*DEDICATED TO…*

*My Beloved Parents-*

*Whose boundless love and silent sacrifices are unmatched by my small achievements...*

*Shri. Balasaheb S. Patil and*
*Sou. Sarita B. Patil*

*…Smita*

# "HETEROSIS AND COMBINING ABILITY STUDIES IN OKRA (*Abelmoschus esculentus* (L.) MOENCH)"

*A thesis submitted to the*

**MAHATMA PHULE KRISHI VIDYAPEETH**

**RAHURI-413 722 Dist. Ahmednagar.**

**(Maharashtra state, India)**

*By*

**MISS SMITA BALASAHEB PATIL**

**Reg. No. 06/034**

**DEPARTMENT OF AGRICULTURAL BOTANY**

**MAHATMA PHULE KRISHI VIDYAPEETH**

**COLLEGE OF AGRICULTURE, PUNE-411 005**

**MAHARASHTRA STATE, (INDIA)**

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*In partial fulfilment of the requirement for the degree of*

**MASTER OF SCIENCE (AGRICULTURE)**

*in*

**AGRICULTURAL BOTANY**
**(CYTOGENETICS AND PLANT BREEDING)**

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**Approved by**

**Dr. P. N. Harer**
**Chairman and Research Guide**
Principal Scientist
Pulses Improvement Project
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413 722

**Dr. S. D. Warade**
**Committee Member**
Head, Deptt. of Horticulture
Mahatma Phule Krishi Vidyapeeth, Rahuri

**Prof. L. C. Mohatkar**
**Committee Member**
Associate Prof. of Agril Botany
College of Agriculture, Pune

**Prof. D. V. Dahat**
**Committee Member**
Assistant Prof. of Agril. Botany
College of Agriculture, Pune

**Prof. M. S. Karkeli**
**Committee Member**
Assistant Prof. of Agril. Statistics
College of Agriculture, Pune

# CANDIDATE'S DECLARATION

I hereby declare that the thesis entitled **"Heterosis and Combining Ability Studies in Okra (*Abelmoschus esculentus* (L.) Moench)"** or part thereof has not been submitted by me or any other person to any other university or institute for a degree or diploma.

**Place:** Pune-411 005

**Date:** /06 /2008 **(Smita Balasaheb Patil)**

**Dr. P. N. Harer**
Principal Scientist
Pulses Improvement Project
Mahatma Phule Krishi Vidyapeeth,
Rahuri-413 722 Dist. Ahmednagar
Maharashtra State, India

# CERTIFICATE

This is to certify that the thesis entitled **"Heterosis and Combining Ability Studies in Okra (*Abelmoschus esculentus* (L.) Moench)",** submitted to the faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar for the award of degree of **MASTER OF SCIENCE (Agriculture)** in Agricultural Botany (Cytogenetics and plant Breeding) embodies the results of a piece of *bona fide* research work carried out by **Miss Smita Balasaheb Patil,** under my guidance and supervision, and that no part of the thesis has been submitted for any other degree or diploma.

The assistance and the help received during the course of this investigation have been duly acknowledged.

**Place:** Pune-411 005 (**P. N. Harer)**
**Date:** / 06 /2008 Research Guide

**Dr. B. R. Ulmek**
Associate Dean
College of Agriculture,
Pune- 411 005
Maharashtra State, India

# CERTIFICATE

This is to certify that the thesis entitled **"Heterosis and Combining Ability Studies in Okra (*Abelmoschus esculentus* (L.) Moench)"** in partial fulfilment of the requirements for the award of degree of **MASTER OF SCIENCE (Agriculture)** in Agricultural Botany (Cytogenetics and plant Breeding) embodies the results of a piece of *bona fide* research work carried out by **Miss Smita Balasaheb Patil** under the guidance and supervision of Dr. P. N. Harer, and that no part of the thesis has been submitted for any other degree or diploma.

**Place:** Pune-411 005 **( B. R. Ulmek )**
**Date:** / /2008 Research Guide

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*Place : Pune*

*Date : /06/2008* *(Smita Balasaheb Patil)*

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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| % | : | Per cent |
| σ | : | Standard Deviation |
| BP | : | Better parent |
| C.D. | : | Critical difference |
| C.V. | : | Coefficient of variance |
| cm | : | Centimeters |
| *et al.* | : | et all (and others) |
| $F_1$ | : | First filial generation |
| $F_2$ | : | Second filial generation |
| g | : | Gram |
| gca | : | General Combining Ability |
| $h^2_{(n.s.)}$ | : | Heritability in narrow sense |
| MP | : | Mid- parent |
| No. | : | Number |
| P | : | Parent |
| PCV | : | Phenotypic coefficient of variation |
| *Per se* | : | Actual |
| r | : | Replication |
| sca | : | Specific Combining Ability |
| S.E. | : | Standard error |
| t | : | Treatment |
| Var | : | Variance |
| Vs. | : | Versus |
| *viz.,* | : | Videlicent (namely) |
| $\overline{x}$ | : | General mean |

# LIST OF PLATES

# ABSTRACT

**"HETEROSIS AND COMBINING ABILITY STUDIES IN OKRA (*Abelmoschus esculentus* (L.) Moench)"**

*By*
**MISS SMITA BALASAHEB PATIL**

*A candidate for the degree of*
**MASTER OF SCIENCE (AGRICULTURE)**
*in*
**CYTOGENETICS AND PLANT BREEDING**
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**COLLEGE OF AGRICULTURE, PUNE - 411 005**

| | |
|---|---|
| **Research Guide:** | **Dr. P. N. Harer**<br>Principal Scientist<br>Pulses Improvement Project<br>Mahatma Phule Krishi Vidyapeeth,<br>Rahuri-413 722 |
| **Major Field:** | **Cytogenetics and plant Breeding** |

The investigation on ''Heterosis and Combining Ability studies in Okra (*Abelmoschus esculentus* (L.) Moench )'' was conducted in *Kharif*, 2007 at Botany Farm, College of Agriculture, Pune. Seven diverse genotypes *viz.,* Parbhani Kranti ($P_1$), Arka Anamika ($P_2$), Arka Vijay ($P_3$), Phule Utkarsha ($P_4$), Ajeet-121 ($P_5$), Pusa Sawani ($P_6$) and Benolt ($P_7$) were intermated in a 7 x 7 half diallel fashion during Summer, 2006 and the resulting 21 hybrids along with seven parents and a check (Panchali) were sown in a randomized block design with three replications during *Kharif*, 2007. The data was recorded on nine quantitative characters *viz.,* days to 50 per cent flowering (No.), plant height at harvest (cm), primary branches per

**Abstract contd.....**

plant (No.), internodes per plant (No.), days to first picking (No.), number of fruits per plant, average fruit length (cm), average fruit girth (cm) and green fruit yield (g/plant); and two qualitative characters *viz.*, reaction to YVM and export parameters. The results were analyzed statistically following Griffing's Model I, Method II for heterosis and combining ability.

The significant mean sum of squares due to parents as well as hybrids for all the characters (except plant height for the hybrids) indicated the presence of variability among them. The significant mean sum of squares due to parents vs. crosses interaction for all the characters (except primary branches per plant, average fruit length and fruit girth); indicating the presence of heterosis for these characters.

Significant heterosis over MP and standard check was observed for all the characters in the present investigation. The highest magnitudes of mean heterobeltiosis (22.89%), relative (49.23%) and economic heterosis (14.92%) were observed for primary branches per plant, followed by green fruit yield which recorded 7.26 per cent mean heterosis over BP, 113.83 per cent over MP and 3.87 per cent over standard check, whereas low heterosis was recorded for days to first picking, fruit length and plant height.

The hybrid Arka Anamika x Benolt exhibited the highest and highly significant heterobeltiosis, average and useful heterosis (55.36, 73.32 and 13.59 % respectively), followed by Arka Vijay x Pusa Sawani (27.11, 34.83 and 22.77 % respectively). The highly heterotic hybrids also recorded high *per se* performance indicating the feasibility of selection based on heterosis coupled with *per se* performance.

The analysis of variance for combining ability revealed significant differences due to gca and sca for all the characters (except for average fruit

**Abstract contd.....**

girth for sca) suggesting the importance of both additive and non additive genetic components.

Based on the gca effects; Benolt was identified as the best general combiners for seven characters including yield and related characters, while Parbhani Kranti was identified as the best combiner for days to first picking and Phule Utkarsha for days to first picking. The gca effects of the parents and their *per se* performances were observed to be closely associated.

Based on sca effects, Arka Anamika x Benolt, followed by Arka Vijay x Pusa Sawani for green fruit yield and Arka Vijay x Ajeet-121 for earliness and fruit length and Parbhani Kranti x Phule Utkarsha for fruit girth were found to be the best specific combinations.

Based on heterosis, sca effects and *per se* performance, Arka Anamika x Benolt appeared to be the best hybrid for green fruit yield and other yield contributing characters. Other superior hybrids were Arka Vijay x Pusa Sawani for green fruit yield and Arka Vijay x Ajeet-121 for earliness and fruit length.

The predominance of dominance gene action for all the characters except plant height and fruit length, suggested the feasibility of exploitation of heterosis. Low to moderate heritability was recorded for all the characters studied.

The parents Benolt, Parbhani Kranti and Phule Utkarsha were identified as the bet general combiners, while the hybrids Arka Anamika x Benolt, Arka Vijay x Pusa Sawani and Arka Vijay x Ajeet-121 were noted as the superior hybrids in the present investigation.

CHAPTER 1

# INTRODUCTION

Okra (*Abelmoschus esculentus* (L.) Moench) is one of the popular vegetables in India, grown extensively all round the year. Okra is an important vegetable crop owing to its high nutritive content, good market value, high export potential and medicinal value.

India led the world in area and production of okra with 36.84 lakh metric tonnes of production obtained from an area of 3.76 lakh ha under the crop. The area under the crop in Maharashtra during 2005-06 was 0.29 lakh ha. The state ranked seventh in the country with the production of 16.5 lakh metric tonnes. However, Maharashtra's productivity (6.3 MT/ha) is much lower than that of the country (9.8 MT/ha)(Anonymous, 2006).

Okra (*Abelmoschus esculentus* (L.) Moench) has its origin in tropical Africa; although some workers believe it to be of Asiatic origin. The geographical distribution of cultivated Okra and related wild species is overlapping in South-east Asia. The Indian and west African regions are also known as centres of diversity of Okra.

Okra belongs to the family Malvaceae, genus - *Abelmoschus.* There is a considerable variation in the chromosome numbers of cultivated Okra. The genus *Abelmoschus* is a poly-species complex consisting of species of apparently three levels of ploidy: the diploids (2x), including *Abelmoschus coccineus* (2n=38), *A. angulosus* (2n=38), *A. tubereculatus* (2n=58), *A. manihot* (2n=60-68), *A. moschatus* (2n=72) *and A. ficulneus* (2n=72); the tetraploids (4x), including *A. esculentus* (2n=120-140), *A. tetraphyllus* (2n=130-138) and *A. pungens* (2n=138); and the hexaploids (6x), including *Abelmoschus manihot,* Guinean type (2n=185-198).

Joshi and Hardas (1956) concluded that Okra is an allopolyploid consisting of two genomes each of 29 and 36 chromosomes. According to them, Indian varieties belong to the group of 2n =130 chromosomes.

The nutritive values of Okra as 88% moisture, 7.7% carbohydrates, 2.2% protein, 1.5% iron, 1.1% fibre, 0.7% mineral matter, 0.09% calcium, 0.2% fat, 0.08% phosphorous and 41 (k.cal) calorific value. The vitamin content is - 58 IU vitamin A, 0.06mg vitamin B, 0.6mg Nicotinic acid, 0.06 mg Riboflavin and 16 mg vitamin C. Besides it has also been put to several domestic and medicinal uses. Okra cortex is shown to be useful as one of the potential sources of mucilage (Girase ***et al***., 2003).

