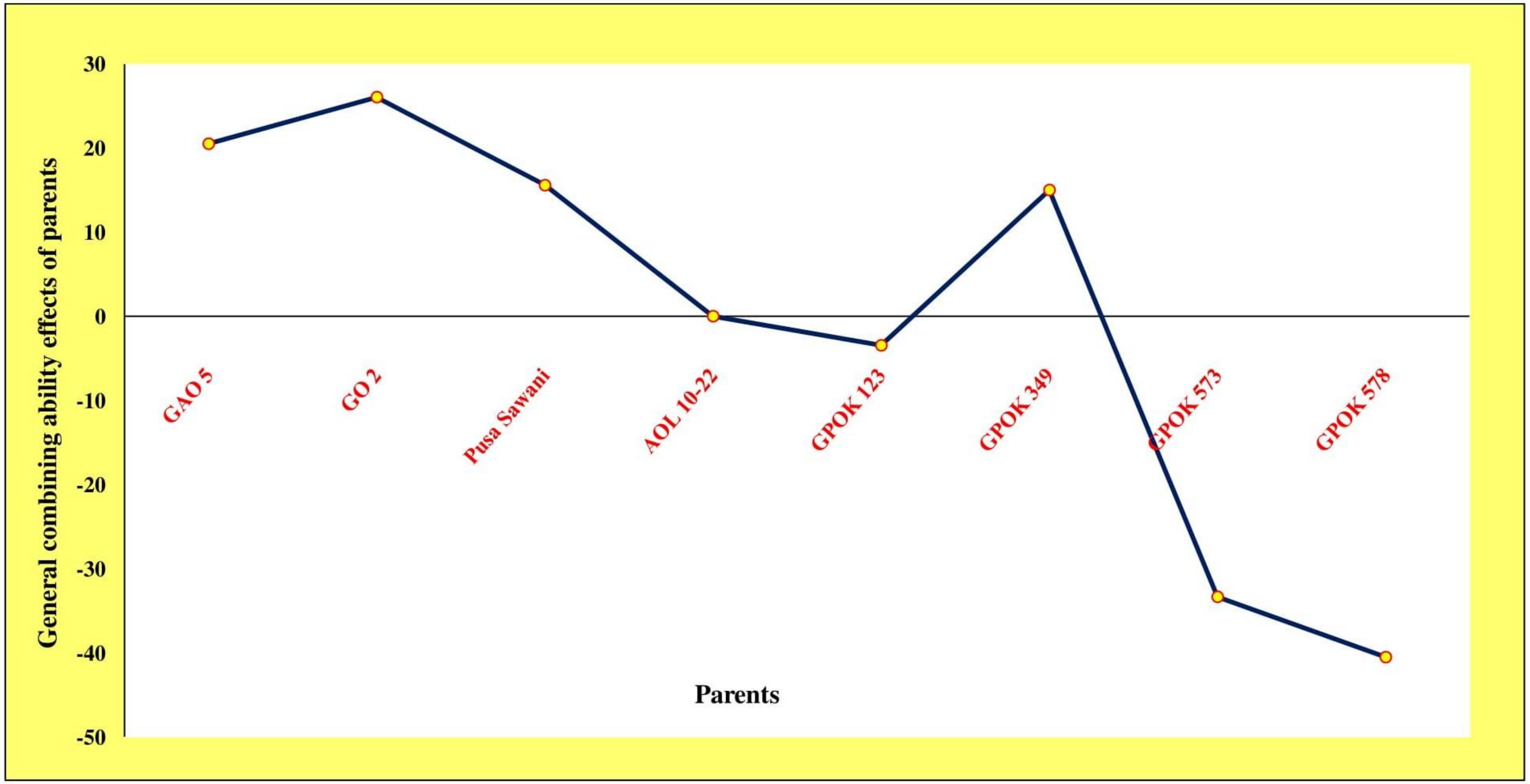

Fig. 4 Phenogram based on general combining ability effects of parents for fruit yield per plant

Table 4.5.1 Specific combining ability effects for fruit yield per plant, days to 50% flowering, first fruiting node and days to first picking in okra

Crosses	Fruit yield per plant	Days to 50% flowering	First fruiting node	Days to first picking
GAO 5 X GO 2	19.51	-0.20	0.57	0.78
GAO 5 X Pusa Sawani	-5.02	1.74**	1.50**	0.81
GAO 5 X AOL 10-22	1.54	0.57	-0.06	0.68
GAO 5 X GPOK 123	9.68	-0.40	-0.70	-1.09
GAO 5 X GPOK 349	-49.12*	1.57**	-0.60	0.48
GAO 5 X GPOK 573	17.24	-1.43	-0.33	-1.35
GAO 5 X GPOK 578	8.08	-2.33	0.20	-1.42
GO 2 X Pusa Sawani	9.11	-1.36	-0.30	-0.29
GO 2 X AOL 10-22	6.34	0.14	0.47	-0.42
GO 2 X GPOK 123	59.48**	-1.16	0.17	-0.85
GO 2 X GPOK 349	-47.66*	0.14	0.94*	0.05
GO 2 X GPOK 573	-67.29**	4.47**	-1.46*	3.88**
GO 2 X GPOK 578	20.54	1.24**	1.40**	1.48**
Pusa Sawani X AOL 10-22	-39.19	2.07**	0.40	1.61**
Pusa Sawani X GPOK 123	15.61	-1.23	-0.23	-1.49
Pusa Sawani X GPOK 349	-56.19**	1.07**	0.20	0.75
Pusa Sawani X GPOK 573	-2.82	0.40*	0.14	0.91*
Pusa Sawani X GPOK 578	22.68	-3.16**	0.34	-1.82
AOL 10-22 X GPOK 123	-5.82	-0.73	0.54	-0.29
AOL 10-22 X GPOK 349	-3.62	-0.43	0.30	-0.05
AOL 10-22 X GPOK 573	-3.26	-1.43	-0.43	-1.89
AOL 10-22 X GPOK 578	49.24**	-2.66*	0.44	-2.62
GPOK 123 X GPOK 349	32.18*	-0.40	0.34	-0.49
GPOK 123 X GPOK 573	4.88	-2.06	0.27	-0.32
GPOK 123 X GPOK 578	-55.29**	7.37**	-0.20	5.95**
GPOK 349 X GPOK 573	-24.92	-1.76	0.04	-1.42
GPOK 349 X GPOK 578	27.24	-2.00	-0.10	-1.49
GPOK 573 X GPOK 578	-33.39*	-1.33	1.17*	-1.32
S. E. (sij) ±	35.769	1.323	1.074	1.673
No. of positive signi. crosses	3	7	4	5
No. of negative signi. crosses	6	2	1	0

*,** Significant at 5 and 1% levels, respectively.

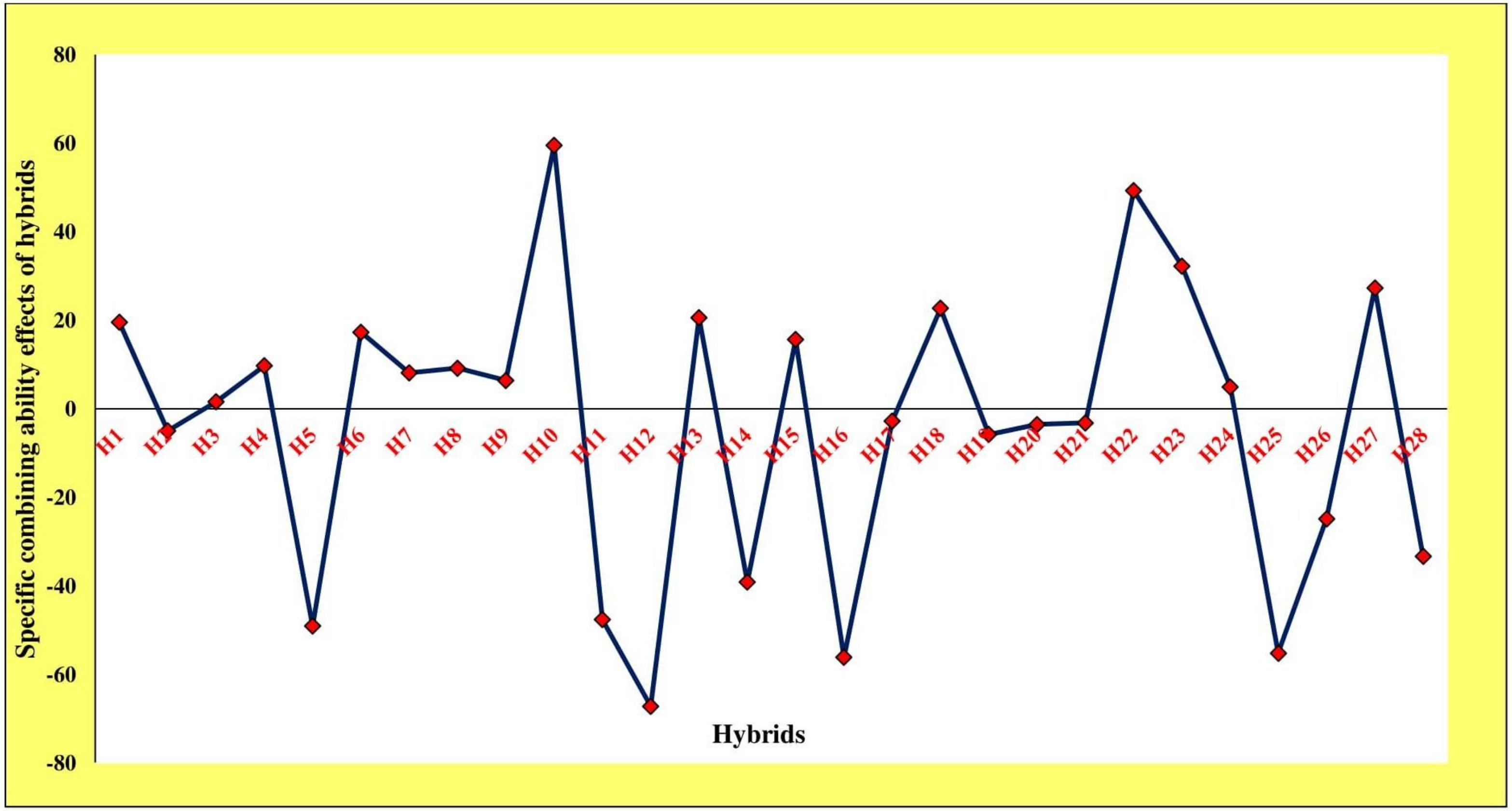

Fig. 5 Phenogram based on specific combining ability effects of hybrids for fruit yield per plant

4.3.2.3 First fruiting node

Only one cross combination GO 2 x GPOK 573 exhibited negative and significant sca effect for first fruiting node.

4.3.3.4 Days to first picking

None of cross exhibited significant and negative sca effect for early picking. On the other hand, five crosses depicted significant and positive sca effects.

4.3.3.5 Fruit length

Significant and positive sca effect were exhibited by five crosses *viz*.; GAO 5 x GPOK 573, GO 2 x Pusa Sawani, GO 2 x GPOK 123, GO 2 x GPOK 578 and Pusa Sawani x GPOK 578. On the other hand, three crosses viz.; GAO 5 x GPOK 349, Pusa Sawani x AOL 10-22 and GPOK 123 x GPOK 578 exhibited significant and negative sca effects.

4.3.3.6 Fruit girth

Out of 28 cross combinations, four crosses viz.; GO 2 x GPOK 123, GO 2 x GPOK 578, GPOK 123 x GPOK 349 and GPOK 349 x GPOK 573 exhibited significant and positive sca effects for fruit girth. Whereas, three crosses exhibited significant and negative sca effects.

4.3.3.7 Fruit weight

Significant and positive sca effects were observed for three crosses. The cross combination GPOK 123 x GPOK 578 was the best followed by Pusa Sawani x GPOK 573, GAO 5 x GO 2. On the contrary, two crosses exhibited significant and negative sca estimates, hence they were considered as poor combiners for fruit weight.