Good nutritive value, popularity, medicinal value, good market value and high export potential are the aspects in favour of ***Bhendi*** or Okra. However, pests such as jassids and bollworms and diseases like yellow vein mosaic, powdery mildew etc. pose problems in okra cultivation by reducing the quality of the produce and increasing the cost of cultivation. Yellow vein mosaic viral disease is a serious challenge in cultivation of Okra. Some good varieties have been developed in okra in India, but many of them suffer from one or the other drawback. Crop improvement in Okra needs to focus on plant height, higher yield, early flowering, more branching, fruit length and tenderness, number of fruits, disease and pest resistance and high yield.

Hence, exploitation of hybrid vigour, understanding the genetics of pest and disease resistance and the improvement of quality aspects with an eye on the export market need to be concentrated upon in okra improvement programs. Exploitation of hybrid vigour in Okra has been recognized as a practical tool in providing the breeders a means of increasing the yield. Photo insensitive nature and shorter growth period enables the plant breeder to grow 2-3 Okra crops in a year, thus genetic studies can be conducted in a short time. Also, relative ease of

hybridization in Okra due to its monadelphous nature, higher degree of fruit set and fairly large number of seeds per fruit points to a good scope for commercial hybrid seed production. There are a few commercial $F_1$ hybrids released by private seed companies which are well received in the market. This shows that exploitation of heterosis and production of $F_1$ hybrids in Okra is a promising area which should be explored.

There is a need to generate more information regarding heterosis, combining ability, the nature of gene action for various traits and adaptability of a cultivar which could help in predicting the effectiveness of selection. The information generated from the experiment could be used, especially in case of exploitation of hybrid vigour.

The proposed project aims at studying heterosis and combining ability in okra which will prove valuable in the isolation of parents for further hybridization programs as well as to identify a superior hybrid of okra for general cultivation. The present study is undertaken with the following objectives:

1) To study the heterosis for yield and its components in okra
2) To study general and specific combining ability of the parents and hybrids, respectively.
3) To find out suitable parents for use in further breeding program
4) To identify a superior parent and hybrids in Okra.

CHAPTER 2

# REVIEW OF LITERATURE

Okra is one of the important vegetable crops grown in India, especially Maharashtra. Due to consistent market demand, good nutritive value, shorter growth period, medicinal and other uses and huge export potential, okra enjoys a place of prime importance among Indian vegetables. Despite this, the information available on okra is still limited. Studies on hybrid vigour, combining ability, heritability and gene action are important in the evaluation and selection of the crop under experimentation. In this chapter, the published information on improvement of okra in relation to the present investigation is reviewed.

The information is presented under the following broad heads:

1. Heterosis
2. Combining ability
3. Heritability
4. Gene action

## 2.1 Heterosis

The superiority of the $F_1$ hybrid over their parents is termed as heterosis. The term heterosis was coined by Shull (1914) for the developmental stimulus resulting from the union of different gametes.

Heterosis is usually measured in terms of various parameters like increased or decreased expression of hybrid over mid parental value called average heterosis, relative or mid parental heterosis and over better parent value called as heterobeltiosis. In many cases, the superior parent of the hybrid may be inferior to the best commercial variety. In such cases it will be desirable to estimate heterosis in relation to the best commercial variety of the crop; such an estimate is known as useful

heterosis or check parent heterosis or economic heterosis or standard heterosis.

Pratap and Dhankhar (1980a) studied 7 x 7 half diallel and found that a cross IC 6653 x IC 6316 displayed heterosis for fruit yield per plant, fruits per plant and fruit length, while IC 6653 x IC 12930 showed heterosis for fruit yield per plant, fruit number per plant and fruit number per branch.

Thaker *et al.* (1982) studied hybrid vigour and inbreeding depression for fruit yield and its components in 21 intervarietal crosses of Okra. The manifestation of heterobeltiosis was the highest for fruit yield per plant (55.74%) followed by number of fruits per plant (40.46%) and fruit length (20.03%).

Interspecific hybridization studies in okra were carried out by Dhillon and Sharma (1982) in which they observed heterosis over the better parent for number of fruits per plant, plant height and number of branches per plant.

Heterosis over mid parent was observed by El-Maksoud *et al.*(1984) for plant height (143.87%), days to first flower anthesis (85.76%) and fruit weight (124.2%).

While identifying the potential hybrids in okra, Agarrado and Rasco (1986) reported heterosis over mid-parent for plant height, pod length, pod weight, number of pods per plant, days to flowering, internodal length and yield. The best hybrid, 124977 x 370028 produced 76.7 per cent higher yield than the open pollinated standard Smooth Green.

Changan and Shukla (1986) studied heterosis and inbreeding depression in okra and reported 18 crosses showing heterosis over mid-parent and 14 crosses showing heterosis over the better parent. Also,

characters showing high heterosis in $F_1$ showed high inbreeding depression in $F_2$ generation for most of the characters studied.

Vijay and Manohar (1986b) studied heterosis over better parent for 11 yield related characters in 45 okra $F_1$ hybrids derived from 10 lines. Pusa Sawani x Clemson Spineless and Pusa Sawani x IC 8911 showed highest heterobeltiosis for fruit yield (64.93 and 66.81 % respectively).

Shukla and Gautam (1990) studied heterosis and inbreeding depression in okra using 16 promising lines and three pollen parents. Hybrid vigour was evident for most of the characters under study and the hybrid combinations which showed higher heterosis, in general, also indicated high inbreeding depression. The cross IC 52392 x Pusa Sawani manifested high heterosis as well as high inbreeding depression.

Mandal and Dana (1993) evaluated the $F_1$ and $F_2$ generations from a 6 x 6 half diallel in okra. EMS-8 x Punjab Padmini showed significant heterosis over the best parent for earliness and the two crosses *viz.*, Sel. 10 x Punjab Padmini and Sel-4 x Punjab Padmini showed significant heterosis over the best parent for plant height and fruits per plant.

Dayasagar (1994) observed Pusa Sawani x Parbhani Kranti as the highest heterobeltiotic cross for yield per plant in a study of nine yield components in respect of six cultivars and their 15 $F_1$ hybrids of okra.

Mohamed *et al.* (1994b) observed the effect of crossing on the immature pods of okra hybrids. All the hybrids had higher pod weight than their parents. Balady x Gold Coast had the greatest value. Three hybrids (Clemson Spineless x Dwarf Green Long Pod, Esmaily x Dwarf Green Long Pod and Esmaily x Clemson Spineless) had low crude fibre content, although there were no significant differences between them. Compared to the other hybrids, Esmaily x Dwarf Green Long Pod showed the highest carbohydrate content.

Mohamed *et al.* (1994a) reported heterosis in crosses among four local and introduced okra cultivars. All the hybrids, Excluding Balady x Dwarf Green Long Pod, showed heterosis for all the characters except pod diameter. Balady x Dwarf Green Long Pod had heterosis for plant height, early flowering, number of pods per plant and total yield per plant.

Patil *et al.* (1996a) studied a diallel set of crosses involving three Indian and seven exotic lines of Okra. IHR 4 × PL 489782; Pusa Sawani × PL 4896620; Pusa Sawani × Smooth Green were found to be the best combinations which produced very high fruit yield.

More and Patil (1997) reported the highest overall mean heterosis over mid-parent and better parent for fruit yield per plant which was 5.65 and 28.94 per cent, respectively. It was mostly due to the heterotic effects of number of fruits per plant, number of fruits per picking and weight of fruits.

Pathak *et al.* (1998) carried out 6×3 line × tester analysis for 16 important characters and identified Arka Abhay, Pusa Makhamali, Parbhani Kranti and Punjab Padmini as the promising parents for improving fruit yield.

Pawar *et al.* (1999a) studied heterosis in a set of 10 × 10 diallel cross excluding reciprocals. Heterosis was found to be higher for number of branches per plant, yield per plant, number of pods per plant and plant height; moderate for first fruiting node, pod girth, pod length and number of nodes per plant; while days to 50 per cent flowering and days to first picking exhibited low heterosis.

Bhalekar (2000) reported significantly high heterosis in desirable direction over mid-parent for all the characters studied except nodes per plant and incidence of YVM. The highest heterosis, observed over better

parent in positive direction, was for yield per hectare (21.94%) followed by first fruiting node (-18.81%), fruits per plant (15.57%), yield per plant (15.13%), fruit length (13.08%), plant height (11.69%) and fruit diameter (- 11.69%). While, the highest heterosis observed over top parent, in favourable direction, was for yield per hectare (15.86%) followed by fruits per plant (15.55%), first fruiting node (-15.46%) and yield per plant (15.13%).

Deshmukh *et al.* (2001) reported heterobeltiosis to the extent of -20.11 per cent for days to first flowering, 23.21 per cent for plant height, 75.00 per cent for number of primary branches on main stem, 59.62 per cent for number of fruiting nodes on main stem, 87.90 per cent for number of fruits per plant, 22.32 per cent for average fruit weight, 23.28 per cent for fruit length and 129.22 per cent for yield per plant was observed. The best performing hybrid was VRO-3 × Arka Abhay, which gave 129.22 per cent higher yield than the better parent.

Dhall *et al.* (2002) studied heterobeltiosis in an 8 x 8 half diallel crosses of okra. Highly significant and desirable heterobeltiosis was observed for all characters, except for YVM virus-related characters. The cross Pusa Makhamali × HRB 9-2 showed significant and desirable heterotic response for node at which the first flower appeared, number of fruits per plant, average fruit weight, marketable yield and total yield, while the cross HRB 9-2 × Punjab-8 exhibited desirable heterosis for days to first flowering, days to first picking and plant height.

Rewale *et al.* (2003a) reported significant heterotic effects in positive direction for all eight yield contributing characters. They also noticed that the parents DVR-4, SOH-02 and Arka Anamika exhibited good gca effects for yield and most of the yield attributes.

Veeraragavathatham *et al.* (2003) studied 3 parents and 4 $F_1$ hybrids and higher heterosis over the highest and best parent was

observed in almost all the characters. Among the hybrids, OHD-1 × PA4 showed the highest heterosis over the best parent for yield and fruit number per plant, fruit length and fruit girth. Hybrid PA4 × Varsha Uphar showed moderate YVM resistance and exhibited higher heterosis over the best parent.

Bendale *et al.* (2003) reported significant heterotic effects in the positive direction for all the yield and yield contributing characters *viz.*, days to initiation of flowering, days to initiation of fruit, days to maturity for green fruit, plant height, branches per plant, nodes per plant, fruits per plant and yield per plant of okra.

Singh *et al.* (2004) studied heterosis and inbreeding depression with 10 parents, 45 $F_1$ and 45 $F_2$ genotypes. Considerable heterosis was observed for fruit yield and its components. The best 5 crosses were KS405 × KS404, PK × KS404, PK × KS405, PS × PK and PK × KS401.

Bendale *et al.* (2004) studied heterosis and combining ability in Okra in an 8 × 8 half diallel fashion and reported that Parbhani Kranti × Gold Finger (446.86%), Long Green Smooth Finger × Green Gold (193.83%) and Local × Green Gold (172.08%) showed desirable heterosis for yield over better parent.

Nimbalkar *et al.* (2004) studied heterosis in okra using 7 diverse pure-lines and their 21 $F_1$s. They observed heterosis in desirable direction for fruit yield and its component characters, except for average fruit weight. The magnitude of the heterosis was higher for incidence of yellow vein mosaic virus, yield per plant. Significant heterosis was found for fruits per plant and yield per plant in Varsha Uphar × Lorm 1, Arka Anamika × Parbhani Kranti, and Arka Anamika × Lorm 1. The crosses Okra No. 6 × Arka Anamika, A.A.D.F.1 × Arka Anamika for yield per plant and A.A.D.F.1 × Parabhani Kranti for fruit diameter showed

significant heterosis over better parent. The highest heterosis over better parent for yield was in A.A.D.F.1 × Arka Anamika (19.29%).

Mamidwar *et al.* (2006) studied heterobeltiosis in a L x T analysis with fourteen lines, 3 testers and their 42 $F_1$ hybrids. Of the 42 crosses, The highest level of heterosis over the better parent for fruit yield was recorded by VRO-6 x Parbhani Kranti (55.57%), followed by Daftari-1 x Arka Abhay (54.31%).