Table 4.5.2 Specific combining ability effects for fruit length, fruit girth, fruit weight, number of fruits per plant and plant height in okra

Crosses	Fruit length	Fruit girth	Fruit weight	Number of fruits per plant	Plant height
GAO 5 X GO 2	-0.15	0.12	1.12*	0.57	-3.61
GAO 5 X Pusa Sawani	-0.34	-0.04	0.31	-0.55	11.55*
GAO 5 X AOL 10-22	0.42	0.03	-0.87	1.57**	2.89
GAO 5 X GPOK 123	0.60	0.15	0.51	0.12	-8.65
GAO 5 X GPOK 349	-1.67**	-0.49*	-2.01**	-1.64	6.72
GAO 5 X GPOK 573	1.68**	-0.32	1.03	2.41**	-0.05
GAO 5 X GPOK 578	0.77	-0.04	-0.07	-0.33	-1.75
GO 2 X Pusa Sawani	0.81*	-0.05	0.35	0.50	-2.51
GO 2 X AOL 10-22	-0.47	-0.15	-0.03	0.53	3.15
GO 2 X GPOK 123	1.62**	0.38**	-0.72	6.97**	-4.71
GO 2 X GPOK 349	0.36	0.09	0.16	-3.59**	-4.68
GO 2 X GPOK 573	-0.39	-0.79**	-0.36	-4.80**	4.89
GO 2 X GPOK 578	1.30**	0.35**	0.70	0.03	24.19**
Pusa Sawani X AOL 10-22	-1.44*	-0.25	-0.47	-1.83	-10.68
Pusa Sawani X GPOK 123	0.02	0.02	0.00	1.71*	4.79
Pusa Sawani X GPOK 349	0.05	-0.09	-0.61	-2.32*	-6.18
Pusa Sawani X GPOK 573	-1.11	-0.08	1.20*	-1.46	-7.95
Pusa Sawani X GPOK 578	1.30*	-0.11	0.06	2.33**	5.69
AOL 10-22 X GPOK 123	0.54	-0.05	-0.74	-0.79	2.79
AOL 10-22 X GPOK 349	-0.27	0.02	-0.33	0.94	-0.85
AOL 10-22 X GPOK 573	-0.67	0.02	0.12	1.00	-7.28
AOL 10-22 X GPOK 578	0.85	0.14	0.95	2.39**	6.69
GPOK 123 X GPOK 349	0.67	0.25*	-0.25	2.69**	0.29
GPOK 123 X GPOK 573	0.01	-0.69**	-0.98	1.28	19.85**
GPOK 123 X GPOK 578	-3.00**	0.15	4.19**	-5.83**	-15.51*
GPOK 349 X GPOK 573	-0.06	0.34**	-0.53	-1.69	-11.45
GPOK 349 X GPOK 578	0.79	-0.24	0.31	2.01*	2.19
GPOK 573 X GPOK 578	1.01	0.01	-2.38**	-0.67	-1.58
S. E. (sij) ±	1.000	0.288	1.213	1.610	12.200
No. of positive signi. crosses	5	4	3	8	3
No. of negative sign. crosses	3	3	2	4	1

*,** Significant at 5 and 1% levels, respectively.

4.3.3.8 Number of fruits per plant

For this trait, eight cross combinations manifested significant and positive sca effects. Among these, three top ranking were GO 2 x GPOK 123, GPOK 123 x GPOK 349 and GAO 5 x GPOK 573. On the other hand, four crosses exhibited significant and negative sca estimates.

4.3.3.9 Plant height

The cross combinations GAO 5 x Pusa Sawani, GO 2 x GPOK 578 and GPOK 123 x GPOK 573 manifested significant and positive sca effects for plant height. Whereas, GPOK 123 x GPOK 578 cross exhibited significant and negative sca effects.

4.3.3.10 Number of nodes per plant

The eleven cross combinations showed significant and positive sca effects and some of these were GPOK 123 x GPOK 349, GPOK 123 x GPOK 578, GO 2 x Pusa Sawani , GAO 5 x GPOK 349 and Pusa Sawani x GPOK 578. Opposite to that, only three crosses exhibited significant and negative sca effects.

4.3.3.11 Number of primary branches per plant

Total twelve cross combinations exhibited significant and positive sca effects. Among them, three top ranked combinations were GO 2 x GPOK 123, AOL 10-22 x GPOK 578 and GAO 5 x GO 2. The significant sca estimates for less number of primary branches per plant observed in eight crosses.

4.3.3.12 Moisture content

For this trait, seven cross combinations showed significant and negative sca effects. Among these, the best three hybrids were GO 2 x Pusa Sawani, Pusa Sawani x GPOK 578 and GO 2 x GPOK 573. Opposite to that, twelve crosses were poor combiners as they exhibited significant and positive sca effects.

Table 4.5.3 Specific combining ability effects for number of nodes per plant, number of primary branches per plant, moisture content and ash content in okra

Crosses	Number of nodes per plant	No. of primary branches per plant	Moisture content	Ash content
GAO 5 X GO 2	-1.39	0.73**	1.56**	-0.90**
GAO 5 X Pusa Sawani	0.18	-0.13	-0.02	-0.54**
GAO 5 X AOL 10-22	1.34**	0.41**	0.05*	1.16**
GAO 5 X GPOK 123	0.84*	-0.54**	-1.25	-0.05
GAO 5 X GPOK 349	1.84**	0.37**	2.84**	0.41**
GAO 5 X GPOK 573	0.01	-0.32*	-0.13*	0.42**
GAO 5 X GPOK 578	0.01	0.12	0.20**	0.59**
GO 2 X Pusa Sawani	1.88**	0.01	-3.06*	0.29**
GO 2 X AOL 10-22	1.38**	0.62**	0.20**	-0.93**
GO 2 X GPOK 123	-0.12	0.87**	-2.15	0.29*
GO 2 X GPOK 349	-2.46**	-0.08	-0.55	-0.21
GO 2 X GPOK 573	0.38	-0.31*	-0.27*	-0.27
GO 2 X GPOK 578	1.04*	-0.37**	-0.95	0.12
Pusa Sawani X AOL 10-22	-3.06**	-0.38*	2.32**	-0.08
Pusa Sawani X GPOK 123	-0.22	0.44**	0.57**	0.84**
Pusa Sawani X GPOK 349	0.11	-0.68**	-0.08*	0.37**
Pusa Sawani X GPOK 573	1.28**	0.26*	1.58**	0.17*
Pusa Sawani X GPOK 578	1.61**	0.40**	-2.83*	-1.07**
AOL 10-22 X GPOK 123	0.28	-0.35*	-0.60	0.93**
AOL 10-22 X GPOK 349	0.94	0.26*	0.62**	0.15
AOL 10-22 X GPOK 573	1.11*	-0.17	1.00**	-0.20
AOL 10-22 X GPOK 578	-1.56*	0.87**	-1.03	0.30**
GPOK 123 X GPOK 349	2.11**	-0.15	-0.12*	-0.65**
GPOK 123 X GPOK 573	-1.39	0.38**	0.19**	-0.61**
GPOK 123 X GPOK 578	1.61**	-0.84**	0.88**	-0.26
GPOK 349 X GPOK 573	-0.06	0.06	-0.46	-0.61**
GPOK 349 X GPOK 578	-1.39	0.37**	-0.48	-0.24
GPOK 573 X GPOK 578	0.44	0.24	-0.02*	0.54**
S. E. (sij) ±	1.217	0.260	1.198	0.308
No. of positive signi. crosses	11	12	12	12
No. of negative sign. crosses	3	8	7	7

*,** Significant at 5 and 1% levels, respectively.

4.3.3.13 Ash content

Out of twenty-eight, twelve cross combinations were manifested significant and positive sca effects. Among them, the best was GAO 5 x AOL 10-22 followed by AOL 10-22 x GPOK 123 and Pusa Sawani x GPOK 123. While, seven crosses showed significant and negative sca effects for ash content.

4.4 ESTIMATION OF COMPONENTS OF GENETIC VARIATION AND GRAPHICAL ANALYSIS

The data of parents and hybrids were analysed for diallel cross. In those cases where additive-dominance model was satisfactory as indicated by non-significant deviation of b (Wr, Vr) from unity, but significant deviation from zero (Hayman, 1954b), components of genetic variance were calculated in addition to graphical analysis. In those cases where additive-dominance model was not adequate, only graphical analysis performed to obtain genetic information regarding the parents. The material under investigation was tested for agreement with the assumptions basic to diallel analysis. The assumptions of diploid segregation, no maternal effects, absence of multiple alleles, absence of linkage, absence of lethal genes and no G x E interaction were difficult to evaluate independently of one another. Therefore, ‘t’ test calculated as deviation of regression coefficient 'b' from zero and unity were employed to diallel analysis for each of the characters studied (Table 4.6).

The information regarding the dominance was given where additive-dominance model did not fit but regression coefficient was significant. The character wise results of regression co-efficient (Table 4.6), genetic components of variation (Table 4.7, 4.8, 4.9 and 4.10) and graphical analysis (Fig. 6 to 17) have been presented and discussed as under.

Table 4.6 Regression coefficient of Wr on Vr with their standard errors and deviation from zero and unity for various characters in okra

Characters	b	SE (b) ±	(b - 0)/SE	(b-1)/SE
Fruit yield per plant	0.8718	0.2944	2.96*	-0.44
Days to 50% flowering	0.5266	0.1188	4.43**	-1.98
First fruiting node	0.8828	0.4473	1.97	-0.26
Days to first picking	0.5620	0.1361	4.13**	-1.22
Fruit length	0.8102	0.0612	13.24**	-3.10**
Fruit girth	0.7449	0.2160	3.45**	-1.18
Fruit weight	0.2695	0.1988	2.36*	-1.68
Number of fruits per plant	0.5130	0.1963	2.61*	-1.48
Plant height	0.7135	0.1537	4.64**	-1.86
Number of nodes per plant	0.2002	0.1188	1.69	-6.73**
Number of primary branches per plant	0.3857	0.1749	2.20*	-3.51**
Moisture content	0.5587	0.4765	1.17	-0.93
Ash content	0.3622	0.5380	0.67	-1.19

4.4.1 Fruit yield per plant

The data for fruit yield per plant, fitted to the additive-dominance model (Table 4.6). Both additive (D) and dominance (H_1 and H_2) components were significant (Table 4.7). This indicated the importance of both additive and non-additive genetic components for controlling the fruit yield. The value of F (covariance of additive and non-additive effects) was significant suggested asymmetrical distribution of dominant and recessive genes in the parents. The mean degree of dominance $[(H_1/D)^{1/2}]$ was 1.24 which suggested the over dominance. This was further confirmed by Vr, Wr graph (Fig. 6). The value of $H_2/4H_1$ (proportion of genes with positive and negative effects in parents) was 0.18, which indicated unequal distribution of positive and negative alleles in the parents. The value (1.83) of K_D / K_R (proportion of dominant and recessive genes in the parents) indicated presence of higher proportion of dominant genes. The value of h^2/H_2 (0.12) suggested that atleast one gene group was responsible for the inheritance of this trait. The estimate of heritability observed moderate (44.39 %).

The Vr, Wr graph (Fig. 6) suggested over dominance (H_1>D) as the regression line intercepted Vr- axis below the point of origin. The array points indicated that GAO 5 (P_1), Pusa Sawani (P_3), AOL 10-22 (P_4) and GPOK 573 (P_7) situated nearer to the point of origin, thus these parents possessed more number of the dominant genes. Whereas, GPOK 123 (P_5) and GPOK 578 (P_8) lying far away from the point of origin, hence they possessed the most of recessive genes. The parents GPOK 349 (P_6) and GO 2 (P_2) whose array points fall in the middle along the regression line, indicated the almost equal proportion of dominant and recessive genes in these genotypes.

4.4.2 Days to 50% flowering

The data on days to 50% flowering fitted to the additive-dominance model, because the regression coefficient (b) was not significantly deviating from unity (Table 4.6) and components of genetic variation (D, H_1 and H_2) were significant (Table 4.7). The Vr, Wr graph shown in Fig. 7 indicated that regression line intercepted Wr- axis above the point of origin suggested partial dominance (D>H_1). The array points indicated that the parents GAO 5, Pusa Sawani, AOL 10-22 and GPOK 349 were situated nearer to the point of origin, thus they possessed most of the dominant genes. Whereas, parental array of GPOK 123 and GPOK 578 laid away from point of origin indicated that these possessed most of the recessive genes. The array points of GO 2 and GPOK 573 situated in the middle along the regression line; hence, they had equal frequencies of dominant and recessive genes. The narrow sense heritability observed moderate as 40.08 per cent.

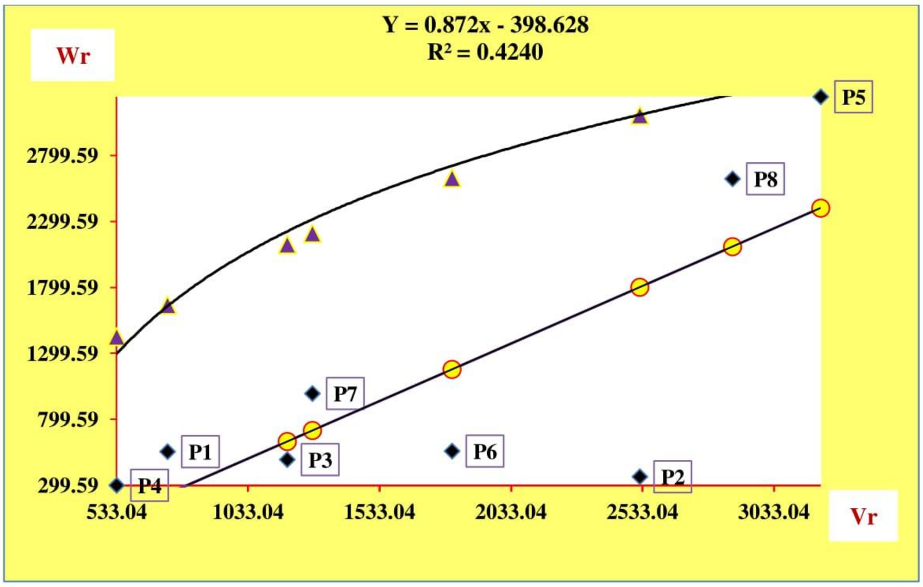

Fig. 6 Vr, Wr graph for fruit yield per plant

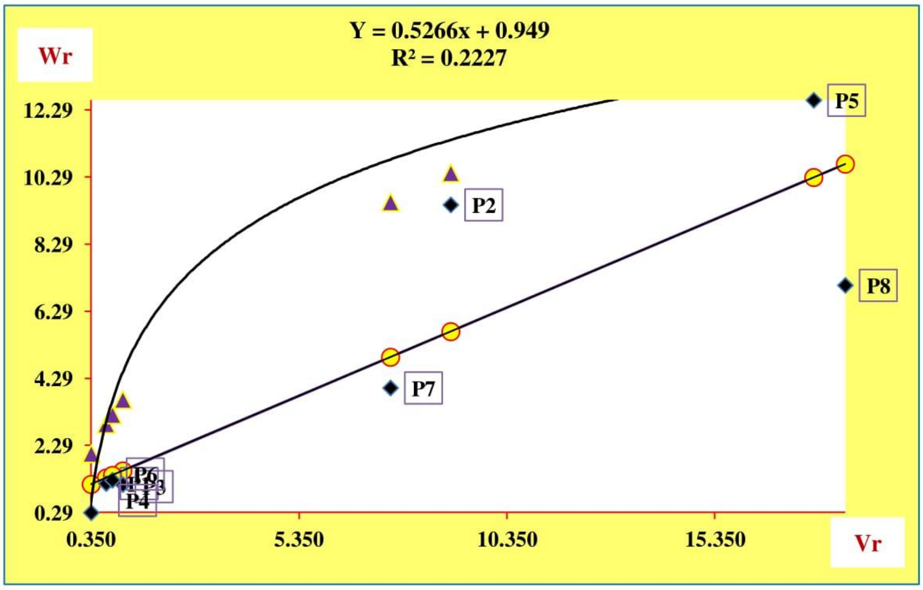

Fig. 7 Vr, Wr graph for days to 50% flowering

Where:

P1= GAO 5 P2= GO 2 P3= Pusa Sawani P4= AOL 10-22

P5= GPOK 123 P6= GPOK 349 P7= GPOK 573 P8= GPOK 578

Table 4.7 Components of genetic variation for fruit yield per plant, days to 50% flowering and first fruiting node

Components / Ratio	Fruit yield per plant	Days to 50% flowering	First fruiting node
D	3436.45** ± 552.21	20.04** ± 17.31	1.61** ± 0.58
H_1	5264.33** ± 1269.46	11.55* ± 10.18	1.11 ± 1.23
H_2	3811.64** ± 1104.43	18.47* ± 15.36	1.31 ± 1.50
h^2	475.64 ± 740.68	0.63 ± 4.27	1.86* ± 1.34
F	2496.88** ± 1304.83	4.87 ± 7.51	0.65* ± 0.60
E	384.57** ± 184.07	1.53* ± 1.06	0.35** ± 0.08
$(H_1 / D)^{1/2}$	1.24	0.76	0.83
$H_2 / 4H_1$	0.18	0.40	0.42
[(4DH1)1/2 + F)] / [(4DH1)1/2 – F)]	1.83	1.38	1.64
h^2 / H_2	0.12	0.03	1.42
Heritability in per cent (Narrow Sense)	44.39	40.08	32.11

4.4.3 First fruiting node

The genetic components of variation for first fruiting node were non-significant and show inadequacy of additive dominance model. It indicated that additive gene effects were requiring for expression of this trait. The value of h^2, F and E were significant, they manifested unidirectional dominance, asymmetrical distribution of dominant and recessive genes in the parents and environment play an important role in the inheritance of this trait. The ratio of K_D / K_R (1.64) indicated presence of higher proportion of dominant genes. The estimated heritability was moderate (32.11%).

The regression line cutting to the Wr- axis above the origin indicated partial dominance and all parents were clustering around regression line near the origin except GPOK 578 showed parents have more dominant genes (Fig. 8).

4.4.4 Days to first picking

The data on days to first picking fitted to the additive-dominance model (Table 4.6). Both additive (D) and dominance (H_1 and H_2) components were significant (Table 4.8). This indicated the importance of both additive and non-additive genetic components for controlling this trait. The Fig. 9 indicated that the regression line intercepted Wr-axis above the point of origin suggested partial dominance. The array points indicated that the parents GAO 5, Pusa Sawani, AOL 10-22 and GPOK 349 situated nearer to the point of origin and thus possessed more number of dominant genes. Whereas, parental array of GPOK 123 and GPOK 578 lay away from point of origin indicated that they possessed most of the recessive genes. The array points of GO 2 and GPOK 573 situated in the middle along the regression line; hence, they had equal frequencies of dominant and recessive genes. The estimate of heritability was moderate (42.14%).

4.4.5 Fruit length

The regression coefficient of Wr on Vr indicated inadequacy of additive-dominance model (Table 4.6). The Vr, Wr graph (Fig. 10) suggested complete dominance as the regression line passes through the origin. The maximum dominant genes observed in all parents, except GPOK 123 and GPOK 578. Whereas, they were exhibited their array points farthest from the origin, had most of the recessive genes. The estimate of heritability was high (67.32%).

4.4.6 Fruit girth

The additive-dominance model fitted well for the trait of fruit girth (Table 4.6). Both additive (D) and dominance (H_1 and H_2) components were significant (Table 4.8). This indicated the importance of both additive and non-additive genetic components for controlling this trait. The value of F was significant suggested asymmetrical distribution of dominant and recessive genes in the parents. The mean degree of dominance $(H_1/D)^{½}$ was 1.28 which suggested the over

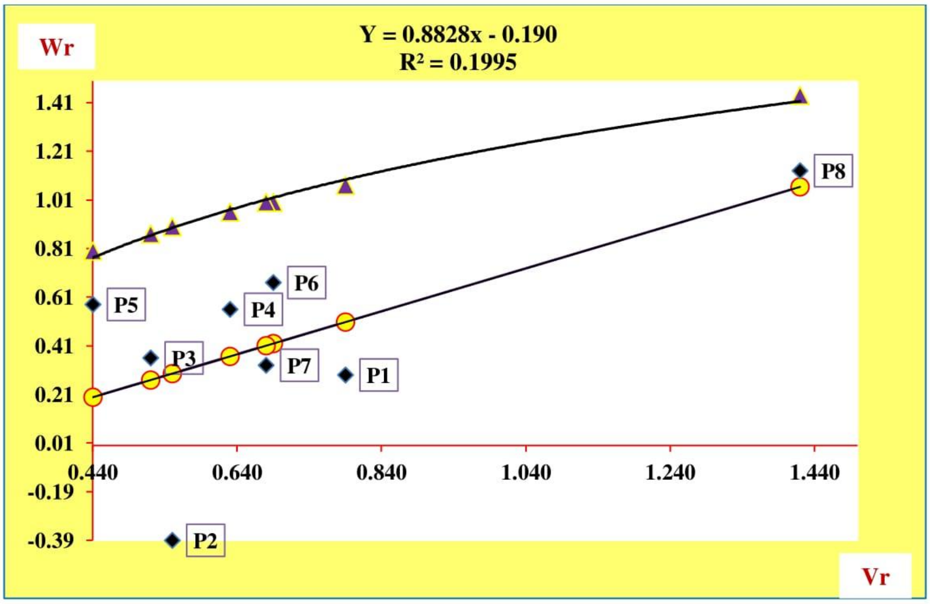

Fig. 8 Vr, Wr graph for first fruiting node

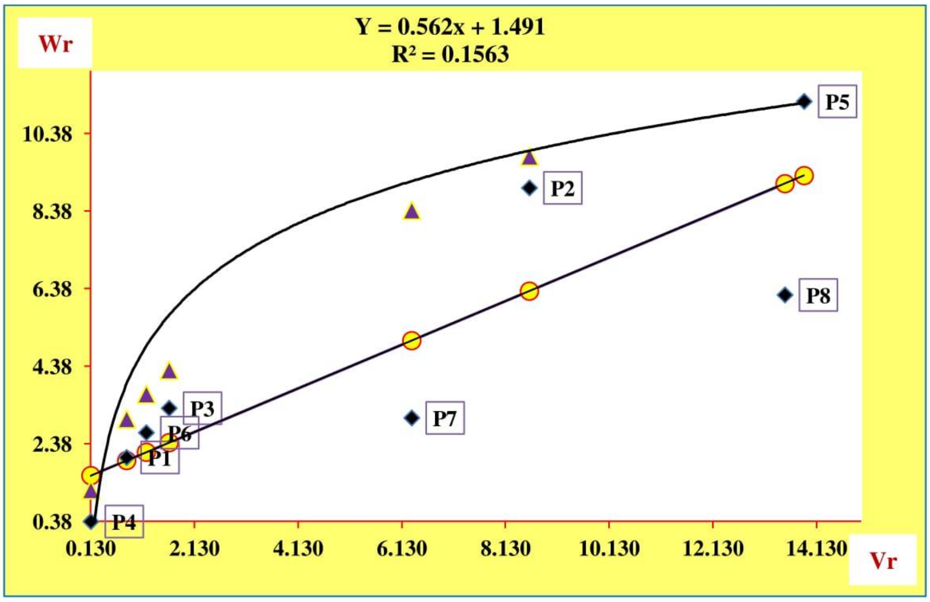

Fig. 9 Vr, Wr graph for days to first picking

Where:

P1= GAO 5	P2= GO 2	P3= Pusa Sawani	P4= AOL 10-22
P5= GPOK 123	P6= GPOK 349	P7= GPOK 573	P8= GPOK 578

dominance. This was further confirmed by Vr, Wr graph (Fig. 11) where the regression line intercepted Vr-axis below the point of origin. The value of $H_2/4H_1$ was 0.18, which indicated unequal distribution of positive and negative alleles. The value of K_D / K_R (2.20) indicated the presence of higher proportion of dominant genes. The value of h^2/H_2 (0.43) suggested that atleast one gene group was responsible for the inheritance of this trait. The estimate of heritability observed moderately high (48.07%).

Fig. 11 revealed that the regression line intercepted the Vr-axis below the point of origin indicated over dominance. The array points of parent GPOK 349 situated in middle along the regression line, which noticed equal frequency of dominant and recessive genes. Parents GAO 5, Pusa Sawani, AOL 10-22, GPOK123 and GPOK 578 occupied their position nearer to the point of origin suggested that they had higher proportion of dominant genes. On the other hand, the array point of GPOK 573 was far away from the point of origin indicated a higher proportion of recessive genes.

Table 4.8 Components of genetic variation for days to first picking, fruit length and fruit girth

Components / Ratio	Days to first picking	Fruit length	Fruit girth
D	12.99** ± 5.42	4.68** ± 4.36	0.25** ± 0.06
H_1	10.33* ± 8.36	4.72 ± 4.83	0.41** ± 0.14
H_2	11.30* ± 7.72	3.99 ± 4.72	0.30** ± 0.12
h^2	0.26 ± 3.16	0.69* ± 0.48	0.13* ± 0.08
F	2.17 ± 5.57	2.68 ± 2.85	0.24* ± 0.14
E	0..79 ± 0.84	0.30 ± 0.32	0.02* ± 0.02
$(H_1 / D)^{1/2}$	0.89	1.00	1.28
$H_2 / 4H_1$	0.27	0.21	0.18
[(4DH1)1/2 + F)] / [(4DH1)1/2 – F)]	1.20	1.63	2.20
h^2 / H_2	0.02	0.17	0.43
Heritability in per cent (Narrow Sense)	42.14	67.32	48.07

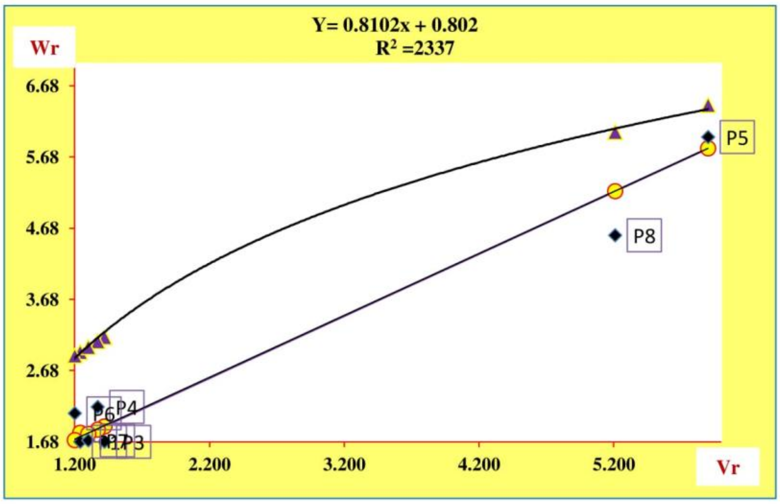

Fig. 10 Vr, Wr graph for fruit length

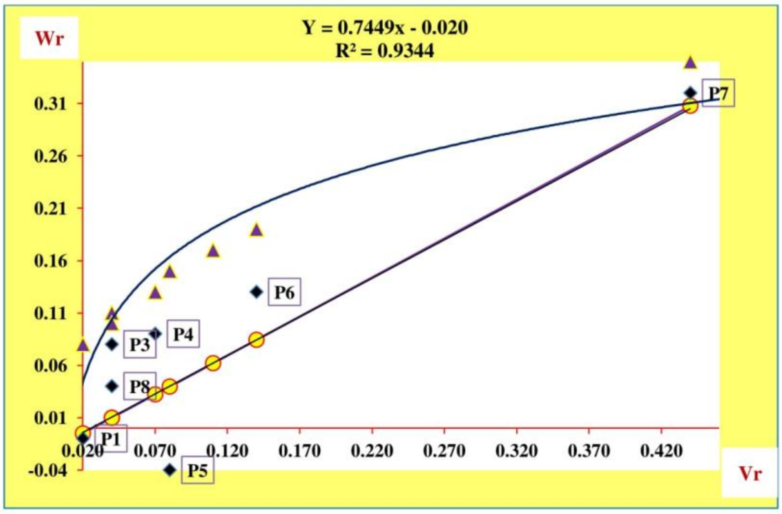

Fig. 11 Vr, Wr graph for fruit girth

Where:

P1= GAO 5
P2= GO 2
P3= Pusa Sawani
P4= AOL 10-22
P5= GPOK 123
P6= GPOK 349
P7= GPOK 573
P8= GPOK 578

4.4.7 Fruit weight

The data on individual fruit weight fitted to the additive-dominance model (Table 4.6) which showed adequacy of model. Both additive (D) and dominance (H_1 and H_2) components were significant (Table 4.9). This indicated the importance of both additive and non-additive genetic components for controlling this trait. The regression line intercepted the Wr-axis above the point of origin (Fig. 12) revealed partial dominance. The array points indicated that parents GAO 5, GO 2, Pusa Sawani, AOL 10-22 and GPOK 573 situated nearest to the point of origin and thus possessed higher proportion of dominant genes. Whereas, GPOK 578 lying far away from the point of origin, indicated that it possessed most of the recessive genes. The parental points of GPOK 123 and GPOK 349 lied in the middle along the regression line; hence, they had equal frequencies of dominant and recessive genes. The estimate of heritability was moderate (30.44%).

4.4.8 Number of fruits per plant

The data on number of fruits per plant fitted to the additive-dominance model (Table 4.6) that showed adequacy of model. Both additive (D) and dominance (H_1 and H_2) components were significant (Table 4.9). This indicated the importance of both additive and non-additive genetic components for controlling this trait. The regression line intercepted the Wr-axis above the point of origin (Fig. 13) suggested partial dominance. In the Vr, Wr graph, parental array of GAO 5, Pusa Sawani, AOL 10-22, GPOK 349 and GPOK 573 located nearer to the point of origin, which showed presence of higher frequency of dominant genes. While, the array point of GPOK 123 fell far away from the point of origin, which indicated the presence of most of recessive genes. The parents GO 2 and GPOK 578 lied in the middle along

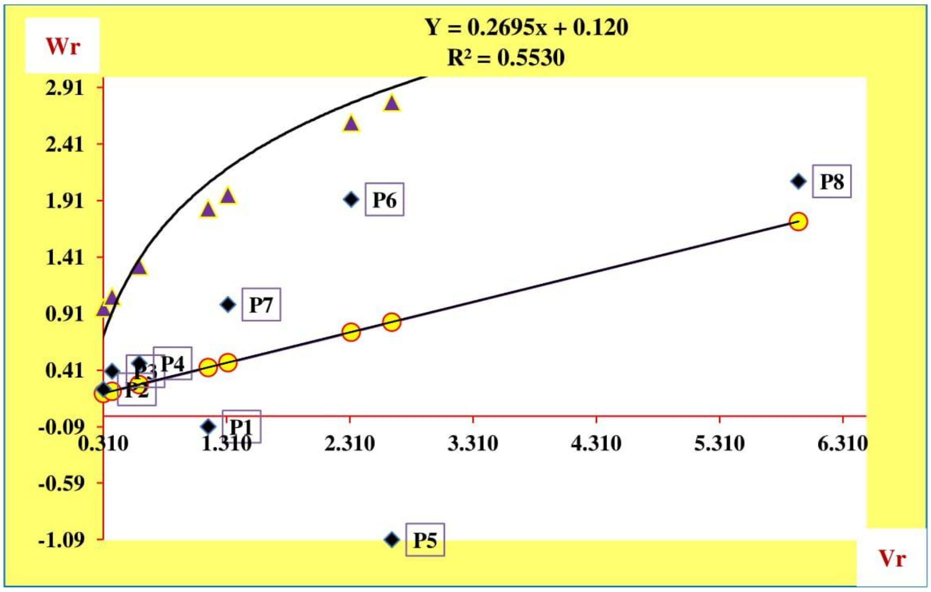

Fig. 12 Vr, Wr graph for fruit weight

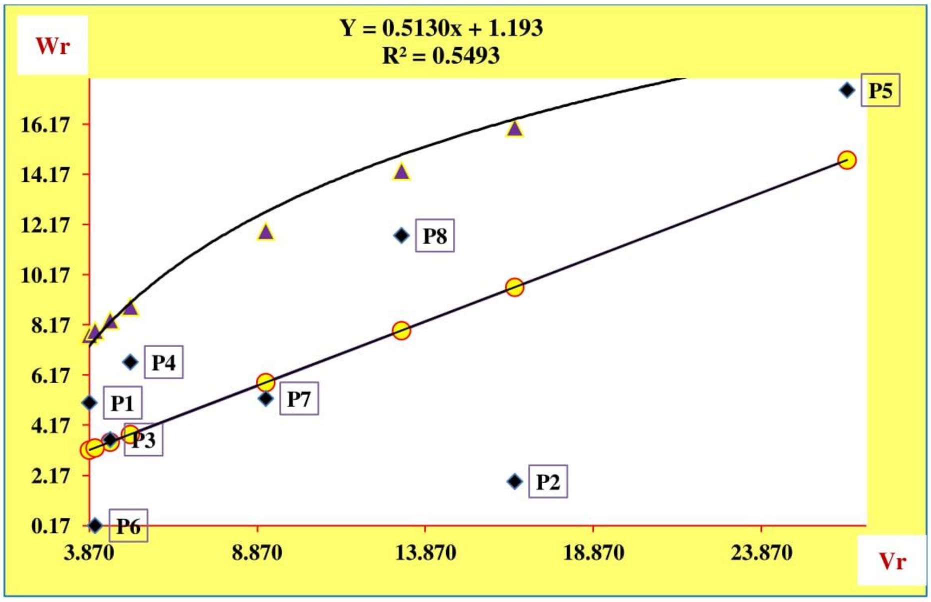

Fig. 13 Vr, Wr graph for number of fruit per plant

Where:

P1= GAO 5	P2= GO 2	P3= Pusa Sawani	P4= AOL 10-22
P5= GPOK 123	P6= GPOK 349	P7= GPOK 573	P8= GPOK 578

the regression line indicated that they possessed intermediate frequency of dominant and recessive genes. The estimate of heritability was moderate (34.65%).

4.4.9 Plant height

The additive-dominance model fitted well to the data for plant height (Table 4.6). Genetic components of variance D, H_1 and H_2 were found to be significant (Table 4.9) indicated that both additive and non-additive components operated in the expression of this trait. The component E was significant indicated that the environment play an important role in the inheritance. The value of F was non-significant suggested equal proportion of dominant and recessive genes in the parents. The ratio of mean degree of dominance as measured by $(H_1/D)^{1/2}$ was less than one (0.96) indicated partial dominance. The regression line, which intercepted the Wr-axis above the point of origin (Fig. 14) also revealed partial dominance for plant height. The value of $H_2/4H_1$ was 0.25 that indicated unequal distribution of positive and negative alleles. The heritability was observed moderate (32.53 %).

In the Vr, Wr graph (Fig. 14), parental array of GAO 5, GO 2, Pusa Sawani, AOL 10-22 and GPOK 349 located nearer to the point of origin, which showed presence of higher frequency of dominant genes. While, GPOK 578 fell far away from the point of origin, which indicated that the presence of higher proportion of the recessive genes. GPOK 123 and GPOK 573 with equal frequencies of dominant and recessive genes occupied an intermediate position.

4.4.10 Number of nodes per plant

The data on number of nodes per plant did not fit to the additive-dominance model due to significant deviation of regression coefficient (b) from unity (Table 4.6). The components of genetic variation H_1 and H_2 were significant (Table 4.10) indicated that non-additive gene action was responsible for inheritance of this trait. The estimated heritability was low (5.87%). For this trait, graphical analysis was not

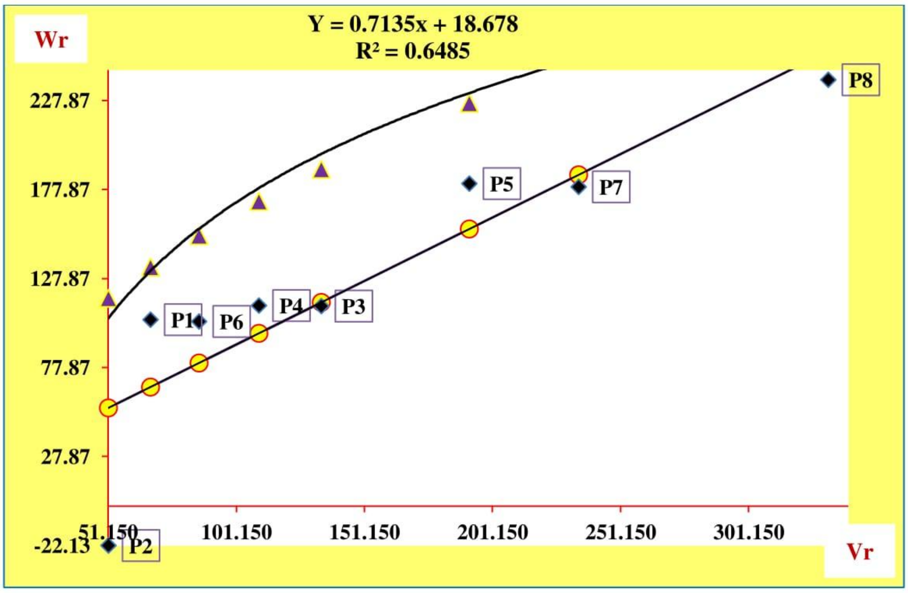

Fig. 14 Vr, Wr graph for plant height

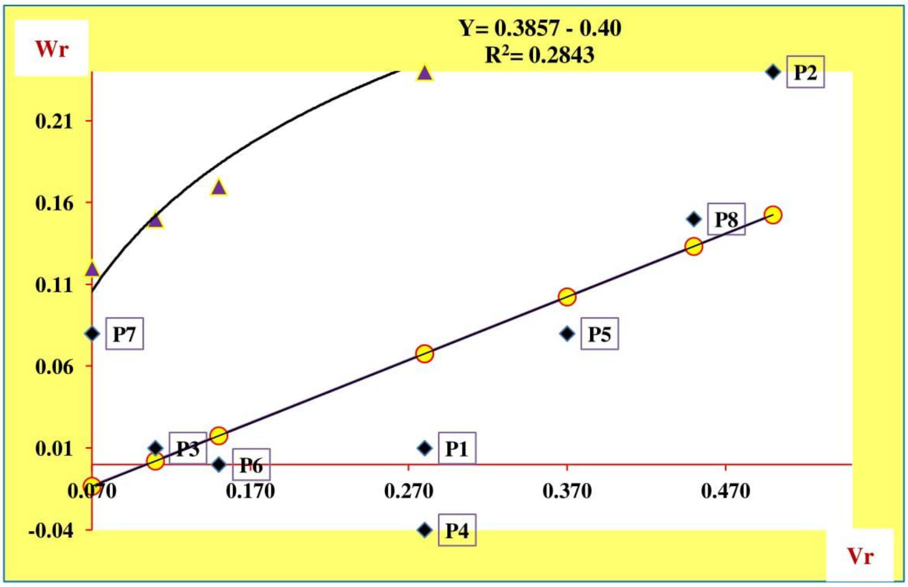

Fig. 15 Vr, Wr graph for number of primary branches per plant

Where:

P1= GAO 5	P2= GO 2	P3= Pusa Sawani	P4= AOL 10-22
P5= GPOK 123	P6= GPOK 349	P7= GPOK 573	P8= GPOK 578

suitable due to scattering of parental array in Vr-Wr graph and regression line was not formed in proper shape due to may be presence of linkages, multiple alleles or lethal genes.

Table 4.9 Components of genetic variation for fruit weight, number of fruits per plant and plant height

Components / Ratio	Fruit weight	Number of fruits per plant	Plant height
D	6.59** ± 2.83	28.82** ± 9.46	242.12** ± 78.35
H_1	2.47* ± 2.23	14.80* ± 13.11	222.02** ± 34.08
H_2	4.89* ± 4.46	24.55** ± 8.23	223.23** ± 68.17
h^2	0.16 ± 1.65	0.15 ± 5.52	14.27 ± 45.72
F	2.71 ± 2.91	4.01 ± 9.72	-39.39 ± 80.54
E	0.44* ± 0.41	0.78* ± 0.37	44.74** ± 11.36
$(H_1 / D)^{1/2}$	0.61	0.72	0.96
$H_2 / 4H_1$	0.49	0.41	0.25
[(4DH1)1/2 + F)] / [(4DH1)1/2 – F)]	2.01	1.22	0.84
h^2 / H_2	0.03	0.006	0.06
Heritability in per cent (Narrow Sense)	30.44	34.65	32.53

4.4.11 Number of primary branches per plant

For this trait, the data did not fit to additive-dominance model (Table 4.6). The component of genetic variation H_1 was significant (Table 4.10) indicated that non-additive gene action was responsible for inheritance of this trait. The graphical presentation (Fig. 15) indicated that regression line intercepted Vr-axis below the point of origin suggested over dominance. The array points of parents Pusa Sawani, GPOK 349 and GPOK 573 situated near to the point of origin suggested that they carry more number of dominant genes. The parents GAO 5, AOL 10-22 and GPOK 123 located in the middle of the regression line suggested that they had equal frequencies of dominant and recessive genes. Parents GO 2 and GPOK 578 lied farthest from the origin, indicating the higher proportion of recessive genes. The estimate of heritability was low (15.68%).