Vermani *et al.* (2006) through a L X T analysis, found that Pusa Makhamali x P-8 showed desirable heterobeltiosis to the maximum extent for fruit yield per plant (27.11%), nodes per plant (19.30%) and plant height ( 26.32%). the cross combination Dhira x Arka Anamika revealed significant heterosis over better parent for internodal length (-22.78%), fruits per plant (20.96%) and fruit length (39.29%).

Nichal *et al.* (2006) studied heterosis in 7 lines and their 21 $F_1$s in okra. The analysis of variance showed significant differences among the parental lines and their hybrids in terms of number of fruits per plant, average fruit weight, fruit length and fruit yield per plant, indicating genetic diversity in the material used.

## 2.2 Combining Ability

The selection of parents is one of the most important decisions a breeder has to make for carrying out any breeding method. If the genetic architecture of the plant is known, then it is useful in understanding the nature and magnitude of the gene action involved in the expression of various traits. Combining ability analysis yields useful information regarding the selection of parents in terms of the performance of their hybrids. On the basis of this information, decisions on the selection of the parents can be taken effectively.

Estimates of general combining ability (gca) and specific combining ability (sca) are widely used in planning of breeding programs. Combining ability analysis is also useful in understanding the dominant and recessive alleles governing a particular character.

Sprague and Tatum (1942) firstly gave the concept of combining ability in terms of genetic variation using single cross in maize. They defined the term 'general combining ability' as an average performance of a line in several hybrid combinations and the term 'specific combining ability' was used to designate those effects in certain combinations which significantly departed from what would be expected on the basis of the average performance of the lines involved. Allard (1960) also defined general combining ability as an average performance of a strain in a series of crosses and specific combining ability as the deviation from the performance predicted on the basis of the general combining ability. According to Griffing (1956a) general combining ability is related to both additive effects as well as additive x additive interactions. The work done on combining ability analysis in okra is reviewed below:

Pratap and Dhankhar (1980b) studied combining ability in okra and found that general combining ability variances were higher than specific combining ability variances for all the traits, indicating the predominance of the additive gene action. Significant sca variances for several traits suggested the involvement of non- additive gene action.

Thaker ***et al.*** (1981a) conducted half-diallel in okra and reported that the additive component was the chief determinant of the genetic variance in fruit yield per plant, single fruit weight and fruit length. Non-additive component governed the number of fruits per plant, girth and single fruit weight. They observed EC 68415, IC 18960 and IC 18974 to be good combiners for these characters respectively.

Singh and Singh (1984) reported that Pusa Sawani was the best general combiner for seven yield contributing traits and cultivar No.7121 for eight traits.

Vijay and Manohar (1986a) studied the combining ability effects from a 10 x 10 diallel, excluding reciprocals for days to fifty per cent flowering, pod number; pod weight, length and thickness; yield, height at the first fruiting node, total plant height, branch number, internodal length and seed number using the Griffing Method II, Model I analysis. General combining ability effects were highly significant for all the characters, except height at first fruiting node. Specific combining ability effects were highly significant for all characters. The crosses Pusa Sawani x Clemson Spineless and Pusa Sawani x IC 8911 were noted for pod yield and most of the yield components, except pod length.

Poshiya and Shukla (1986) studied fruit yield per plant and five related characters in a 7 x 7 half diallel and observed higher specific combining ability effects to be higher for fruit yield per plant. General and specific combining ability effects were significant for days to 50 per cent flowering, fruit length, number of fruits per plant and nodes on the main stem. The cross New Selection x AE 91 was the most promising cross for improving the fruit yield.

Jawili and Rasco (1990) identified Smooth Green as a good general combiner from a study of 19 characters on six parents and their 15 $F_1$s in okra.

Chaudhary *et al.* (1991) reported Pusa Makhamali and Punjab Padmini as the best combiners and Pusa Sawani x P7 as the best combination for yield and major yield contributing characters.

Mandal and Das (1992) in eight parental half diallel revealed highly significant gca and sca variances. Pusa Sawani was reported as a

good combiner for yield and most other characters while the cross Punjab Padmini x Selection 10 showed the best sca effects for yield per plant.

In a 10 x 10 half diallel cross, Patel *et al.* (1994) reported significant gca and sca effects for all the characters studied except fruiting branches per plant. The gca and sca ratio indicated predominance of non-additive gene action for dry seed yield per plant, number and weight of seeds per plant and hundred seed weight and additive gene action for the remaining characters. Gujarat Bhendi was the best general combiner for dry seed yield per plant and hundred seed weight.

Sivakumar *et al.* (1995) observed Punjab 7 as the best general combiner for fruit yield and number of fruits per plant and the hybrid Punjab 7 x AE 128 had the greatest sca for fruit yield, number of fruits, earliness and plant height.

Vasaline and Ganesan (1995) observed lines, AE 110 and AE 158 as good general combiners while the hybrid Pusa Sawani x CO 2 normal with the highest sca effects and *per se* performance.

Poshiya and Vashi (1995b) found that the variances due to gca were higher in magnitude than their respective sca for all the characters studied.

Patil *et al.* (1996a) in a 10 x 10 half diallel reported line PL 489782 as the best general combiner for marketable yield and total number of pods per plant. The crosses IHR 4 x PL 48972, Pusa Sawani x Smooth Green, Pusa Sawani x PL 496620 and IHR 4 x Green Velvet produced significantly positive sca effects for marketable yield.

Pathak *et al.* (1998) carried out 6 x 3 line x tester analysis for 16 important characters and identified Arka Abhay, Pusa Makhamali, Parbhani Kranti and Punjab Padmini as the promising parents for improving fruit yield. The crosses IC 9275 x HB 55, Arka Abhay x

Punjab Padmini, Pusa Makhamali x EC 16511 showed significant positive sca effects for fruit yield.

Pawar *et al.* (1999b) carried out combining ability analysis in okra. Information on combining ability was derived from data on 11 yield components in 10 parents and their $F_1$ hybrids. HRB-55, Pusa Sawani, DL-1-87-5 and Jo-5 were good general combiners for yield per plant.

Nichal *et al.* (2001) studied combining ability effects in 21 okra $F_1$ hybrids and 7 parental cultivars and revealed that the mean square due to gca and sca were highly significant for all the characters studied except average fruit weight.

Duzyaman and Vural (2002) performed an 8 x 8 half diallel analysis using okra genotypes of Indian, West African, USA and Turkish origins. Promising crosses with statistically significant general or specific combining abilities in yield were obtained particularly in combinations among genotypes of different ecogeographic origin.

Rewale *et al.* (2003) reported that DVR-4, SOH-02 and Arka Anamika showed good gca effects for yield and most of the yield attributes. Among the hybrids, NK- 01 x Ankur 40 and JNDO- 5 x Arka Anamika showed best performance for yield, number of seeds per plant and plant height.

Bendale *et al.* (2004) studied heterosis and combining ability in Okra in an 8 × 8 half diallel fashion and reported that Parbhani Kranti × Gold Finger (446.86%), Long green Smooth Finger × Green Gold (193.83%) and Local × Green Gold (172.08%) showed desirable heterosis for yield over better parent. Among the parents, Gold Finger was found to be a good general combiner and among the hybrids, Parbhani Kranti × Gold Finger showed the highest positive significant specific combining ability for fruit yield per plant.

Dahake (2004) carried out an 8 × 8 half diallel cross and observed that Arka Anamika and Hissar Unnat exhibited significant gca effects for various characters, while the combinations Arka Anamika × Hissar Unnat and Arka Anamika × Ankur 40 were identified as best hybrids which can be used for immediate exploitation.

Yadav *et al.* (2005) evaluated 6 hybrids of okra for combining ability analysis through diallel analysis. Significant general and specific combining was a good general combiner for plant height and fruit length and width. The cross combinations Azad Bhindi-2 × Azad Bhindi-1, Azad Bhindi-2 × BO-2 and Azad Bhindi-1 × Parbhani Kranti exhibited high heterosis in terms of yield. Most of the superior specific combiners for different characters also had a good *per se* performance.

Kumar *et al.* (2006) carried out combining ability analysis in okra through a 6 x 3 line × tester. The lines Mahanoor Local, TCR 2056, Gobi Local and testers, Parbhani Kranti and Punjab Padmini were adjudged as the superior performers for seed yield per plant based on general combining ability effects.

## 2.3 Heritability

Yield is a polygenically controlled character and it is also subjected to the environmental influence, therefore direct selection for yield is often misleading. For planning an efficient breeding program, the knowledge of phenotypic and genotypic correlations between yield and important yield contributing characters, magnitude and nature of variability and heritability for various characters is very useful.

Swamy Rao and Ramu (1975) observed that narrow sense heritability was high for number of pods per plant and yield per plant. High additive and non-additive components of genetic variance were

observed for plant height, number of pods per plant and yield per plant. For days to flowering and number of seeds per pod, neither additive nor non-additive component of genetic variance was found to be high.

Lal *et al.* (1977) observed that, the heritability (in broad sense) was the highest for days to flowering, internodal length, fruit length and fruit diameter.

Singh and Singh (1978) reported that the estimates of heritability (broad sense) and expected genetic advance were the greatest for days to flowering.

Singh and Singh (1979) observed high heritability estimates for internodal distance, plant height and height of first fruiting node together with high to moderate estimates for genetic advance. Estimates of heritability were high but those of genetic advance were low for fruit diameter.

Thaker *et al.* (1981b) observed that the heritability estimates were moderate for plant height, fruits per plant, fruit length and low for remaining characters. High genetic advance was found for five characters viz. plant height, leaf area, fruits per plant, fruit weight and yield per plant.

Singh (1986) estimated genetic variances of yield and other characters of okra and reported that heritability estimates were higher in the $F_2$ than $F_1$, except for number of days to flowering.

Sundhari *et al.* (1992a) in a 6 x 6 full diallel cross found gca / sca ratios to be less than unity, indicating the role of non-additive gene action.

## 2.4 Gene Action

Kulkarni *et al.* (1976) studied gene action through genetic components of diallel analysis and observed that both additive and non-

additive type of gene actions were operating for days to flowering, plant height and number of fruits per plant. Number of fruits per plant showed predominantly additive gene action while days to flowering and plant height showed non-additive gene action. Dominance was found to be acting in the direction of earliness, tallness and greater number of fruits per plant. Over dominance was observed for all the characters studied.

Sharma and Mahajan (1978) studied nine agronomic traits in okra in a 16 x 4 L x T analysis and reported that, all the traits were influenced by non-additive gene action, whereas over dominance was observed for days to flowering, plant height, fruit weight and yield.

Pratap *et al.* (1981) observed that both additive and non-additive gene actions were important for yield per plant. For days to first fruiting node and days to fifty per cent flowering only the non-additive gene actions were important, while for other three traits additive gene actions were important.

Singh (1986) concluded that the dominance effects of yield and its components were greater than the additive effects by estimating genetic variance of yield and other characters in okra.

Korla and Sharma (1987) in generation mean analysis revealed the presence of non-allelic interaction for yield in all the crosses, except Vaishali Vadhu x IC 16260, Pusa Sawani x IC 16260 and Long Green x EC 68475, suggesting that the epistasis was important in the expression of yield. The three exceptions exhibited partial to complete dominance for yield, with additive gene effects being significant. Over dominance was observed in two crosses and it was concluded that simple or pedigree selection should be used where additive gene effects were important.

Arora (1993) in a diallel analysis reported that both additive and non-additive genetic components were important for controlling the inheritance of all the characters studied.

Poshiya and Vashi (1995a) reported, while studying combining ability over environments that the additive and non-additive variances may be exploited following intermating among the progenies within and between promising crosses in early segregating generations.

More and Patil (1997) observed a close relationship between heterosis and inbreeding depression, suggesting the preponderance of non additive gene action.

Liou Min Li *et al.* (2002) studied 6 x 6 diallel in okra and reported that days to flowering, number of fruits per plant, yield, fruit diameter and fruit weight were controlled by additive and non-additive genes.

The inheritance of characteristics of okra (*Abelmoschus esculentus*) through 6×6 diallel technique was studied under normal and drought conditions in Pakistan, by Abid Mahmood *et al.* (2004). They observed additive gene action for fresh fruit yield per plant under drought conditions, days to maturity under normal conditions and days to first flower and seed yield per plant under both conditions and suggested effective selection in early segregating generations for these traits. However, over dominance for days to maturity under water stress, fresh fruit yield per plant under normal and relative growth rates under both normal and water stress conditions indicated the feasibility of heterosis breeding for these characteristics.

Mahajan and Ghai (2004) conducted generation mean analysis for the inter-varietal crosses i.e. Cross-I (Arka Anamika × Varsha Uphar), Cross-II (Arka Anamika × Pusa Sawani) and Cross-III (Varsha Uphar × Pusa Sawani). Additive-dominance model was adequate to explain total genetic variability for fruit weight. Additive × additive type of epistasis was found more in magnitude for fruit number in Crosses-II and III and for total yield in Crosses-I and II. Dominance × dominance type of epistasis was found more in magnitude for days to flowering and plant

height in all the three crosses and for marketable yield in Crosses-II and III.

Kumar *et al.* (2005), based on the generation mean analysis, reported that the number of days to first flower, number of nodes, plant height, single fruit weight, fruit length, and fruit yield were mainly controlled by dominance gene effects, followed by dominance × dominance interaction effects. The dominance effects can be exploited through heterosis breeding. The number of fruits per plant was controlled by additive gene effect in Punjab Padmini × Parbhani Kranti. Simple pedigree breeding was suggested for the improvement of this trait.

Adenji and Kehinde (2007) reported through the component analysis that dominant genetic action predominated other genetic effects in the inheritance of the length and width of pods. The non-additive genetic effects accounted for a low to moderate heritability estimate in narrow sense and both oligogenic and polygenic action were found.

CHAPTER 3

# MATERIAL AND METHODS

The present investigation entitled “Heterosis and Combining Ability Studies in Okra ( *Abelmoschus esculentus* (L.) Moench)”, was carried out in *Kharif*, 2007 at Botany Farm, College of Agriculture, Pune. The details of the materials used and the procedures adopted are given below.

## 3.1 Material

The experimental material for the present investigation comprised of seven promising lines of okra *viz.,* Parbhani Kranti, Arka Anamika, Arka Vijay, Phule Utkarsha, Ajeet-121, Pusa Sawani and Benolt and their 21 $F_1$s. The genotypes Parbhani Kranti, Arka Anamika, Arka Vijay and Phule Utkarsha were obtained from the Senior Vegetable Breeder, All India Co-ordinated Vegetable Improvement Project, Mahatma Phule Krishi Vidyapeeth, Rahuri; Pusa Sawani and Benolt were obtained from National Bureau of Plant Genetic Resources, New Delhi and Ajeet-121 was obtained from Ajeet Seeds, Aurangabad.

The parents selected were of diverse origin and exhibited variability in different morphological characters. The salient features of these genotypes are given in the Table 3.1.

## 3.2 Methods

### 3.2.1 Production of $F_1$ hybrid seed

The seeds of the seven parental genotypes were sown in the field during summer, 2007 to constitute the crossing block. The crosses were made between the seven parents following the scheme of 7 **x** 7 half diallel.

**Table 3.1. Salient features of parents used in 7 x 7 half diallel of okra**

| Sr. No. | Genotype | Salient Features |
|---|---|---|
| 1 | **Parbhani Kranti** | Early flowering, tall, medium maturity, dark green, smooth and tender fruits, YVM |
| 2 | **Arka Anamika** | Medium tall, slightly pigmented stem and petioles, dark green fruits with five ridges- less |
| 3 | **Arka Vijay** | Moderate height, late flowering, green stem and green coloured fruits |
| 4 | **Phule Utkarsha** | Moderate height, green, five-ridged, shiny, tender and heavy fruits, tolerant to YVM |
| 5 | **Ajeet-121** | Green coloured stem and fruits |
| 6 | **Pusa Sawani** | Purple patch on petals on both sides, YVM resistant (but now susceptibility recorded). |
| 7 | **Benolt** | Exotic variety with long and slender fruits, high yield |

The floral buds likely to open the next day morning were selected for emasculation. Emasculation was done by hand in the evening. The buds were given a slight cut at the base with the help of blade and petals along with calyx and sheath were removed to expose staminal column and stigma. The undehisced anthers were removed with a pair of forceps. Such emasculated flowers were bagged using butter paper bags. Next morning, the emasculated buds were pollinated with the male flowers bagged a day earlier. Such pollinated flowers were then bagged and labeled. After a few days the bags were removed. The fruits were harvested after reaching maturity.

### 3.2.2 Experimental design

All the twenty one crosses along with the seven parents and a standard check were sown in a Randomized Block Design with three replications in *Kharif*, 2007 at Botany Farm, College of Agriculture, Pune. Each genotype was entered as a separate treatment and was represented by a single row of 4.0 m length spaced 30 cm apart in which the seeds were dibbled.

### 3.2.3 Sowing and cultural practices

The field was prepared for sowing by ploughing, harrowing and leveling and 50 kg N, 50 Kg $P_2O_5$ and 50 Kg $K_2O$ per ha was applied as a basal dose and 50 Kg N was later applied at 30 DAS. The seeds were dibbled at a spacing of 30 **x** 15 cm. All other cultural operations like weeding, hoeing, irrigation and crop protection were carried out as per the requirement. The fruits were harvested at their marketable stage.

## 3.3 Observations

Five plants per treatment from each replication were selected randomly for recording the following observations:

### 3.3.1 Days to 50 per cent flowering (No.)

The number of days required from sowing to the day on which at least 50 per cent of the total plants flowered was recorded.

### 3.3.2 Plant height at the harvest (cm)

The height of the plant from the ground level to the last node was measured in centimeters at harvest.

### 3.3.3 Days to first picking (No.)

Number of days from sowing to the first picking were recorded.

### 3.3.4 Primary branches per plant (No.)

The number of branches arising from the main stem were counted and recorded as number of primary branches per plant.

### 3.3.5 Internodes per plant (No.)

The total number of internodes including the internodes on the main stem and the primary branches were recorded.

### 3.3.6 Number of fruits per plant

At each harvesting, the number of fruits harvested from each observational plant were counted and the average was worked out.

### 3.3.7 Average fruit length (cm)

The fruits were harvested at the marketable stage and the length was measured from the pedicel to the blossom end and the average was worked out.

### 3.3.8 Average fruit girth (cm)

The fruits used for measuring the fruit length were used for recording the fruit girth also. Fruit girth was measured as the circumference at the middle of the fruit and the average was worked out.

### 3.3.9 Green fruit yield (g/plant)

Fresh marketable fruits were harvested on every alternate day, weight of the fruits from each observational plant was taken and summed up after last harvesting.

### 3.3.10 Other observations

**a) Reaction to yellow vein mosaic**

Incidence of the yellow vein mosaic was recorded in terms of the number of plants affected at the harvest.

**b) Export parameters**

The export parameters of Okra fruits in terms of length, girth and weight were compared with the fruits obtained from each observational plant.

## 3.4 Statistical Procedures

### 3.4.1 Analysis of Variance for treatment differences

To test the significance of differences between treatments, the analysis of variance for randomized block design (RBD) was carried out by following Panse and Sukhatme (1967), for all metric characters under study was done as below:

**Table 3.2. Analysis of variance**

| Source of variation | D. F. | MSS | Expected mean squares |
|---|---|---|---|
| Replications | ( r-1) | RSS | $\sigma^2e + t\,\sigma^2r$ |
| Treatments | (t-1) | TSS | $\sigma^2e + r\,\sigma^2t$ |
| Error | (r-1) (t-1) | ESS | $\sigma^2e$ |

Where,

r = Number of replications.

t = Number of treatments.

DF = Degrees of freedom.

RSS = Replication sum of squares

TSS = Treatment sum of squares

ESS = Error sum of squares

Standard error (SE), critical difference (CD) and coefficient of variation (CV) were calculated as follows :

$SE (\pm) = \sqrt{2Me / r}$

$CD = SE \times \sqrt{2} \times$ 't' ( at error degrees of freedom )

$CV (\%) = \sigma / \bar{x} \times 100$

Where,

| | | |
|---|---|---|
| Me | : | Error mean square |
| T | : | Table 't' value at error degrees of freedom at 5 and 1 percent level. |
| r | : | Number of replication |
| $\sigma$ | : | Standard deviation |
| $\bar{x}$ | : | Mean |

### 3.4.2 Estimation of Heterosis

Heterosis (expressed in percentage) was worked out over mid parent, better parent and standard check hybrid for all characters as described by Rai (1979). Following formulae were used to calculate different heterosis:

Percent heterosis over

1. Mid parent (relative heterosis) $= (\bar{F}_1 - \overline{MP} / \overline{MP}) \times 100$
2. Better parent (heterobeltiosis) $= (\bar{F}_1 - \overline{BP} / \overline{BP}) \times 100$
3. Standard check (standard heterosis)

$= \bar{F}_1 - \overline{Std.\ Check} / \overline{Std.\ Check} \times 100$

Where,

| | | |
|---|---|---|
| $\bar{F}_1$ | : | Average performance of $F_1$ hybrid |
| $\overline{MP}$ | : | Mid parental value = (P1 + P2 )/2 |
| $\overline{BP}$ | : | Better parental value. |
| $\overline{Std.\ check}$ | : | standard check value. |

Mean heterobeltiosis, relative heterosis and standard heterosis was worked out for all the characters by summing up the heterotic effects of all the hybrids and dividing it by the total number of hybrid combinations.

**Test of significance**

The heterosis was tested by least significant difference at 5% and at 1% level of significance for error degrees of freedom as follows

For testing heterosis over mid parent

$$SE\ (diff)\ (MP) = \sqrt{3Me} / 2r$$

Fore testing heterosis over better parents and standard check

$$SE\ (diff)\ (BP) = \sqrt{2Me} / r$$

$$SE\ (diff)\ (S.C.) = \sqrt{2Me} / r$$

Where,

Me = Error variance

r = Number of replications

**Critical difference**

CD = SE (diff) x ( t at error d.f. at 5 and 1 per cent level of significance). Heterosis was considered significant when( $\overline{F_1} - \overline{MP}$) or ( $\overline{F_1} - \overline{BP}$ ) was higher than critical difference.

## 3.4.3 Combining ability analysis

### 3.4.3.1 Analysis of variance

Combining ability analysis was based on the mean data averaged over replications for all the characters under study. The combining ability analysis was carried out by following Griffing's (1956a) Model I, Method II.

The mathematical model assumed is:

$$X_{ij} = \mu + g_i + g_j + s_{ij} + 1/bc \Sigma k \Sigma l \, eijkl$$

Where,

i, j = 1, 2, 3,…..,p

k = 1, 2, 3,……..,b

l = 1, 2, 3,....……,c

$X_{ij}$ = Mean of the (ixj )$^{th}$ genotype over k and 1

$\mu$ = population mean,

$g_i$ ($g_j$) = gca effect of i$^{th}$ (j$^{th}$) parent,

$S_{ij}$ = sca effect of cross between i$^{th}$ parent and j$^{th}$ parent such that Sij = Sji, and

Eijkl = The environmental effect related to ijkl$^{th}$ observation.

The table for analysis of variance for combining ability was set up as follows:

**Table 3.3. ANOVA for combining ability in Griffing's Model I, method II**

| **Source** | **d.f.** | **SS** | **MSS** | **Expectation of MSS** |
|---|---|---|---|---|
| **GCA** | (p-1) | Sg | Mg | $\sigma^2 e + (p+2)[1/(p-1)] \Sigma gi^2$ |
| **SCA** | P(p-1)/2 | Ss | Ms | $\sigma^2 e + [2/p(p-1)] \Sigma\Sigma Sij^2$ |
| **Error** | e | Se | M'e | $\sigma^2 e$ |

Where,

Sg : $1/p+2 [\Sigma (X_i. = X_{ii})^2 – 4/p X^2..]$

Ss : $\Sigma_{i \leq j} \Sigma x_{ij}^2 - 1/(p+2) \Sigma_i (X_i + X_{ii})^2 + 2/(p+1)(p+2) X^2..$

The mean sum of squares pf gca (Mg) and sca (Ms) were calculated by dividing the respective sum of squares by corresponding degrees of freedom. Whereas, mean error variances was obtained by dividing error mean sum of squares (Me) for randomized block design by the number of replications as below :

$$M'_e = M_e/r = \sigma^2_e$$

Where $M_e$ is the error mean squares for the randomized block design and r is the number of replications. For the F test, each mean square was tested against $M'_e$.