4.4.12 Moisture content

For this trait, the data fitted to the additive-dominance model (Table 4.6). In Fig. 16, the regression line touching Wr-axis above the origin suggested partial dominance ($D>H_1$). The parents GAO 5, AOL 10-22, GPOK 123, GPOK 349 and GPOK 573 were located nearer to the origin thereby suggested the existence of more number of dominant genes. The parent GO 2 fell far away from the point of origin thereby suggested the existence of more number of recessive genes. The parent GPOK 578 had equal proportion of dominant and recessive genes as their array points were situated in the middle along the regression line. This trait showed high narrow sense heritability (84.61%) (Table 4.10).

4.4.13 Ash content

The data on ash content fitted to the additive-dominance model (Table 4.6). The array points (Fig. 17) indicated that parents Pusa Sawani, GPOK 349 and GPOK 578 were situated nearer to the point of origin and thus possessed most of the dominant genes. Whereas, GAO 5, GO 2 and GPOK 123 were far away from the point of origin, indicated that they possessed most of the recessive genes. The parental array of AOL 10-22 and GPOK 573 were in the middle along the regression line; hence, they had equal frequencies of dominant and recessive genes. This trait showed medium ranged heritability (39.98%) (Table 4.10).

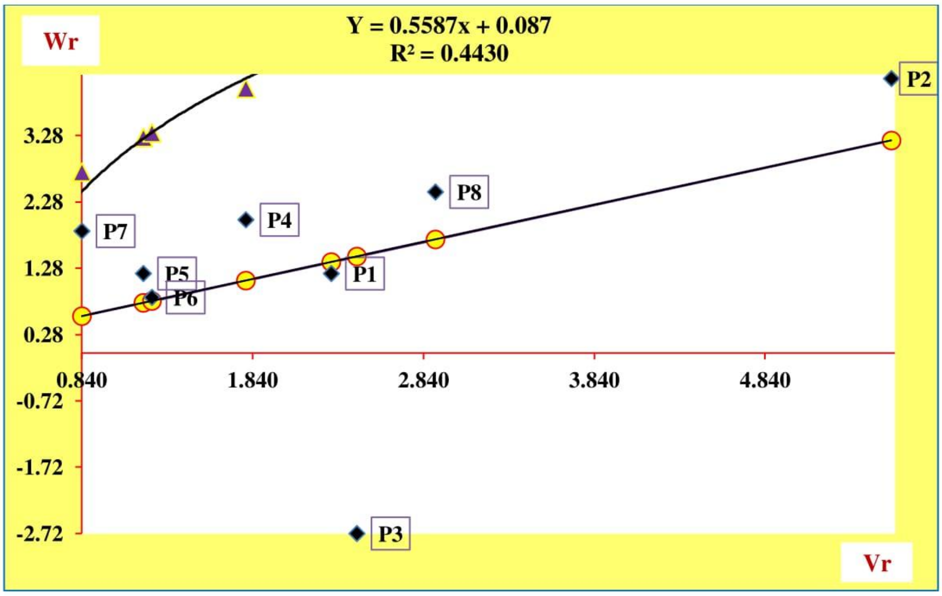

Fig. 16. Vr, Wr graph for moisture content

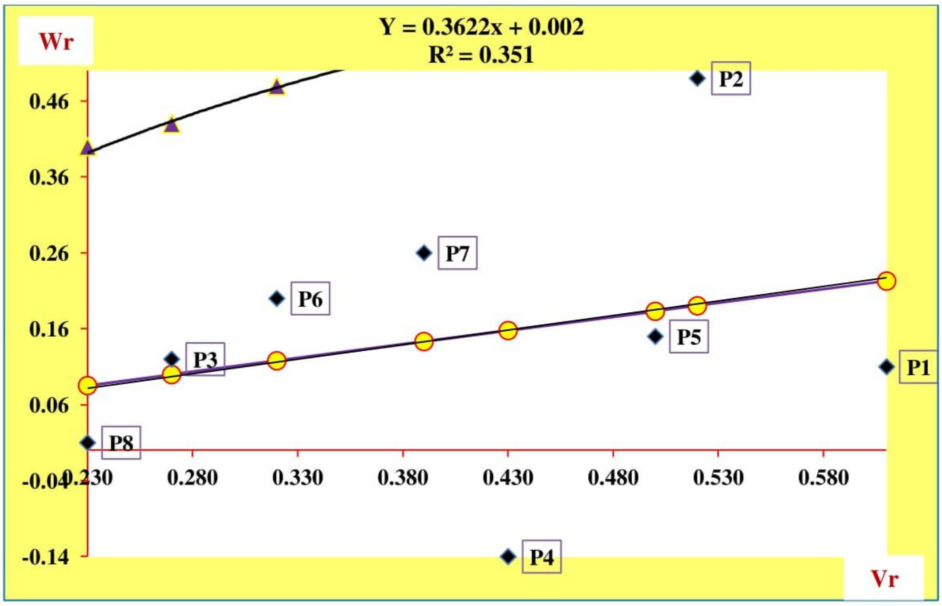

Fig. 17 Vr, Wr graph for ash content

Where:

P1= GAO 5 P2= GO 2 P3= Pusa Sawani P4= AOL 10-22
P5= GPOK 123 P6= GPOK 349 P7= GPOK 573 P8= GPOK 578

Table 4.10 Components of genetic variation for number of nodes per plant, number of primary branches per plant, moisture content and ash content

Components / Ratio	Number of nodes per plant	Number of primary branches per plant	Moisture content	Ash content
D	0.57 ± 0.59	0.18 ± 0.19	11.34** ± 3.24	1.66** ± 0.34
H_1	6.70** ± 1.36	0.98** ± 0.20	8.39** ± 1.41	0.67** ± 0.15
H_2	6.69** ± 1.18	0.85 ± 0.93	7.22** ± 2.81	1.31** ± 0.29
h^2	3.44** ± 0.79	0.33 ± 0.42	1.86 ± 1.89	0.01 ± 0.20
F	-0.65 ± 1.40	0.10 ± 0.21	11.53** ± 3.33	0.77* ± 0.35
E	0.45* ± 0.20	0.02 ± 0.03	0.43 ± 0.47	0.03 ± 0.05
$(H_1 / D)^{1/2}$	3.43	2.34	0.86	0.64
$H_2 / 4H_1$	0.25	0.22	0.21	0.49
[(4DH1)1/2 + F)] / [(4DH1)1/2 – F)]	0.71	1.27	3.89	2.15
h^2 / H_2	0.51	0.39	0.26	0.007
Heritability in per cent (Narrow Sense)	5.87	15.68	84.61	39.98

V. DISCUSSION

Okra [*Abelmoschus esculentus* (L.) Moench] is an important delicious fruit vegetable. Exploitation of hybrid vigour has recognized as an important tool for increasing genetic yield ceiling. The reproductive biology of the okra offers good scope for exploitation of heterosis. Therefore, proper choice of parents for hybridization is essential in generating heterotic hybrids. Further, relevant information about the inheritance of different fruit yield characters has an important role in deciding proper selection strategies, besides creation of variability. Okra is an often cross-pollinated crop. Emasculation and pollination events are easier due to large flower and monoadelphous stamens.

It is essential to mitigate the future thrust of higher productivity by estimating the extent of combining ability in lines and crosses for choosing lines of best general combining ability and crosses of specific combining ability. GCA reveals the preponderance of additive gene effects while SCA reveals the intra-allelic (dominance) and inter-allelic interactions (epistasis). For judicious application of heterotic vigour, it is imperative to assess the magnitude of genetic differences among the parents involved in the crosses, because high genetic diversity between parents shows maximum heterotic response.

The analysis of quantitative inheritance of fruit yield and its related traits was an important objective to gain knowledge regarding the nature and magnitude of gene action, which has an important bearing on the choice of most appropriate and efficient breeding methodology.

In this context, the present investigation was undertaken to elucidate information on heterosis, combining ability and gene action for fruit yield and its components traits. Okra genotypes identified for the investigation based on diversity for fruit yield, its components and morphological traits (Table 3.1).

5.1 ANALYSIS OF VARIANCE

The analysis of variance indicated significant differences among the genotypes, parents and hybrids for all the traits studied (Table 4.1). This indicated that materials used for investigation had adequate diversity for different traits. This might be due to their diverse origin. Significant differences among the hybrids for all the characters may be due to better combination of genes, derived from the diverse parents for maximization of hybrid vigour in respect of fruit yield and its components. The significant differences due to parents *vs* hybrids for fruit yield per plant, days to 50% flowering, first fruiting node, fruit length, fruit girth, number of nodes per plant, number of branches per plant, moisture content and ash content traits indicated that the parents and hybrids were completely differ from each other and hybridisation may create variability in the materials. The existence of overall heterosis was also evidence from this comparison.

5.2 ESTIMATION OF HETEROSIS

The aim of estimation of heterosis in the investigation was to identify the superior crosses with high degree of useful heterosis and characterization of parents for their prospectus for future uses in breeding programme.

The successful heterosis-breeding programme involved two important strategies *viz.*, the presence of significant heterotic effect in the hybrids that can be exploits easily and the feasibility of the hybrid seed production on commercial base. Okra being an often-pollinated crop, hand emasculation and hand pollination found feasible with higher success rate of fruit setting and more number of seeds per fruit. The cost of hybrid seed production at a commercial scale may also be lower due to simple floral biology, more number of seeds per cross and higher percentage of successful crosses. In the present study, heterosis over mid parent, better parent and standard check (GAO 5) were estimated for fruit yield and its attributing traits in 28 hybrids derived from the 8 x 8 diallel mating design without reciprocals.

The results of relative heterosis, thirteen cross combinations were exhibit significantly higher fruit yield, among those GPOK 123 x GPOK 349, AOL 10-22 x GPOK 578 and GO 2 x GPOK 123 were the best hybrids. In case of heterobeltiosis, four crosses exhibited significant and positive value for fruit yield than their respective better parent. A comparative study of three most heterobeltiotic crosses *viz.,* GPOK 123 x GPOK 349, GO 2 x GPOK 123 and AOL 10-22 x GPOK 578 for fruit yield corresponding to other attributes are presented in table 5.1. In the most of cases, former two crosses also exhibited significant and desirable heterosis for fruit length, number of fruits per plant and moisture content.

In case of standard heterosis, the trait fruit yield per plant was observed significant in four hybrids *viz.,* GO 2 x GPOK 123, GAO 5 x GO 2, GO 2 x Pusa Sawani and GPOK 123 x GPOK 578. Comparative studies of these most heterotic crosses for fruit yield corresponding to other attributes are presented in Table 5.1. Crosses also exhibited significant and desirable heterosis for first fruiting node, days to first picking, fruit length, fruit weight and plant height. These studies thus substantiate the finding of Grafius (1956) who indicated that heterosis in yield was reflected through heterosis in individual yield components.

Table 5.1

The high heterotic effect for fruit yield and its components in okra was also reported by Kumbhani *et al.* (1993), Poshiya and Vashi (1995), Dhankhar *et al.* (1996), Singh *et al.* (1996), Panda and Singh (1999), Dhaduk *et al.* (2003), Rawale *et al.* (2003), Ahlawat (2004), Bhalekar *et al.* (2004), Borgaonkar *et al.* (2006), Singh *et al.* (2006), Desai *et al.* (2007), Khanpara *et al.* (2009), Dabandata *et al.* (2010), Ramya and Senthil (2010), Wammanda *et al.* (2010), Solankey *et al.* (2013), Medagam *et al.* (2013) and Ashwani *et al.* (2013).

It was interesting to note that the expression of heterosis for fruit yield per plant in various hybrids of the present study was associated with heterotic manifestation in some other yield contributing traits. However, none of the hybrid showed heterotic effects for all the traits studied. This was because the components compete for sum total of metabolic substances produced by the plant and the conditions favouring the development of one component may adversely affect the other component. Therefore, to obtain maximum yield, desired levels of each component needed to know in a selection programme.

A good number of hybrids significantly exceeded the mid parent, better parent and standard check heterosis for various traits. The magnitude of standard heterosis was high for fruit yield per plant, fruit length, fruit weight, number of fruits per plant and number of primary branches per plant; medium for first fruiting node, plant height, number of nodes per plant and ash content and low for days to 50% flowering, days to first picking, fruit girth and moisture content.

A perusal of Table 5.1 indicated that all the three best heterotic hybrids for various traits involved GO 2 and GPOK 123 as a common parent. This suggested that the involvement of GO 2 and GPOK 123 as a parent resulted in expression of high heterosis for fruit yield per plant, fruit length and number of fruits per plant.

It is clear, from the above discussion that three crosses GPOK 123 x GPOK 349, AOL 10-22 x GPOK 578, GO 2 x GPOK 123 and GAO 5 x GO 2 found to be most promising for fruit yield and other desirable traits. Hence, could be further evaluated in heterosis breeding programme and simultaneously, advanced in segregating generations to obtain desirable segregates for the development of superior genotypes.