### 3.4.3.2 Estimation of gca and sca effects

The combining ability effects are estimated as :

gca effects $= g_i = 1/(p+2)\ [X_{i.} + X_{ii} - 2/p \times X..]$

sca effects $= S_{ij} = X_{ij}\text{-}1/p+2[X_{i.}+X_{ii}+X_{.j}+X_{ij}] +[2/(p+1)(p+2)]\ X..$ for individual crosses.

Where,

p : number of parent,

$X_i$ : Array total involving i as recurrent parent,

$X_j$ : Array total involving j as recurrent parent,

X.. : Total of all observations.

### 3.4.3.3 Standard error of the estimates :

Standard error of an estimate was calculated as the square root of its variance.

The variance of any parent or F1 mean value is :

$$\text{Var}\ (X_{ij}) = \sigma^2_e = M'e$$

$$\text{SE}\ (g_i) = [\ (p\text{-}1)\ \sigma^2_e / (p\ (p+2)]^{1/2}$$

$$\text{SE}\ (s_{ii}) = [(p\ (p\text{-}1))\ \sigma^2_e / ((p+1)\ (p+2)]^{1/2}$$

$$\text{SE}\ (s_{ij}) = [(p^2 + p + 2)\ \sigma^2_e / ((p+1)\ (p+2)]^{1/2} \quad (i \neq j)$$

The standard errors of differences between effects were calculated as follows :

For general combining ability estimates,

$$\text{Var}\,(g_i - g_j) = [(2\,\sigma^2_e / (p + 2)]^{1/2} \qquad (i \neq j)$$

For specific combining ability estimates in an array,

$$\text{Var}\,(S_{ij} - S_{jk}) = [(2\,(p + 1)\sigma^2_e / (p + 2)]^{1/2} \qquad (i \neq j)$$

For any two specific combining ability estimates,

$$\text{Var}\,(S_{ij} - S_{kl}) = [(2p)\sigma^2_e / (p + 2)]^{1/2} \qquad (i \neq j, k; j \neq k)$$

and,

$$\text{Var}\,(S_{ii} - S_{jj}) = [(2(p - 2))\sigma^2_e / (p + 2)]^{1/2} \qquad (i \neq j)$$

Critical Difference (CD) was calculated by multiplying the corresponding SE (difference) with the 't' value at error degrees of freedom as below :

Critical difference, $CD = SE \times t \times \sqrt{2}$

Where,

S.E. : $\sqrt{\text{Variance}}$

t : Table ' t' value at error d.f at 5% or 1% level of significance.

CHAPTER 4

# EXPERIMENTAL RESULTS

The present investigation entitled 'Heterosis and Combining Ability Studies in Okra (*Abelmoschus esculentus* (L.) Moench)' was conducted during *Kharif,* 2007. The experimental results obtained from the evaluation of the 21 crosses and their seven parents on nine quantitative and two qualitative characters are summarized below:

## 4.1 Analysis of variance

Analysis of variance presented in Table 4.1 revealed highly significant treatment differences for all the characters studied. The parents showed highly significant differences for days to 50 per cent flowering, days to first picking, average fruit length and average fruit girth, whereas, significant differences were observed for number of fruits per plant. The hybrids exhibited significant differences for all the characters except plant height. Among them all the characters were highly significant except internodes per plant, which was significant. The parents vs. hybrids which can be taken as a measure of heterosis exhibited highly significant differences for the traits days to 50 per cent flowering and days to first picking, whereas, the differences were significant for the traits plant height at harvest, internodes per plant, number of fruits per plant and green fruit yield per plant.

## 4.2 Mean Performance of parents and crosses

The data on mean performance of parents, crosses and check. is presented in Table 4.2.

## Table 4.1. Analysis of variance for 9 characters in 7 x 7 half diallel of okra

**Mean sum of squares**

| Sources of variation | D. F. | Days to 50 per cent flowering (No.) | Plant height at harvest (cm) | Primary branches per plant (No.) | Internodes per plant (No.) | Days to first picking (No.) | Number of fruits per plant | Average fruit length (cm) | Average fruit girth (cm) | Green fruit yield (g/plant) |
|---|---|---|---|---|---|---|---|---|---|---|
| **Replication** | 2 | 0.414 | 2.875 | 0.212 | 11.292 | 0.375 | 3.940 | 0.249 | 0.013 | 566.5 |
| **Treatment** | 27 | 4.145** | 548.926** | 0.189** | 22.741** | 2.848** | 18.650** | 0.712** | 0.091** | 2751.815** |
| **Parents** | 6 | 3.845** | 601.287 | 0.131 | 8.123 | 3.492** | 11.415* | 1.257** | 0.161** | 940.989 |
| **Hybrids** | 20 | 3.716** | 404.125 | 0.214** | 24.602* | 2.709** | 18.474** | 0.584** | 0.074** | 3108.95** |
| **Parents Vs. Hybrids** | 1 | 14.539** | 3130.781* | 0.017 | 73.188* | 1.766** | 65.568* | 0.0977 | 0.010 | 6474.063* |
| **Error** | 54 | 0.537 | 305.408 | 8.542 | 11.028 | 0.3318 | 3.625 | 0.172 | 0.013 | 1172.426 |

$P_1$-Parbhani Kranti, $P_2$ -Arka Anamika, $P_3$- Arka Vijay, $P_4$-Phule Utkarsha, $P_5$ -Ajeet-121, $P_6$ -Pusa Sawani, $P_7$ -Benolt

*, ** - significant at 5 and 1 per cent level, respectively

## Table 4.2. Mean performance of parents, $F_1$s and check in a 7 x 7 half diallel of okra

| Sr. No. | Parents/ Hybrids | Days to 50 per cent flowering | Plant height at harvest (cm) | Primary branches per plant (No.) | Internodes per plant (No.) | Days to first picking (No.) | Number of fruits per plant | Average fruit length (cm) | Average fruit girth (cm) | Green fruit yield (g/plant) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | Parabhani Kranti ($P_1$) | 46.33 | 176.07 | 0.40 | 16.53 | 52.33 | 13.73 | 10.93 | 5.38 | 152.57 |
| 2 | Arka Anamika ($P_2$) | 47.50 | 156.20 | 0.13 | 14.07 | 53.67 | 12.33 | 11.84 | 5.08 | 142.14 |
| 3 | Arka Vijay ($P_3$) | 49.33 | 139.97 | 0.07 | 16.20 | 55.00 | 15.30 | 10.60 | 5.09 | 155.01 |
| 4 | Phule Utkarsha ($P_4$) | 47.33 | 138.60 | 0.07 | 12.83 | 53.33 | 11.17 | 12.18 | 5.38 | 129.09 |
| 5 | Ajeet-121 ($P_5$) | 47.33 | 163.17 | 0.13 | 13.77 | 53.33 | 12.17 | 11.22 | 5.28 | 129.54 |
| 6 | Pusa Sawani ( $P_6$) | 49.00 | 153.87 | 0.07 | 15.00 | 54.67 | 13.23 | 11.54 | 5.36 | 137.26 |
| 7 | Benolt ($P_7$) | 49.00 | 169.73 | 0.60 | 17.33 | 55.33 | 16.80 | 12.35 | 4.75 | 179.33 |
| 8 | $P_1$ x $P_2$ | 46.33 | 171.80 | 0.20 | 16.70 | 53.33 | 15.27 | 11.18 | 5.11 | 164.56 |
| 9 | $P_1$ x $P_3$ | 47.33 | 162.93 | 0.43 | 16.07 | 54.00 | 14.53 | 10.68 | 5.50 | 157.86 |
| 10 | $P_1$ x $P_4$ | 45.33 | 156.20 | 0.07 | 14.07 | 52.33 | 12.47 | 11.19 | 4.95 | 140.00 |
| 11 | $P_1$ x $P_5$ | 48.33 | 185.20 | 0.20 | 18.87 | 54.33 | 17.13 | 11.58 | 5.39 | 176.05 |
| 12 | $P_1$ x $P_6$ | 46.33 | 174.87 | 0.13 | 16.47 | 53.00 | 14.80 | 11.57 | 5.25 | 162.52 |
| 13 | $P_1$ x $P_7$ | 47.33 | 172.13 | 0.36 | 16.93 | 54.00 | 16.63 | 11.38 | 5.08 | 134.71 |
| 14 | $P_2$ x $P_3$ | 47.33 | 162.33 | 0.13 | 16.20 | 54.00 | 14.43 | 11.23 | 5.22 | 143.08 |
| 15 | $P_2$ x $P_4$ | 45.33 | 158.47 | 0.17 | 16.43 | 52.33 | 14.47 | 12.02 | 5.37 | 155.58 |
| 16 | $P_2$ x $P_5$ | 47.33 | 183.40 | 0.07 | 16.33 | 53.33 | 14.82 | 11.58 | 5.20 | 151.16 |
| 17 | $P_2$ x $P_6$ | 49.33 | 149.53 | 0.00 | 12.70 | 55.33 | 11.30 | 11.21 | 5.15 | 116.24 |
| 18 | $P_2$ x $P_7$ | 46.33 | 198.07 | 1.13 | 26.93 | 53.00 | 24.07 | 12.15 | 5.35 | 278.59 |
| 19 | $P_3$ x $P_4$ | 46.33 | 157.13 | 0.07 | 17.00 | 54.00 | 15.80 | 11.79 | 5.20 | 160.58 |
| 20 | $P_3$ x $P_5$ | 46.00 | 180.53 | 0.13 | 17.50 | 52.00 | 15.40 | 11.82 | 5.30 | 172.90 |
| 21 | $P_3$ x $P_6$ | 46.33 | 164.33 | 0.73 | 21.00 | 52.33 | 17.80 | 11.56 | 5.53 | 197.03 |
| 22 | $P_3$ x $P_7$ | 49.00 | 182.00 | 0.33 | 19.27 | 55.00 | 17.40 | 10.81 | 5.14 | 186.32 |
| 23 | $P_4$ x $P_5$ | 48.66 | 173.13 | 0.13 | 16.67 | 54.67 | 14.40 | 11.10 | 5.17 | 156.72 |
| 24 | $P_4$ x $P_6$ | 46.33 | 170.40 | 0.20 | 16.07 | 53.33 | 13.93 | 12.06 | 5.21 | 162.00 |
| 25 | $P_4$ x $P_7$ | 46.33 | 165.67 | 0.07 | 16.80 | 54.33 | 15.00 | 11.97 | 4.98 | 161.67 |
| 26 | $P_5$ x $P_6$ | 46.67 | 165.00 | 0.00 | 14.13 | 53.33 | 14.80 | 11.51 | 5.26 | 153.06 |
| 27 | $P_5$ x $P_7$ | 47.33 | 177.87 | 0.13 | 17.77 | 54.33 | 15.93 | 11.85 | 4.99 | 170.27 |
| 28 | $P_6$ x $P_7$ | 47.67 | 177.87 | 0.40 | 18.53 | 54.67 | 16.67 | 12.35 | 5.13 | 199.66 |
| 29 | Check | 47.66 | 171.73 | 0.20 | 16.73 | 53.66 | 15.2 | 11.58 | 5.31 | 160.48 |

### 4.2.1 Days to 50 per cent flowering (No.)

From Table 4.2 it is clear that among the parents, Parbhani Kranti was the earliest to flower (46.33 days), while Arka Vijay was the late flowering (49.33 days). Among the crosses, the range for days to 50 per cent flowering was 45.33 to 49.33 days. The combinations Parbhani Kranti x Phule Utkarsha and Arka Anamika x Phule Utkarsha were the earliest to flower (45.33 days) followed by Arka Vijay x Ajeet-121 (46 days), Parbhani Kranti x Arka Anamika (46.33 days) and Parbhani Kranti x Pusa Sawani (46.33 days). The combination Arka Anamika x Pusa Sawani required 49.33 days to 50 per cent flowering showing late flowering behaviour. The check required 47.66 days to 50 per cent flowering, while 4 parents and 17 crosses showed early flowering as compared to the check.