5.3 COMBINING ABILITY ANALYSIS

The success of any breeding programme largely depends on choice of parents and breeding procedure adopted. Combining ability is an efficient tool to discriminate good as well as poor combiners and for choosing suitable parental lines in hybridization programme. It also provides information of specific promising combinations to exploit heterosis. In the crops like okra, the breeder will primarily be interested in higher magnitude of additive genetic variance for establishing superior genotypes. On the other side, specific combining ability is mainly a function of dominance variance. If epistasis were present, it would generally include additive x dominance and dominance x dominance type of gene interactions. The selection of suitable parents with desirable characters is essential for exploitation of heterosis in okra where hybrid seed production is economical.

The analysis of variance for combining ability (Table 4.3) suggested that both additive and non-additive gene actions were responsible for the inheritance of all the traits except first fruiting node and plant height, where only gca effect was significant. The SCA variance component was observed higher than respective GCA variance component for all the traits, suggested the predominant role of non-additive gene action for the inheritance of these traits. The results confirmed the finding obtained by Arora (1993) for fruit yield; Singh *et al*. (1996) for plant height; Sood and Kalia

(2001) for fruit yield, number of fruits per plant and plant height; Weerasekara *et al.* (2008) for fruit weight and fruit length; Wammanda *et al.* (2010) for days to 50% flowering and Reddy *et al.* (2012) for fruit weight, fruit length, plant height, days to 50% flowering, first fruiting node, yield per plant and number of fruits per plant.

The general combining ability effects of parents (Table 5.2) indicated that none of the parents was found good general combiner for all the characters investigated. The parents GAO 5, GO 2, Pusa Sawani, AOL 10-22 and GPOK 349 were good general combiners for fruit yield per plant, days to 50% flowering and fruit length. In addition to fruit yield, parents GAO 5, GO 2 and AOL 10-22 were also observed good general combiner for days to first picking, number of fruits per plant and plant height. Hence, these parents could consider in future breeding programme to generate more number of desirable segregates for fruit yield and its component traits. The parent GPOK 123 was good general combiner for first fruiting node, fruit length and fruit weight. Likewise, GPOK 349 found good general combiner for fruit yield, day to 50% flowering, first fruiting node, fruit length, fruit weight, fruit girth, moisture content and ash content. The parent GPOK 573 manifested good general combing ability for number of nodes per plant, fruit girth, moisture content and ash content. These parents may be utilizing in the component breeding programme.

The potentiality of a parent in hybridization may be assessed by it's *per se* performance and gca effects. For the present study, these top ranking parents for *per se* performance and gca effects for different traits are presented in Table 5.3. The results revealed that most of the characters had relatively high degree of correspondence between *per se* performance and gca effects. This can be ascribing to the predominant role of additive and additive x additive type of gene action for the inheritance of these traits.

Table 5.2 Classification of parents with respect to general combining ability for various traits in okra

Characters	GAO 5	GO 2	Pusa Sawani	AOL 10-22	GPOK 123	GPOK 349	GPOK 573	GPOK 578
Fruit yield per plant	G	G	G	G	P	G	P	P
Days to 50% flowering	G	G	G	G	P	G	P	P
First fruiting node	G	P	G	A	G	G	P	P
Days to first picking	G	G	G	G	P	P	P	P
Fruit length	G	G	G	G	G	G	A	P
Fruit girth	P	P	P	P	P	G	G	G
Individual fruit weight	P	G	G	P	G	G	P	P
Number of fruits per plant	G	G	G	G	A	P	A	P
Plant height	G	G	P	G	P	A	P	A
Number of nodes per plant	G	P	G	P	P	P	G	P
Number of primary branches per plant	G	G	G	G	A	P	P	A
Moisture content	G	P	G	G	A	G	G	P
Ash content	P	P	G	P	P	G	G	G

G= Good combiner
A= Average combiner
P= Poor combiner

In self-pollinated crops, sca effects are not much important as they are related with non-additive gene effects that cannot be fixed in a pure line. However, if a cross combination exhibited high sca effects as well as *per se* performance having at least one parent as good general combiner for a particular trait, it expected that such cross combinations would throw desirable transgressive segregates in later generations. Significant sca effects of those combinations involving good x good combiners showed the major role of additive type of gene effects, which is fixable. However, two good general combiners may not necessarily throw good segregates. Similarly, the superior crosses involving both the poor x poor general combiners, very little gain is expected from such crosses because high sca effects may dissipate with the progress towards homozygosity.

In the present study, top three crosses, which exhibited high sca effects for fruit yield (Table 5.3), involved at least one good general combiner. Such types of results were also obtained by Kulkarni *et al.* (1991), Sundhari *et al.* (1992), Poshiya and Vashi (1995), Singh *et al.* (1996), Pawar *et al.* (1999), Kumar *et al.* (2006), Pal and Sabesan (2009), Wammanda *et al.* (2010), Raghuvanshi *et al.* (2011), Prakash *et al.* (2012), Reddy *et al.* (2012), Ashwani *et al.* (2013) and Kumar *et al.* (2013) in okra.

The specific combining ability effects (Table 5.3) indicated that top yielding hybrids GO 2 x GPOK 123 (good x poor) possessed first position for sca effect and economic heterosis; third in relative heterosis and second position in heterobeltiosis for fruit yield. Second top yielding hybrid GAO 5 x GO 2 (good x good) possessed third rank for economic heterosis. The third top yielding hybrid was AOL 10-22 x GPOK 578 (good x poor), which ranked second for sca effect and relative heterosis; third for heterobeltiosis for yield. In crops like okra where improved varieties are under cultivation, these crosses could evaluated further and utilized to get desirable segregates for improvement. Moreover, these three top yielding crosses exhibited high sca effects as well as *per se* performance having at least one or both parents as good general combiner for green fruit yield. Hence, these crosses could be advance for selection in segregating generations to identify superior segregates for the development of improved varieties.

Considering the gca effects of parents involved for the expression of sca effects in a particular hybrid, the significant crosses may be grouped into six categories, namely good x good, good x average, good x poor, average x average,

average x poor and poor x poor, in which the parents belonged to either of the categories. However, the crosses involving high sca effects did not always involve parents with high gca effects, thereby suggesting the presence of intra-allelic gene interactions. The sca effects of certain crosses in the undesirable direction could be due to the failure of desirable alleles of the parents to co-operate. As a result, a cross from good general combiner parents may exhibit poor sca effects. Table 5.3 revealed that there was some degree of correspondence between *per se* performance and sca effects of hybrids as well as gca effects of parents and estimates of heterosis for most of traits. Hence, gca effect, sca effects and *per se* performance all are play an important role in manifestation of heterosis for various traits.

5.4 ESTIMATION OF COMPONENTS OF GENETIC VARIATION AND GRAPHICAL ANALYSIS

The material under investigation was test for agreement with the assumptions basic to diallel analysis. The assumptions of diploid segregation, no maternal effects, absence of multiple alleles, absence of linkage, absence of lethal genes and no genotype x environment interaction were difficult to evaluate independently of one another. Therefore, ‘t’ test calculated as deviation of regression co-efficient ‘b’ from zero and unity were employed to determine the assumptions basic to diallel analysis for each of the characters studied (Table 4.6).

The component analysis provides information on two main genetic components, namely, additive and dominance. The results obtained through this analysis, therefore, provide a clear picture of the relative importance of additive and dominance variances for the control of a particular character.

Table 5.3

Table 5.3

The estimates of D, which measured the variance due to additive genetic effects as well as H_1 and H_2, which measured the variance due to dominance genetic effects were significant for fruit yield per plant, first fruiting node, fruit girth, plant height, moisture and ash content. The results indicated that both additive and dominance components were important for the inheritance of these traits. The findings of combining ability analysis as discussed previously are also in confirmation of these findings. The present findings are also in agreement with those obtained by Shinde *et al.* (1995), Kumar *et al.* (2006), Reddy *et al.* (2012) and Hazem *et al.* (2013).

To obtain further information about the genetic system operating for each trait, various estimates and ratios were calculated using the genetic parameters. The average degree of dominance $(H_1/D)^{1/2}$ for fruit yield was in the range of over-dominance.

The equal distribution of positive and negative genes in the parents helps the breeders to select a particular desirable trait without loosing any other important one. The ratio of $H_2/4H_1$ indicated asymmetrical distribution of positive and negative alleles in the parents for the all characters studied. This showed that these traits could not be select individually without loosing any other desirable traits.

The estimation of quantity $[(4DH_1)^{1/2} + F] / [(4DH_1)^{1/2} - F]$ or K_D / K_R ratio suggested an excess of dominant alleles in the parents. High heritability observed for fruit length and moisture content, while it was low in nodes per plant and primary branches per plant and moderate for fruit yield per plant, days to 50% flowering, first fruiting node, days to first picking, fruit girth, fruit weight, number of fruits per plant, plant height and ash content.

It is difficult to estimate the number of gene groups exhibiting dominance effect because the ratio h^2/H_2 is underestimated if dominance effects of all genes affecting that trait are not equal in size and direction (Mather, 1949) or if the distribution of the genes is correlated (Jinks, 1954). The ratio h^2/H_2 gives an estimate of number of gene or gene groups exhibiting dominance. In case of fruit yield per plant, first fruiting node, fruit girth, plant height, moisture and ash content atleast one gene or gene group exhibited dominance.

Regression co-efficient deviated significantly from unity for days to 50% flowering, days to first picking, fruit length, fruit weight, number of fruits per plant, number of nodes per plant and number of primary branches per plant. It indicated partial failure of assumption and role of interactions. Hence, conclusion drawn therefore subjected to those limitations of the technique.

In general, wide scattering of parental points along the regression line in Vr, Wr graphs were observed for fruit yield, fruit weight, number of fruits per plant, number of nodes per plant, number of primary branches per plant, moisture content and ash content. This suggested sufficient diversity among the parents for these traits. On the other side, days to 50% flowering, first fruiting node, days to first picking, fruit length, fruit girth and plant height exhibited narrow scattering of the parental arrays indicated less diversity among the parents for these traits.

The relative position of parental array along the regression line indicated the distribution of dominant and recessive genes in the parents. The location of array points near the point of origin and far away from the point of origin suggest higher proportion of dominant and recessive genes in the parents, respectively.

The higher proportion of dominant genes observed in the parents GAO 5, Pusa Sawani, AOL 10-22 and GPOK 573 for fruit yield per plant; GAO 5, Pusa Sawani, AOL 10-22 and GPOK 349 for days to 50% flowering; GAO 5, GO 2, Pusa Sawani, AOL 10-22, GPOK 123, GPOK 349 and GPOK 573 for first fruiting node;

GAO 5, Pusa Sawani, AOL 10-22 and GPOK 349 for days to first picking; GAO 5, GO 2, Pusa Sawani, AOL 10-22, GPOK 349 and GPOK 573 for fruit length; GAO 5, GO 2, Pusa Sawani, AOL 10-22, GPOK 123 and GPOK 578 for fruit girth; GAO 5, GO 2, Pusa Sawani, AOL 10-22 and GPOK 573 for fruit weight; GAO 5, Pusa Sawani, AOL 10-22, GPOK 349 and GPOK 573 for fruits per plant; GAO 5, GO 2, Pusa Sawani, AOL 10-22 and GPOK 349 for plant height; Pusa Sawani, GPOK 349 and GPOK 573 for primary branches per plant; AOL 10-22, GPOK 123 GPOK 349 and GPOK 573 for moisture content and Pusa Sawani, GPOK 349 and GPOK 578 for ash content.

On the other hand, higher proportion of recessive genes were manifested in the parents GPOK 123 and GPOK 578 for fruit yield, days to 50% lowering, days to first picking and fruit length; GPOK 578 for first fruiting node; GPOK 573 for fruit girth; GPOK 578 for fruit weight and plant height; GPOK 123 for fruits per plant; GO 2 and GPOK 578 for primary branches per plant; GO 2 for moisture content and GAO 5, GO 2 and GPOK 123 for ash content.

The parents which exhibited complementary type of gene interaction were GO 2 and GPOK 349 for fruit yield; GO 2 and GPOK 573 for days to 50% flowering and days to first picking; GPOK 349 for fruit girth; GPOK 349 and GPOK 123 for fruit weight; GO 2 and GPOK 578 for fruits per plant; GPOK 123 and GPOK 573 for plant height; GAO 5, AOL 10-22 and GPOK 123 for primary branches per plant; GAO 5, Pusa Sawani and GPOK 123 for moisture content and AOL 10-22 and GPOK 573 for ash content.

5.5 FUTURE BREEDING METHODOLOGY

To plan an efficient breeding strategy, breeders should have knowledge of genetics of plant species under investigation. The knowledge of genetic architecture determines the expression of trait in relation to adaptability and productivity that greatly helps in the utilization of available genetic resources. Therefore, certain suggestions can made for future okra improvement programme based on the materials used and results obtained from the present study.

Both additive and non-additive genetic effects were observed for fruit yield per plant, days to 50% flowering, days to first picking, fruit girth, fruit weight, number of fruits per plant, plant height, moisture content and ash content. For these traits, recurrent selection procedure may be useful for further improvement.

Additive gene action for first fruiting node indicated that simple selection would be effective for improving this trait. Non-additive gene action for number of nodes per plant and number of primary branches per plant indicated the feasibility of heterosis breeding.

The hybrids GO 2 x GPOK 123, GAO 5 x GO 2, AOL 10-22 x GPOK 578 and GPOK 123 x GPOK 349 were showing superior performance and found promising for higher fruit yield.

VI. SUMMARY AND CONCLUSION

The field experiment was undertaken to study “Diallel analysis in okra [*Abelmoschus esculentus* (L.) Moench]”. The experimental material comprised of eight parents and its 28 cross combinations produced through half-diallel. The experiment was laid out in a randomized block design with three replications at Main Vegetable Research Station, Anand Agricultural University, Anand during *kharif* 2014. The data obtained for thirteen characters including fruit yield, its components and quality traits. The data subjected to half diallel analysis. The salient features of the results obtained are summarizing as below.

6.1 ANALYSIS OF VARIANCE

The analysis of variance indicated significant differences among the genotypes for all the traits studied. Partitioning of genotypes suggested that significant differences also observed among the parents as well as hybrids for all the traits under study. This indicated that materials used for present investigation had adequate diversity for different traits.

6.2 ESTIMATION OF HETEROSIS

The data on heterosis calculated over mid parent, better parent and standard check GAO 5 revealed superiority of some outstanding cross combinations. The crosses GPOK 123 x GPOK 349, AOL 10-22 x GPOK 578 and GO 2 x GPOK 123 showed significant and desirable heterosis for fruit yield per plant over mid parent and better parent. In most of the cases, these crosses, also exhibited significant and desirable heterosis for fruit girth, fruits per plant, nodes per plant and fruit weight.

The crosses GO 2 x GPOK 123, GAO 5 x GO 2 and GO 2 x Pusa Sawani showed significant and desirable heterosis for fruit yield per plant over standard check.

A perusal of *per se* performance and heterosis indicated that crosses GO 2 x GPOK 123, GAO 5 x GO 2 and AOL 10-22 x GPOK 578 found the most promising for fruit yield and other desirable traits, hence could be further evaluated to exploit the heterosis or utilized in future breeding programme to obtain desirable segregates for the development of superior genotypes.

6.3 COMBINING ABILITY ANALYSIS

The gca and sca mean squares were significant for all the traits except sca mean square for first fruiting node. The ratio of GCA and SCA variances indicated the preponderance of non-additive gene effects for the inheritance of all the traits.

The estimates of general combining ability suggested that parents GAO 5, GO 2, Pusa Sawani and AOL 10-22 were observed good general combiners for fruit yield per plant. Moreover, these parents were also good combiner for days to 50% flowering, days to first picking, plant height, fruit length, fruits per plant and primary branches per plant.

The perusal of sca effects revealed that the cross combinations GO 2 x GPOK 123, AOL 10-22 x GPOK 578 and GPOK 123 x GPOK 349 manifested good specific combining ability for fruit yield and some of its related traits.

6.4 ESTIMATION OF COMPONENTS OF GENETIC VARIATION AND GRAPHICAL ANALYSIS

The components of genetic variation and graphical analysis supported the results obtained through combining ability analysis and revealed that both additive as well as non-additive gene actions were important for most of the traits.

The graphical analysis and value of $[(H_1/D)^{1/2}]$ exhibited over dominance for fruit yield per plant, fruit girth, nodes per plant and primary branches per plant. The higher narrow sense heritability observed for moisture content (84.61%) and fruit length (67.31%); medium ranged heritability found in fruit yield (44.38%), days to 50% flowering (40.08%), first fruiting node (32.11%), days to first picking (42.14%), fruit girth (48.07%), fruit weight (30.44%), number of fruits per plant (34.65%), plant height (32.53%) and ash content (39.98%) and low for number of nodes per plant (5.89%) and number of primary branches per plant (15.69%).

The graphical analysis indicated that all the traits were controlled by either partial dominant or over dominance. Moreover, the complementary type of gene interaction involved for the control of fruit length.

The parents had greater diversity as their array points scattered throughout the graph for the traits like fruit yield, fruit weight, number of fruits per plant, number of nodes per plant, number of primary branches per plant, moisture content and ash content.

From the present findings, it can be concluded that additive and non-additive gene effects controlled the expression of fruit yield per plant, days to 50% flowering, days to first picking, fruit girth, fruit weight, number of fruits per plant, plant height, moisture content and ash content traits, hence recurrent selection suggested for the improvement of these traits.

Additive gene action for first fruiting node indicated that simple selection would be effective for improving this trait. Non-additive gene action for number of nodes per plant and number of primary branches per plant indicated the feasibility of heterosis breeding.

Table 5.1 Manifestation of heterosis for other traits in the best three heterotic hybrids for fruit yield per plant

Characters	**Relative Heterosis**			**Heterobeltiosis**			**Standard Heterosis**		
	GPOK 123 x GPOK 349	AOL 10-22 x GPOK 578	GO 2 x GPOK 123	GPOK 123 x GPOK349	GO 2 x GPOK 123	AOL 10-22 x GPOK 578	GO 2 x GPOK 123	GAO 5 x GO 2	GO 2 x Pusa Sawani
Fruit yield per plant	47.09**	38.27**	34.46**	47.09**	11.48**	5.36**	16.84**	10.43**	4.28**
Days to 50% flowering	0.00	-7.32**	0.00	0.00	-1.30	-14.61**	2.01*	1.34	-0.67
First fruiting node	3.57	21.74**	6.90	3.57	3.33	16.67**	24.00**	24.00**	16.00**
Days to first picking	0.00	-6.59**	1.27	0.00	-1.23	-13.33**	2.56**	2.56**	0.00
Fruit length	7.36*	14.76**	21.52**	7.36*	19.22**	-21.61**	22.91**	9.79**	16.95**
Fruit girth	9.92	2.07	6.75	9.92	5.63	-0.15	4.57	-1.06	-0.85
Fruit weight	5.84*	12.90**	0.61	5.84	0.24	1.24	19.08**	21.39**	22.25**
Number of fruits per plant	62.73**	26.74**	58.81**	62.73**	25.72**	7.73**	6.77**	-2.15	-14.46**
Plant height	-7.89**	13.18**	-0.73*	-7.89**	-8.06**	-5.42**	4.91**	9.20**	2.45**
Number of nodes per plant	25.00**	-6.67**	5.38*	25.00**	0.00	-10.64**	-5.77*	-5.77*	9.62**
Number of primary branches per plant	-12.00	113.7**	83.53**	-12.00	56.00*	65.96*	30.00	41.67*	0.00
Moisture content	-1.57**	-1.65**	-4.88**	-1.57**	-7.45**	-4.86**	0.11	2.14**	-1.20*
Ash content	0.78	11.05	0.09	0.78	-13.58*	-1.61	20.17*	-2.81	37.54**

*,** Significant at 5 and 1 per cent levels, respectively.

Table 5.3 The best three parents and hybrids reported for estimation of *per se* performance, combining ability and heterosis for various traits in okra

Characters	***Per se* performance**		**Combining ability effects**		**Magnitude of heterosis over**		
	Parents	**Hybrids**	**GCA**	**SCA**	**Mid parent**	**Better parent**	**Standard check**
Fruit yield per plant	GPOK 349 Pusa Sawani GO 2	GO 2 x GPOK 123 GAO 5 x GO 2 AOL 10-22 x GPOK 578	GAO 5 GO 2 Pusa Sawani	GO 2 x GPOK 123 AOL 10-22 x GPOK 578 GPOK 123 x GPOK 349	GPOK 123 x GPOK 349 AOL 10-22 x GPOK 578 GO 2 x GPOK 123	GPOK 123 x GPOK 349 GO 2 x GPOK 123 AOL 10-22 x GPOK 578	GO 2 x GPOK 123 GAO 5 x GO 2 GO 2 x Pusa Sawani
Days to 50% flowering	GAO 5 GO 2 Pusa Sawani	GAO 5 x GPOK 573 Pusa Sawani x GPOK 578 AOL 10-22 x GPOK 578	GAO 5 GO 2 Pusa Sawani	Pusa Sawani x GPOK 578 AOL 10-22 x GPOK 578 GAO 5 x GPOK 578	GPOK 349 x GPOK 573 Pusa Sawani x GPOK 578 AOL 10-22 x GPOK 578	Pusa Sawani x GPOK 578 AOL 10-22 x GPOK 578 GPOK 349 x GPOK 573	GO 2 x Pusa Sawani GAO 5 x AOL 10-22 Pusa Sawani x GPOK 123
First fruiting node	AOL 10-22 Pusa Sawani GAO 5	GO 2 x GPOK 573 GAO 5 x GPOK 123 AOL 10-22 x GPOK 573	GAO 5 Pusa Sawani GPOK 123	GO 2 x GPOK 573 GAO 5 x GPOK 123 GAO 5 x GPOK 349	GO 2 x GPOK 573 GPOK 123 x GPOK 578 GAO 5 x GPOK 123	AOL 10-22 x GPOK 573 GAO 5 x GPOK 573 GO 2 x GPOK 573	GAO 5 x AOL 10-22 GAO 5 x GPOK 123 GAO 5 x GPOK 349
Days to first picking	Pusa Sawani GO 2 AOL 10-22	GAO 5 x GPOK 573 GAO 5 x GPOK 578 Pusa Sawani x GPOK 578	GAO 5 GO 2 Pusa Sawani	AOL 10-22 x GPOK 573 AOL 10-22 x GPOK 578 Pusa Sawani x GPOK 578	AOL 10-22 x GPOK 578 AOL 10-22 x GPOK 573 GPOK 349 x GPOK 573	AOL 10-22 x GPOK 578 Pusa Sawani x GPOK 578 AOL 10-22 x GPOK 573	GAO 5 x AOL 10-22 Pusa Sawani x GPOK 123 GO 2 x AOL 10-22
Fruit length	AOL 10-22 Pusa Sawani GO 2	GO 2 x GPOK 123 GAO 5 x GPOK 573 GAO 5 x GPOK 578	GO 2 AOL 10-22 GAO 5	GAO 5 x GPOK 573 GO 2 x Pusa Sawani GO 2 x GPOK 123	GO 2 x GPOK 578 GPOK 349 x GPOK 573 GAO 5 x GPOK 578	GO 2 x GPOK 123 GO 2 x Pusa Sawani GAO 5 x GPOK 123	GO 2 x GPOK 123 GO 2 x Pusa Sawani GAO 5 x AOL 10-22
Fruit girth	GPOK 573 GPOK 578 GPOK 349	GPOK 123 x GPOK 578 GO 2 x GPOK 123 GO 2 x GPOK 578	GAO 5 GO 2 Pusa Sawani	GO 2 x GPOK 123 GO 2 x GPOK 578 GPOK 123 x GPOK 349	GPOK 349 x GPOK 573 GPOK 123 x GPOK 349 GO 2 x GPOK 123	GPOK 123 x GPOK 349 GO 2 x GPOK 123 GPOK 349 x GPOK 573	GPOK 349 x GPOK 573 GPOK 573 x GPOK 578 GO 2 x GPOK 578