### 4.2.2 Plant height at harvest (cm)

Among the parents, Phule Utkarsha was the dwarfest with 138.60 cm height, while Parbhani Kranti was the tallest with 176.07 cm plant height at harvest, followed by Benolt and Ajeet-121. Among the crosses, the maximum plant height (198.07cm) was recorded by the combination Arka Anamika x Benolt, followed by Parbhani Kranti x Ajeet-121 (185.20cm) and Arka Anamika x Ajeet-121 (183.40cm) whereas Arka Anamika x Pusa Sawani exhibited the minimum plant height (149.53cm). Ten crosses were taller than the check, Panchali (171.73cm).

### 4.2.3 Primary branches per plant (No.)

The maximum number of primary branches per plant was produced by the parent Benolt (0.60) followed by Parbhani Kranti (0.40) and were higher than the check, Panchali (0.20). The parents *viz.*, Arka Vijay, Phule Utkarsha and Pusa Sawani exhibited the least number of branches per plant (0.07 each). Among the hybrids, the combination Arka Anamika x Benolt displayed the highest number of primary branches (1.13),

whereas Arka Anamika x Pusa Sawani and Ajeet-121 x Pusa Sawani were branchless.

**4.2.4 Internodes per plant (No.)**

Among the parents the highest number of internodes per plant was exhibited by Benolt (17.33), followed by Parbhani Kranti (16.53), Arka Vijay (16.20), Pusa Sawani (15.00) and Arka Anamika (14.07). The lowest number of internodes was exhibited by the parent Phule Utkarsha (12.83).

Among the crosses, the combination Arka Anamika x Benolt showed maximum (26.93) number of internodes per plant, followed by Arka Vijay x Pusa Sawani (21.00), Arka Vijay x Benolt (19.27) and Parbhani Kranti x Ajeet-121 (18.87). The minimum number of internodes per plant (12.70) was exhibited by Arka Anamika x Pusa Sawani. Ten crosses showed more number of internodes than the check, Panchali (16.73).

**4.2.5 Days to first picking**

Among the parents, Parbhani Kranti recorded 52.33 days to first picking followed by Phule Utkarsha (53.33 days), Ajit-121 (53.33 days) and Arka Anamika (53.67 days). Benolt recorded the maximum (55.33 days) number of days to first picking.

Among the hybrids, Arka Vijay x Ajit-121 recorded the minimum (52.00 days) number of days to first picking, while Arka Anamika x Pusa Sawani recorded the maximum (55.33 days) number of days to first picking. Ten crosses showed better performance than the check (53.66 days).

**4.2.6 Fruits per plant (No.)**

The highest number of fruits per plant among the parents was recorded by Benolt (16.80), followed by Arka Vijay (15.30), Parbhani Kranti (13.73) and Pusa Sawani (13.23).

The hybrid Arka Anamika x Benolt recorded the highest (24.07) number of fruits per plant, while Arka Anamika x Pusa Sawani (11.30) recorded the lowest number of fruits. Ten crosses showed more number of fruits than the check, Panchali (15.2).

**4.2.7 Average fruit length (cm)**

The maximum average fruit length was recorded by Benolt (12.35 cm) followed by Phule Utkarsha (12.18 cm) and Arka Anamika (11.84 cm). The minimum fruit length was recorded by Arka Vijay (10.60 cm).

Among the hybrids, Pusa Sawani x Benolt recorded the maximum (12.35 cm) average fruit length. It was followed by Arka Anamika x Benolt (12.15 cm) and Phule Utkarsha x Pusa Sawani (12.06 cm).

**4.2.8 Average fruit girth (cm)**

Parbhani Kranti and Phule Utkarsha registered the highest fruit girth (5.38 cm each), while Benolt recorded the lowest (4.75 cm) fruit girth. Only three parents (Parbhani Kranti, Phule Utkarsha and Pusa Sawani) exhibited higher fruit girth than the check (5.32 cm).

The highest (5.53 cm) fruit girth among the hybrids was exhibited by Arka Vijay x Pusa Sawani, followed by Parbhani Kranti x Arka Vijay(5.50 cm), Parbhani Kranti x Ajeet-121(5.39 cm), Arka Anamika x Phule Utkarsha (5.37 cm) and Arka Anamika x Benolt (5.35 cm). The hybrid Parbhani Kranti x Phule Utkarsha exhibited the minimum average fruit girth (4.95 cm). Five hybrids exhibited more average fruit girth than the check (5.32 cm).

**4.2.9 Green fruit yield (g/plant)**

The marketable green fruit yield ranged from 129.09 g to 179.33g among the parents. Benolt produced the maximum fruit yield (179.3g), followed by Arka Vijay (155.01g), Parbhani Kranti (152.57g) and Arka Anamika (142.14g). Phule Utkarsha exhibited the minimum number of

fruit yield (129.09g). Among the parents, Benolt (179.33g) alone performed better than the check (169.49g) for green fruit yield (g/plant).

The range expressed by the hybrids for green fruit yield per plant was between 116.24g and 278.59g. The hybrid Arka Anamika x Benolt produced the highest (278.59g) green fruit yield per plant, followed by Pusa Sawani x Benolt (199.66g), Arka Vijay x Pusa Sawani (197.03g) and Arka Vijay x Benolt (186.32g). The hybrid Arka Anamika x Pusa Sawani exhibited the lowest (116.24g) green fruit yield per plant. Five hybrids exhibited better performance for green fruit yield (g/plant) than the check (169.49g).

### 4.2.10 Other characters

#### 4.2.10.1 Reaction to Yellow Vein Mosaic

Yellow Vein Mosaic (YVM) is a serious viral disease of the okra crop. In the present investigation, the okra plants were seen to be affected with YVM towards the end of the cropping season. Among the parents, Parbhani Kranti and Arka Anamika showed very low incidence of YVM, while Benolt showed moderate incidence. Among the hybrids, moderate YVM was seen on Parbhani Kranti x Benolt, Arka Vijay x Benolt, Arka Anamika x Pusa Sawani and Pusa Sawani x Benolt. The hybrid Parbhani Kranti x Arka Anamika recorded the best performance among the hybrids as it recorded the trace incidence of YVM.

#### 4.2.10.2 Export parameters

In the present investigation, most of the parents and hybrids complied with the export parameters such as tenderness, green colour and fruit length required in the international market. The parents *viz.,* Arka Anamika, Phule Utkarsha and Benolt and the hybrids *viz.,* Parbhani Kranti x Arka Anamika, Parbhani Kranti x Arka Vijay, Arka Anamika x

Benolt and Arka Vijay x Pusa Sawani complied with the export parameters.

## 4.3 Heterosis

Heterosis estimated in per cent values over the better parent (BP), mid-parent (MP) and the check are presented in table 4.3.

Negative heterosis was considered as desirable for days to 50 per cent flowering, days to first picking and average fruit girth. For the rest of the characters studied, positive heterosis was considered desirable.

### 4.3.1 Days to 50 per cent flowering (No.)

Heterosis in the negative direction is considered as desirable as early flowering is a preferred trait. The range of heterosis for this character was -4.40 to 3.20 per cent over mid-parent (MP), -6.76 to 2.82 per cent over better parent (BP) and -4.90 to 3.50 per cent over the check.

The highest negative heterosis over the better parent was exhibited by Phule Utkarsha x Ajeet-121(-6.76%), followed by Arka Vijay x Pusa Sawani (-4.83%). The highest negative heterosis over the mid-parent was exhibited by Arka Anamika x Phule Utkarsha (-4.40%), while Parbhani Kranti x Phule Utkarsha (-4.90%) exhibited highest heterosis over the check in the negative direction. Significant heterosis in the positive direction was exhibited by Phule Utkarsha x Ajeet-121 (2.82%). Among the hybrids, 71.43 per cent (15 crosses) exhibited significant heterosis over the check. Out of them, eleven (52.38 %) crosses registered highly significant standard heterosis in the desirable (negative) direction.

### 4.3.2 Plant height at harvest (cm)

The per cent heterobeltiosis, relative heterosis and economic heterosis for this character ranged from -11.28 to 16.70 per cent, -3.55 to 21.54 per cent and -12.93 to 15.33 per cent respectively.

## Table 4.3. Per cent heterosis over BP, MP and check for 9 characters in okra

| Sr. No. | Hybrids | Days to 50 per cent flowering (No.) | | | | | | Plant height at harvest (cm) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | | | Per cent Heterosis over | | | Mean | | | Per cent Heterosis over | | |
| | | F | BP | MP | BP | MP | CHECK | F | BP | MP | BP | MP | CHECK |
| 1 | $P_1$ x $P_2$ | 46.33 | 47.50 | 46.91 | -2.46 | -1.243 | -2.80** | 171.80 | 176.07 | 166.44 | -2.42 | 3.41 | 0.04 |
| 2 | $P_1$ x $P_3$ | 47.33 | 49.33 | 47.83 | -4.05** | -1.05 | -0.70 | 162.93 | 176.07 | 158.02 | -7.46 | 3.11 | -5.12 |
| 3 | $P_1$ x $P_4$ | 45.33 | 47.33 | 46.83 | -4.23** | -3.20** | -4.90** | 156.20 | 176.07 | 157.52 | -11.28 | -0.72 | -9.05 |
| 4 | $P_1$ x $P_5$ | 48.33 | 47.33 | 46.83 | 2.11 | 3.20** | 1.33* | 185.20 | 176.07 | 169.62 | 5.19 | 9.19 | 7.84 |
| 5 | $P_1$ x $P_6$ | 46.33 | 49.00 | 47.66 | -5.44** | -2.80* | -2.80** | 174.87 | 176.07 | 164.97 | -0.68 | 6.00 | 1.83 |
| 6 | $P_1$ x $P_7$ | 47.33 | 49.00 | 47.66 | -3.40** | -0.70 | -0.70 | 172.13 | 176.07 | 172.9 | -2.23 | -0.44 | 0.23 |
| 7 | $P_2$ x $P_3$ | 47.33 | 49.33 | 48.41 | -4.05** | -2.24 | -0.70 | 162.33 | 156.20 | 148.09 | 3.93 | 9.62 | -5.47 |
| 8 | $P_2$ x $P_4$ | 45.33 | 47.50 | 47.41 | -4.56** | -4.40** | -4.90** | 158.47 | 156.20 | 147.40 | 1.45 | 7.51 | -7.73 |
| 9 | $P_2$ x $P_5$ | 47.33 | 47.50 | 47.41 | -0.35 | -0.18 | -0.70 | 183.40 | 163.17 | 159.69 | 12.40 | 14.85 | 6.79 |
| 10 | $P_2$ x $P_6$ | 49.33 | 49.00 | 48.25 | 0.68 | 2.25** | 3.50** | 149.53 | 156.20 | 155.04 | -4.27 | -3.55 | -12.93 |
| 11 | $P_2$ x $P_7$ | 46.33 | 49.00 | 48.25 | -5.44** | -3.97** | -2.80** | 198.07 | 169.73 | 162.96 | 16.70 | 21.54** | 15.33* |
| 12 | $P_3$ x $P_4$ | 46.33 | 49.33 | 48.33 | -6.08** | -4.14** | -2.80** | 157.13 | 139.97 | 139.29 | 12.27 | 12.82 | -8.50 |
| 13 | $P_3$ x $P_5$ | 46.00 | 49.33 | 48.33 | -6.76** | -4.83** | -3.50** | 180.53 | 163.17 | 151.57 | 10.64 | 19.11* | 5.12 |
| 14 | $P_3$ x $P_6$ | 46.33 | 49.33 | 49.16 | -6.08** | -5.76** | -2.80** | 164.33 | 153.87 | 146.92 | 6.80 | 11.86 | -4.31 |
| 15 | $P_3$ x $P_7$ | 46.33 | 49.33 | 49.16 | -0.68 | -0.34 | 2.80** | 182.00 | 169.73 | 154.85 | 7.23 | 17.53 | 5.98 |
| 16 | $P_4$ x $P_5$ | 48.66 | 47.33 | 47.33 | 2.82** | 2.817** | 2.10** | 173.13 | 163.70 | 150.89 | 6.11 | 14.75 | 0.82 |
| 17 | $P_4$ x $P_6$ | 46.33 | 49.00 | 48.16 | -5.44** | -3.81** | -2.80** | 170.40 | 153.87 | 146.24 | 10.80 | 16.53 | -0.78 |
| 18 | $P_4$ x $P_7$ | 46.33 | 49.00 | 48.16 | -5.44** | -3.81** | -2.80** | 165.67 | 169.73 | 154.17 | -2.40 | 7.46 | -3.53 |
| 19 | $P_5$ x $P_6$ | 46.67 | 49.00 | 48.16 | -4.77** | -3.11** | -2.10** | 165.00 | 163.17 | 158.52 | 1.12 | 4.09 | -3.92 |
| 20 | $P_5$ x $P_7$ | 47.33 | 49.00 | 48.16 | -3.40** | -1.73** | -0.70 | 177.87 | 169.73 | 166.45 | 4.80 | 6.86 | 3.57 |
| 21 | $P_6$ x $P_7$ | 47.67 | 49.00 | 49.00 | -2.72** | -2.72** | 0.000 | 177.87 | 169.73 | 161.8 | 4.80 | 9.93 | 3.57 |
| | Mean | | | | -3.32 | -1.99 | -1.37 | | | | 3.50 | 9.12 | -0.49 |
| | S. E. ± | | | | 0.60 | 0.52 | 1.60 | | | | 14.26 | 12.35 | 14.26 |
| | C.D.at 5% | | | | 1.20 | 1.04 | 1.20 | | | | 28.61 | 24.77 | 28.61 |
| | C. D. at 1 % | | | | 1.60 | 1.39 | 1.60 | | | | 38.13 | 32.99 | 38.13 |

$P_1$-Parbhani Kranti, $P_2$ -Arka Anamika, $P_3$- Arka Vijay, $P_4$-Phule Utkarsha, $P_5$ -Ajeet-121, $P_6$ -Pusa Sawani, $P_7$ -Benolt

*,** - significant at 5 and 1 per cent level, respectively

## Table 4.3. (Contd.)…

| Sr. No. | Hybrids | Primary branches per plant (No.) | | | | | | Internodes per plant (No.) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | | | Per cent Heterosis over | | | Mean | | | Per cent Heterosis over | | |
| | | F | BP | MP | BP | MP | CHECK | F | BP | MP | BP | MP | CHECK |
| 1 | $P_1$ x $P_2$ | 0.20 | 0.40 | 0.27 | -50.0 | -25.00 | 0.00 | 16.70 | 16.53 | 15.2 | 1.09 | 9.15 | -0.12 |
| 2 | $P_1$ x $P_3$ | 0.43 | 0.40 | 0.24 | 8.33 | 85.71 | 116.67 | 16.07 | 16.53 | 16.37 | -2.83 | -1.83 | -3.99 |
| 3 | $P_1$ x $P_4$ | 0.07 | 0.40 | 0.24 | -83.33 | -71.43 | -66.67 | 14.07 | 16.53 | 14.68 | -14.92 | -4.20 | -15.94 |
| 4 | $P_1$ x $P_5$ | 0.20 | 0.40 | 0.27 | -50.00 | -25.00 | 0.000 | 18.87 | 16.53 | 15.15 | 14.12 | 24.53 | 12.75 |
| 5 | $P_1$ x $P_6$ | 0.13 | 0.40 | 0.24 | -66.67 | -42.86 | -33.33 | 16.47 | 16.53 | 15.77 | -0.41 | 4.44 | -1.60 |
| 6 | $P_1$ x $P_7$ | 0.36 | 0.60 | 0.50 | -40.00 | -28.00 | 80.00 | 16.93 | 17.33 | 16.93 | -2.31 | 0.00 | 1.20 |
| 7 | $P_2$ x $P_3$ | 0.13 | 0.13 | 0.10 | 0.000 | 33.33 | -33.33 | 16.20 | 16.20 | 15.14 | 0.00 | 7.05 | -3.19 |
| 8 | $P_2$ x $P_4$ | 0.17 | 0.13 | 0.10 | 25.00 | 66.67 | -16.67 | 16.43 | 14.07 | 13.45 | 17.07 | 22.43 | -1.60 |
| 9 | $P_2$ x $P_5$ | 0.07 | 0.13 | 0.13 | -50.00 | -50.00 | -66.67 | 16.33 | 14.07 | 13.92 | 16.12 | 17.37 | -2.40 |
| 10 | $P_2$ x $P_6$ | 0.00 | 0.13 | 0.10 | -100.0 | -100.0 | -100.0 | 12.70 | 15.00 | 14.54 | -15.33 | -12.62 | -24.10 |
| 11 | $P_2$ x $P_7$ | 1.13 | 0.60 | 0.37 | 88.89** | 209.09** | 466.67** | 26.93 | 17.33 | 15.7 | 55.39** | 71.55** | 60.96** |
| 12 | $P_3$ x $P_4$ | 0.07 | 0.07 | 0.07 | 0.00 | 0.00 | -66.67 | 17.00 | 16.20 | 14.52 | 4.94 | 17.11 | 1.60 |
| 13 | $P_3$ x $P_5$ | 0.13 | 0.13 | 0.1 | 0.00 | 33.33 | -33.33 | 17.50 | 16.20 | 14.99 | 8.03 | 16.80 | 4.58 |
| 14 | $P_3$ x $P_6$ | 0.73 | 0.07 | 0.07 | 942.54** | 942.54** | 266.67* | 21.00 | 16.20 | 15.6 | 29.63 | 34.62* | 25.50 |
| 15 | $P_3$ x $P_7$ | 0.33 | 0.60 | 0.34 | -44.44 | 0.000 | -66.67 | 19.27 | 17.33 | 16.77 | 11.16 | 14.91 | 15.14 |
| 16 | $P_4$ x $P_5$ | 0.13 | 0.13 | 0.1 | 0.00 | 33.33 | -33.33 | 16.67 | 13.77 | 13.3 | 21.07 | 25.31 | -0.40 |
| 17 | $P_4$ x $P_6$ | 0.20 | 0.07 | 0.07 | 200.0 | 200.00 | 0.000 | 16.07 | 15.00 | 13.92 | 7.11 | 15.45 | -3.99 |
| 18 | $P_4$ x $P_7$ | 0.07 | 0.60 | 0.34 | -88.89* | -80.00 | -66.67 | 16.80 | 17.33 | 15.08 | -3.08 | 11.38 | 0.40 |
| 19 | $P_5$ x $P_6$ | 0.00 | 0.13 | 0.1 | -100.0 | -100.0 | -100.00 | 14.13 | 15.00 | 14.39 | -5.78 | -1.74 | -15.54 |
| 20 | $P_5$ x $P_7$ | 0.13 | 0.60 | 0.37 | -77.78 | -63.64 | -33.33 | 17.77 | 17.33 | 15.55 | 2.50 | 14.26 | 6.18 |
| 21 | $P_6$ x $P_7$ | 0.40 | 0.60 | 0.34 | -33.33 | 20.00 | 100.0 | 18.53 | 17.33 | 16.17 | 6.93 | 14.64 | 10.76 |
| | Mean | | | | 22.89 | 49.43 | 14.92 | | | | 7.16 | 14.30 | 3.15 |
| | S. E. ± | | | | 0.24 | 0.21 | 0.24 | | | | 2.71 | 2.35 | 2.71 |
| | C.D.at 5% | | | | 0.48 | 0.42 | 0.48 | | | | 5.44 | 4.71 | 5.44 |
| | C. D. at 1 % | | | | 0.64 | 0.55 | 0.64 | | | | 7.241 | 6.27 | 7.24 |

$P_1$-Parbhani Kranti, $P_2$ -Arka Anamika, $P_3$- Arka Vijay, $P_4$-Phule Utkarsha, $P_5$ -Ajeet-121, $P_6$ -Pusa Sawani, $P_7$ -Benolt

*,** - significant at 5 and 1 per cent level, respectively

## Table 4.3. (Contd.)….

| Sr. No. | Hybrids | Days to first picking (No.) | | | | | | Number of fruits per plant | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | | | Per cent Heterosis over | | | Mean | | | Per cent Heterosis over | | |
| | | F | BP | MP | BP | MP | CHECK | F | BP | MP | BP | MP | CHECK |
| 1 | $P_1$ x $P_2$ | 53.33 | 53.67 | 53.00 | -0.62 | 0.63 | -0.62** | 15.27 | 13.73 | 13.03 | 11.17 | 17.14 | 0.44 |
| 2 | $P_1$ x $P_3$ | 54.00 | 55.00 | 53.67 | -1.82* | 0.62 | 0.62 | 14.53 | 15.30 | 14.52 | -5.01 | 0.12 | -4.39 |
| 3 | $P_1$ x $P_4$ | 52.33 | 53.33 | 52.84 | -1.88* | -0.95 | -2.49** | 12.47 | 13.73 | 12.45 | -9.22 | 0.13 | -17.98 |
| 4 | $P_1$ x $P_5$ | 54.33 | 53.33 | 52.84 | 1.88* | 2.84** | 1.24 | 17.13 | 13.73 | 12.95 | 24.73* | 32.28** | 12.70 |
| 5 | $P_1$ x $P_6$ | 53.00 | 54.67 | 53.5 | -3.05** | -0.94 | -1.24 | 14.80 | 13.73 | 13.48 | 7.77 | 9.77 | -2.63 |
| 6 | $P_1$ x $P_7$ | 54.00 | 55.33 | 53.83 | -2.41* | 0.31 | 0.62 | 16.63 | 16.80 | 15.27 | -0.99 | 8.96 | 9.43 |
| 7 | $P_2$ x $P_3$ | 54.00 | 55.00 | 54.34 | -1.82* | -0.61 | 0.62 | 14.43 | 15.30 | 13.82 | -5.66 | 4.46 | -5.04 |
| 8 | $P_2$ x $P_4$ | 52.33 | 53.67 | 53.50 | -2.49** | -2.18** | -2.49** | 14.47 | 12.33 | 11.75 | 17.30 | 23.12* | -4.83 |
| 9 | $P_2$ x $P_5$ | 53.33 | 53.67 | 53.50 | -0.62 | -0.31 | -0.62 | 14.82 | 12.33 | 12.95 | 20.14 | 20.95 | -2.52 |
| 10 | $P_2$ x $P_6$ | 55.33 | 54.67 | 54.17 | 1.22 | 2.15** | 3.11** | 11.30 | 13.23 | 13.48 | -14.61 | -11.60 | -25.66* |
| 11 | $P_2$ x $P_7$ | 53.00 | 55.33 | 54.5 | -4.22** | -2.75** | -1.24 | 24.07 | 16.80 | 12.27 | 43.26* | 65.22** | 58.33** |
| 12 | $P_3$ x $P_4$ | 54.00 | 55.00 | 54.17 | -3.64** | -2.15** | -1.24 | 15.80 | 15.30 | 13.82 | 3.27 | 19.40 | 3.95 |
| 13 | $P_3$ x $P_5$ | 52.00 | 55.00 | 54.17 | -5.46** | -4.00** | -3.11** | 15.40 | 15.30 | 13.74 | 0.66 | 12.14 | 1.32 |
| 14 | $P_3$ x $P_6$ | 52.33 | 55.00 | 54.84 | -4.85** | -4.56** | -2.49** | 17.80 | 15.30 | 14.27 | 16.34 | 24.77* | 17.11 |
| 15 | $P_3$ x $P_7$ | 55.00 | 55.33 | 55.17 | -0.60 | -0.30 | 2.49** | 17.40 | 16.80 | 16.05 | 3.57 | 8.41 | 14.47 |
| 16 | $P_4$ x $P_5$ | 54.67 | 53.33 | 53.33 | 2.50** | 2.50** | 1.86* | 14.40 | 12.17 | 11.67 | 18.36 | 23.43* | -5.26 |
| 17 | $P_4$ x $P_6$ | 53.33 | 54.67 | 54.00 | -2.44* | -1.24 | -0.62 | 13.93 | 13.23 | 12.2 | 5.29 | 14.21 | -8.33 |
| 18 | $P_4$ x $P_7$ | 54.33 | 55.33 | 54.33 | -1.81* | 0.00 | 1.24 | 15.00 | 16.80 | 13.99 | -10.78 | 7.27 | -1.32 |
| 19 | $P_5$ x $P_6$ | 53.33 | 54.67 | 54.00 | -2.44* | -1.24 | -0.62 | 14.80 | 13.23 | 12.70 | 11.84 | 16.54 | -2.63 |
| 20 | $P_5$ x $P_7$ | 54.33 | 55.33 | 54.33 | -1.81* | 0.00 | 1.24 | 15.93 | 16.80 | 14.49 | -5.16 | 10.01 | 4.83 |
| 21 | $P_6$ x $P_7$ | 54.67 | 55.33 | 55.00 | -1.21 | 0.61 | 1.86* | 16.67 | 16.80 | 15.02 | -0.79 | 10.99 | 9.65 |
| | Mean | | | | -1.79 | -0.55 | -0.09 | | | | 6.26 | 15.13 | 2.46 |
| | S. E. ± | | | | 0.47 | 0.41 | 0.47 | | | | 1.56 | 1.35 | 1.56 |
| | C.D.at 5% | | | | 0.94 | 0.82 | 0.94 | | | | 3.12 | 2.70 | 3.18 |
| | C. D. at 1 % | | | | 1.26 | 1.01 | 1.26 | | | | 4.15 | 3.59 | 4.15 |