Table 5.3 Contd…

Characters	***Per se* performance**		**Combining ability effects**		**Magnitude of heterosis over**		
	Parents	**Hybrids**	**GCA**	**SCA**	**Mid parent**	**Better parent**	**Standard check**
Fruit weight	GPOK 349 GPOK 123 GO 2	GPOK 123 x GPOK 578 GAO 5 x GO 2 GO 2 x GPOK 578	GO 2 Pusa Sawani GPOK 123	GPOK 123 x GPOK 578 Pusa Sawani x GPOK 573 GAO 5 x GO 2	GPOK 123 x GPOK 578 GO 2 x GPOK 578 AOL 10-22 x GPOK 578	GPOK 123 x GPOK 578 Pusa Sawani x GPOK 573 GPOK 123 x GPOK 349	GPOK 123 x GPOK 578 GO 2 x GPOK 349 GPOK 123 x GPOK 349
Number of fruits per plant	GAO 5 GO 2 Pusa Sawani	GO 2 x GPOK 123 Pusa Sawani x GPOK 123 GAO 5 x GO 2	GAO 5 GO 2 Pusa Sawani	GO 2 x GPOK 123 GPOK 123 x GPOK 349 GAO 5 x GPOK 573	GPOK 123 x GPOK 349 GO 2 x GPOK 123 AOL 10-22 x GPOK 578	GPOK 123 x GPOK 349 GO 2 x GPOK 123 GPOK 349 x GPOK 573	GO 2 x GPOK 123 GAO 5 x GO 2 GAO 5 x AOL 10-22
Plant height	GAO 5 GPOK 123 GPOK 573	GO 2 x GPOK 573 GO 2 x GPOK 578 GPOK 123 x GPOK 573	GAO 5 GO 2 GPOK 123	GAO 5 x Pusa Sawani GO 2 x GPOK 578 GPOK 123 x GPOK 573	GO 2 x GPOK 578 GPOK 123 x GPOK 573 GAO 5 x Pusa Sawani	GPOK 123 x GPOK 573 GAO 5 x Pusa Sawani GO 2 x GPOK 573	GO 2 x GPOK 578 GPOK 123 x GPOK 573 GO 2 x GPOK 573
Number of nodes per plant	GAO 5 Pusa Sawani GO 2	GAO 5 x GPOK 349 GO 2 x Pusa Sawani PS x GPOK 578	GAO 5 Pusa Sawani GPOK 573	GPOK 123 x GPOK 349 GPOK 123 x GPOK 578 GO 2 x Pusa Sawani	GPOK 123 x GPOK 349 GAO 5 x GPOK 349 Pusa Sawani x GPOK 578	GPOK 123 x GPOK 349 GO 2 x Pusa Sawani GPOK 349 x GPOK 573	GAO 5 x GPOK 349 GO 2 x Pusa Sawani GAO 5 x AOL 10-22
Number of primary branches per plant	Pusa Sawani GAO 5 GPOK 123	GAO 5 x GO 2 AOL 10-22 x GPOK 578 GO 2 x GPOK 123	GAO 5 GO 2 Pusa Sawani	GO 2 x GPOK 123 AOL 10-22 x GPOK 578 GPOK 123 x GPOK 578	AOL 10-22 x GPOK 578 GO 2 x AOL 10-22 GO 2 x GPOK 123	GO 2 x AOL 10-22 AOL 10-22 x GPOK 578 GO 2 x GPOK 123	GAO 5 x GO 2 GAO 5 x AOL 10-22 GO 2 x Pusa Sawani
Moisture content	AOL 10-22 GPOK 573 GPOK 349	GAO 5 x Pusa Sawani GO 2 x Pusa Sawani PS x GPOK 578	GAO 5 Pusa Sawani AOL 10-22	GO 2 x Pusa Sawani PS x GPOK 578 GO 2 x GPOK 573	Pusa Sawani x GPOK 578 GO 2 x GPOK 123 GO 2 x GPOK 578	GO 2 x Pusa Sawani GO 2 x GPOK 123 PS x GPOK 578	Pusa Sawani x GPOK 578 GAO 5 x Pusa Sawani GO 2 x Pusa Sawani
Ash content	Pusa Sawani GO 2 GPOK 578	GAO 5 x AOL 10-22 AOL 10-22 x GPOK 123 Pusa Sawani x GPOK 123	Pusa Sawani GPOK 349 GPOK 573	GAO 5 x AOL 10-22 AOL 10-22 x GPOK 123 Pusa Sawani x GPOK 123	GAO 5 x AOL 10-22 AOL 10-22 x GPOK 123 Pusa Sawani x GPOK 123	GAO 5 x AOL 10-22 AOL 10-22 x GPOK 123 GAO 5 x GPOK 123	GPOK 573 x GPOK 578 GAO 5 x AOL 10-22 Pusa Sawani x GPOK 123

✍…………………………………..…………………………………
………………………………………..*Discussion*

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* Original not seen

APPENDIX- I

Weekly meteorological data for the duration of crop season (July - October 2014) recorded at the meteorological observatory, AAU, Anand, Gujarat

Month of year 2014	Standard week	Temperature (^{o}C)		Relative humidity (%)		Sunshine hours	Rainfall (mm)
		Max.	Min.	Morn.	Even.		
July	28	36.2	26.0	85.9	59.9	4.1	64.0
	29	30.1	25.0	95.9	82.0	1.3	44.7
	30	33.0	26.1	90.9	74.6	2.3	13.9
	31	32.7	25.9	93.3	74.3	2.3	15.6
	32	33.0	25.3	93.6	74.7	4.3	105.8
August	33	30.4	25.4	94.9	89.6	0.6	147.1
	34	30.0	25.0	96.6	86.1	2.2	122.2
	35	31.0	25.5	96.7	78.9	1.9	113.3
	36	31.4	24.9	98.1	85.4	2.5	114.8
September	37	30.7	25.3	96.6	79.6	2.9	99.4
	38	31.1	25.0	96.9	76.0	3.5	11.1
	39	31.5	24.4	96.4	65.9	7.0	24.9
	40	33.0	23.9	88.3	56.4	8.0	1.0
October	41	34.3	23.8	83.9	45.0	9.2	0.0
	42	37.3	24.1	81.7	40.0	8.1	0.0
	43	37.9	22.0	89.0	34.0	8.6	0.0
	44	36.9	18.4	81.4	26.6	9.8	0.0
	45	35.8	19.9	75.9	27.7	8.8	0.0

APPENDIX- II

Mean performance of parents and their hybrids for various characters in okra

Genotypes	Fruit yield per plant (g)	Days to 50% flowering	First fruiting node	Days to first picking
Parents				
GAO 5 (Standard Check)	249.3	49.7	8.3	52.0
GO 2	261.3	50.0	10.0	51.3
Pusa Sawani	268.3	50.0	8.0	50.7
AOL 10-22	206.7	50.0	7.3	51.3
GPOK 123	172.0	51.3	9.3	54.0
GPOK 349	300.3	52.3	8.7	55.3
GPOK 573	197.3	55.7	11.0	57.3
GPOK 578	108.7	59.3	8.0	60.0
Hybrids				
GAO 5 X GO 2	275.3	50.3	10.3	53.3
GAO 5 X Pusa Sawani	240.3	51.3	10.3	52.0
GAO 5 X AOL 10-22	231.3	49.7	8.3	51.3
GAO 5 X GPOK 123	236.0	50.3	8.3	52.0
GAO 5 X GPOK 349	195.7	52.0	8.3	53.3
GAO 5 X GPOK 573	213.7	50.3	9.3	52.7
GAO 5 X GPOK 578	197.3	51.3	9.3	54.0
GO 2 X Pusa Sawani	260.0	49.3	9.7	52.0
GO 2 X AOL 10-22	241.7	50.3	10.0	51.3
GO 2 X GPOK 123	291.3	50.7	10.3	53.3
GO 2 X GPOK 349	202.7	51.7	11.0	54.0
GO 2 X GPOK 573	134.7	57.3	9.3	59.0
GO 2 X GPOK 578	215.3	56.0	11.7	58.0
PS X AOL 10-22	185.7	51.3	9.0	52.0
PS X GPOK 123	237.0	49.7	9.0	51.3
PS X GPOK 349	183.7	51.7	9.3	53.3
PS X GPOK 573	188.7	52.3	10.0	54.7
PS X GPOK 578	207.0	50.7	9.7	53.3
AOL 10-22 X GPOK 123	200.0	49.7	9.3	52.0
AOL 10-22 X GPOK 349	220.7	49.7	9.0	52.0
AOL 10-22 X GPOK 573	172.7	50.0	9.0	51.3
AOL 10-22 X GPOK 578	218.0	50.7	9.3	52.0
GPOK 123 X GPOK 349	253.0	51.3	9.7	54.0
GPOK 123 X GPOK 573	177.3	51.0	10.3	55.3
GPOK 123 X GPOK 578	110.0	62.3	9.3	63.0
GPOK 349 X GPOK 573	166.0	51.0	10.0	54.0
GPOK 349 X GPOK 578	211.0	52.7	9.3	55.3
GPOK 573 X GPOK 578	102.0	54.7	11.3	56.7
General Mean	209.2	51.8	9.4	53.8
S. E. (±)	19.61	0.73	0.59	0.92
C. V. (%)	16.23	2.42	10.78	2.95
C. D. (at 5%)	55.31	2.05	1.66	2.59

Appendix-II Contd…

Genotypes	Fruit length (cm)	Fruit girth (cm)	Fruit weight (g)	Number of fruits per plant
Parents				
GAO 5 (Standard Check)	11.5	6.3	11.5	21.7
GO 2	11.9	6.2	13.6	18.4
Pusa Sawani	12.3	6.7	12.9	18.4
AOL 10-22	13.3	6.5	13.4	14.7
GPOK 123	11.4	6.1	13.7	10.7
GPOK 349	11.6	6.8	16.4	17.5
GPOK 573	9.2	7.7	13.0	14.9
GPOK 578	4.9	6.8	10.6	10.3
Hybrids				
GAO 5 X GO 2	12.6	6.2	14.0	21.2
GAO 5 X Pusa Sawani	11.7	6.1	12.7	19.6
GAO 5 X AOL 10-22	12.9	6.2	11.3	21.2
GAO 5 X GPOK 123	12.5	6.2	13.6	18.4
GAO 5 X GPOK 349	10.2	5.9	11.2	17.6
GAO 5 X GPOK 573	12.5	6.2	12.8	20.3
GAO 5 X GPOK 578	10.0	6.4	12.0	16.2
GO 2 X Pusa Sawani	13.5	6.2	14.1	18.5
GO 2 X AOL 10-22	12.6	6.1	13.4	18.1
GO 2 X GPOK 123	14.1	6.6	13.7	23.1
GO 2 X GPOK 349	12.8	6.5	14.7	13.5
GO 2 X GPOK 573	11.0	5.8	12.8	10.9
GO 2 X GPOK 578	11.2	6.9	14.1	14.4
PS X AOL 10-22	10.9	6.1	12.5	15.2
PS X GPOK 123	11.8	6.3	14.0	17.4
PS X GPOK 349	11.8	6.4	13.4	14.3
PS X GPOK 573	9.5	6.6	13.9	13.8
PS X GPOK 578	10.4	6.5	13.0	16.2
AOL 10-22 X GPOK 123	12.8	6.2	13.0	14.4
AOL 10-22 X GPOK 349	11.9	6.5	13.4	17.1
AOL 10-22 X GPOK 573	10.4	6.7	12.5	15.8
AOL 10-22 X GPOK 578	10.4	6.8	13.6	15.8
GPOK 123 X GPOK 349	12.3	6.7	14.5	17.5
GPOK 123 X GPOK 573	10.5	5.9	12.4	14.7
GPOK 123 X GPOK 578	6.0	6.7	17.8	6.2
GPOK 349 X GPOK 573	10.4	7.2	12.9	12.7
GPOK 349 X GPOK 578	9.7	6.5	14.0	15.0
GPOK 573 X GPOK 578	8.9	7.0	9.9	10.9
General Mean	11.1	6.4	13.2	16.0
S. E. (±)	0.55	0.16	0.67	0.88
C. V. (%)	8.52	4.24	8.71	9.55
C. D. (at 5%)	1.55	0.55	1.88	2.49

Appendix-II Contd…

Genotypes	Plant height (cm)	Number of nodes per plant	Number of primary branches/ plant	Moisture content (%)	Ash content (%)
Parents					
GAO 5 (Standard Check)	108.7	17.3	2.0	86.8	4.6
GO 2	124.0	16.3	1.2	93.8	6.4
Pusa Sawani	98.0	16.7	2.1	88.6	6.5
AOL 10-22	98.3	15.7	1.6	84.7	4.9
GPOK 123	105.7	14.7	1.7	88.8	4.7
GPOK 349	96.0	15.7	1.6	86.6	6.2
GPOK 573	102.3	16.3	1.1	85.7	6.1
GPOK 578	66.0	14.3	0.9	90.6	6.4
Hybrids					
GAO 5 X GO 2	118.7	16.3	2.8	88.6	4.5
GAO 5 X Pusa Sawani	115.3	18.3	2.1	85.4	5.3
GAO 5 X AOL 10-22	107.3	18.7	2.7	86.4	6.6
GAO 5 X GPOK 123	100.0	18.3	1.4	85.9	5.0
GAO 5 X GPOK 349	107.3	19.3	2.4	90.0	5.9
GAO 5 X GPOK 573	106.3	18.0	1.4	86.6	5.9
GAO 5 X GPOK 578	92.3	17.0	1.9	87.8	6.4
GO 2 X Pusa Sawani	111.3	19.0	2.0	85.7	6.4
GO 2 X AOL 10-22	117.7	17.7	2.7	88.4	4.7
GO 2 X GPOK 123	114.0	16.3	2.6	86.8	5.6
GO 2 X GPOK 349	106.0	14.0	1.7	88.4	5.5
GO 2 X GPOK 573	121.3	17.3	1.2	88.3	5.5
GO 2 X GPOK 578	128.3	17.0	1.2	88.5	6.1
PS X AOL 10-22	85.3	13.7	1.8	88.8	6.0
PS X GPOK 123	105.0	16.7	2.3	87.9	6.6
PS X GPOK 349	86.0	17.0	1.2	87.2	6.5
PS X GPOK 573	90.0	18.7	1.9	88.4	6.4
PS X GPOK 578	91.3	18.0	2.1	84.9	5.4
AOL 10-22 X GPOK 123	103.7	16.3	1.5	86.1	6.2
AOL 10-22 X GPOK 349	92.0	17.0	2.2	87.3	5.9
AOL 10-22 X GPOK 573	91.3	17.7	1.5	87.3	5.5
AOL 10-22 X GPOK 578	93.0	14.0	2.6	86.2	6.3
GPOK 123 X GPOK 349	97.3	18.3	1.5	87.4	4.7
GPOK 123 X GPOK 573	122.7	15.3	1.7	87.3	4.8
GPOK 123 X GPOK 578	75.0	17.3	0.6	88.9	5.4
GPOK 349 X GPOK 573	83.3	16.7	1.5	86.6	5.2
GPOK 349 X GPOK 578	84.7	14.3	1.8	87.5	5.9
GPOK 573 X GPOK 578	86.7	16.7	1.4	87.5	6.7
General Mean	100.9	16.7	1.7	87.5	5.7
S. E. (±)	6.69	0.67	0.14	0.66	0.17
C. V. (%)	11.48	6.91	13.96	1.30	5.09
C. D. (at 5%)	18.87	1.88	0.40	1.85	0.48

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