$P_1$-Parbhani Kranti, $P_2$ -Arka Anamika, $P_3$- Arka Vijay, $P_4$-Phule Utkarsha, $P_5$ -Ajeet-121, $P_6$ -Pusa Sawani, $P_7$ -Benolt

*,** - significant at 5 and 1 per cent level, respectively

## Table 4.3. (Contd.)….

| Sr. No. | Hybrids | Average fruit length (cm) | | | | | | Average fruit girth (cm) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | | | Per cent Heterosis over | | | Mean | | | Per cent Heterosis over | | |
| | | F | BP | MP | BP | MP | CHECK | F | BP | MP | BP | MP | CHECK |
| 1 | $P_1$ x $P_2$ | 11.18 | 11.84 | 11.39 | -5.55 | -1.79 | -3.42 | 5.11 | 5.38 | 5.23 | -5.02** | -2.34 | -3.94* |
| 2 | $P_1$ x $P_3$ | 10.68 | 10.93 | 10.77 | -2.30 | -0.80 | -7.75* | 5.50 | 5.38 | 5.23 | 2.30** | 5.09** | 3.46 |
| 3 | $P_1$ x $P_4$ | 11.19 | 12.18 | 11.55 | -8.12** | -3.154 | -3.34 | 4.95 | 5.38 | 5.38 | -8.01** | -8.00** | -6.97** |
| 4 | $P_1$ x $P_5$ | 11.58 | 11.22 | 11.08 | 3.26 | 4.59 | 0.04 | 5.39 | 5.38 | 5.33 | 0.30 | 1.18 | 1.43 |
| 5 | $P_1$ x $P_6$ | 11.57 | 11.54 | 11.24 | 0.23 | 2.95 | -0.09 | 5.25 | 5.38 | 5.37 | -2.37 | -2.18 | -1.26 |
| 6 | $P_1$ x $P_7$ | 11.38 | 12.35 | 11.44 | -7.85** | -2.22 | -1.68 | 5.08 | 5.38 | 5.06 | -5.56** | 0.14 | -4.48* |
| 7 | $P_2$ x $P_3$ | 11.23 | 11.84 | 11.02 | -5.20 | 0.04 | -3.06 | 5.22 | 5.09 | 5.08 | 2.48 | 2.58 | -1.85 |
| 8 | $P_2$ x $P_4$ | 12.02 | 12.18 | 11.51 | -1.33 | 0.07 | 3.80 | 5.37 | 5.38 | 5.23 | -0.19 | 2.61 | 0.92 |
| 9 | $P_2$ x $P_5$ | 11.58 | 11.84 | 11.53 | -2.19 | 0.45 | 0.01 | 5.20 | 5.28 | 5.18 | -1.51 | 0.39 | -2.14 |
| 10 | $P_2$ x $P_6$ | 11.21 | 11.84 | 11.69 | -5.37 | -4.16 | -3.24 | 5.15 | 5.36 | 5.22 | -3.91 | -1.39 | -3.20 |
| 11 | $P_2$ x $P_7$ | 12.15 | 12.35 | 12.10 | -1.66 | 0.43 | 4.92 | 5.35 | 5.09 | 5.05 | 5.35** | 8.94** | 0.71 |
| 12 | $P_3$ x $P_4$ | 11.79 | 12.18 | 11.39 | -3.26 | 3.45 | 1.78 | 5.20 | 5.38 | 5.23 | -3.35 | -0.73 | -2.29 |
| 13 | $P_3$ x $P_5$ | 11.82 | 11.22 | 10.91 | 5.34 | 8.31** | 2.06 | 5.30 | 5.28 | 5.18 | 0.39 | 2.28 | -0.26 |
| 14 | $P_3$ x $P_6$ | 11.56 | 11.54 | 11.07 | 0.12 | 4.37 | -0.20 | 5.53 | 5.36 | 5.22 | 3.23 | 5.84** | 4.00 |
| 15 | $P_3$ x $P_7$ | 10.81 | 12.35 | 11.48 | -12.47 | -5.79* | -6.61* | 5.14 | 5.08 | 4.92 | 0.92 | 4.45** | -3.35 |
| 16 | $P_4$ x $P_5$ | 11.10 | 12.18 | 11.70 | -8.87** | -5.12* | -4.13 | 5.17 | 5.38 | 5.33 | -3.80* | -2.96 | -2.73 |
| 17 | $P_4$ x $P_6$ | 12.06 | 12.18 | 11.86 | -1.04 | 1.62 | 4.11 | 5.21 | 5.38 | 5.37 | -3.03 | -2.86 | -1.96 |
| 18 | $P_4$ x $P_7$ | 11.97 | 12.35 | 12.27 | -3.08 | -2.40 | 3.41 | 4.98 | 5.38 | 5.06 | -7.43** | -1.69 | -6.41** |
| 19 | $P_5$ x $P_6$ | 11.51 | 11.54 | 11.38 | -0.32 | 1.10 | -0.63 | 5.26 | 5.36 | 5.32 | -1.76 | -1.08 | -1.03 |
| 20 | $P_5$ x $P_7$ | 11.85 | 12.35 | 11.758 | -4.10 | 0.53 | 2.32 | 4.99 | 5.36 | 5.01 | -5.54** | 1.63 | -6.15** |
| 21 | $P_6$ x $P_7$ | 12.35 | 12.35 | 11.945 | 0.00 | 3.40 | 6.69* | 5.13 | 5.36 | 5.05 | -4.15** | 1.63 | -3.44 |
| | Mean | | | | -3.03 | -0.28 | -0.24 | | | | -1.94 | 0.64 | -1.95 |
| | S. E. ± | | | | 0.34 | 0.29 | 0.34 | | | | 0.09 | 0.08 | 0.05 |
| | C.D.at 5% | | | | 0.68 | 0.59 | 0.68 | | | | 0.19 | 0.17 | 0.19 |
| | C. D. at 1 % | | | | 0.90 | 0.78 | 0.90 | | | | 0.25 | 0.22 | 0.25 |

$P_1$-Parbhani Kranti, $P_2$ -Arka Anamika, $P_3$- Arka Vijay, $P_4$-Phule Utkarsha, $P_5$ -Ajeet-121, $P_6$ -Pusa Sawani, $P_7$ -Benolt

*,** - significant at 5 and 1 per cent level, respectively

## Table 4.3. (Contd.)….

| Sr. No. | Hybrids | Green fruit yield (g/plant) | | | | | |
|---|---|---|---|---|---|---|---|
| | | Mean | | | Per cent Heterosis over | | |
| | | F | BP | MP | BP | MP | CHECK |
| 1 | $P_1$ x $P_2$ | 164.56 | 152.57 | 147.36 | 7.86 | 11.68 | 2.54 |
| 2 | $P_1$ x $P_3$ | 157.86 | 155.01 | 153.79 | 1.84 | 2.65 | -1.64 |
| 3 | $P_1$ x $P_4$ | 140.00 | 152.57 | 140.83 | -8.24 | -0.59 | -12.77 |
| 4 | $P_1$ x $P_5$ | 176.05 | 152.57 | 141.056 | 15.40 | 24.81 | 9.70 |
| 5 | $P_1$ x $P_6$ | 162.52 | 152.57 | 144.92 | 6.5 | 12.15 | 1.26 |
| 6 | $P_1$ x $P_7$ | 134.71 | 179.33 | 165.95 | -24.88 | -18.82 | -16.06 |
| 7 | $P_2$ x $P_3$ | 143.08 | 155.01 | 135.15 | 7.695 | -3.70 | -10.85 |
| 8 | $P_2$ x $P_4$ | 155.58 | 142.14 | 135.62 | 9.45 | 14.72 | -3.06 |
| 9 | $P_2$ x $P_5$ | 151.16 | 142.14 | 135.94 | 6.34 | 11.28 | -5.82 |
| 10 | $P_2$ x $P_6$ | 116.24 | 142.14 | 139.7 | -18.23 | -16.80 | -27.57 |
| 11 | $P_2$ x $P_7$ | 278.59 | 179.33 | 160.74 | 55.36** | 73.32** | 73.59* |
| 12 | $P_3$ x $P_4$ | 160.58 | 155.01 | 142.05 | 3.60 | 13.05 | 0.06 |
| 13 | $P_3$ x $P_5$ | 172.90 | 155.01 | 142.28 | 11.54 | 21.53 | 7.73 |
| 14 | $P_3$ x $P_6$ | 197.03 | 155.01 | 146.14 | 27.11 | 34.83* | 22.77 |
| 15 | $P_3$ x $P_7$ | 186.32 | 179.33 | 167.17 | 3.90 | 11.46 | 16.09 |
| 16 | $P_4$ x $P_5$ | 156.72 | 129.54 | 129.32 | 20.99 | 21.20 | -2.35 |
| 17 | $P_4$ x $P_6$ | 162.00 | 137.26 | 133.18 | 18.03 | 21.65 | 0.94 |
| 18 | $P_4$ x $P_7$ | 161.67 | 179.33 | 154.21 | -9.85 | 4.84 | 0.74 |
| 19 | $P_5$ x $P_6$ | 153.06 | 197.26 | 133.4 | 11.51 | 14.74 | -4.63 |
| 20 | $P_5$ x $P_7$ | 170.27 | 179.33 | 154.44 | -5.05 | 10.25 | 6.10 |
| 21 | $P_6$ x $P_7$ | 160.66 | 179.33 | 158.30 | 11.54 | 26.13 | 24.41 |
| | Mean | | | | 7.26 | 13.83 | 3.87 |
| | S. E. ± | | | | 27.96 | 24.21 | 27.96 |
| | C.D.at 5% | | | | 56.05 | 48.54 | 56.05 |
| | C. D. at 1 % | | | | 74.70 | 64.69 | 74.70 |

$P_1$-Parbhani Kranti, $P_2$ -Arka Anamika, $P_3$- Arka Vijay, $P_4$-Phule Utkarsha, $P_5$ -Ajeet-121, $P_6$ -Pusa Sawani, $P_7$ -Benolt

*, ** - significant at 5 and 1 per cent level, respectively

The hybrid Arka Anamika x Benolt produced highest heterobeltiosis, relative heterosis and economic heterosis. The cross Parbhani Kranti x Phule Utkarsha (-11.28) recorded maximum heterobeltiosis in the negative direction, while Arka Anamika x Pusa Sawani exhibited maximum heterosis over MP and check in the negative direction.

**4.3.3 Primary branches per plant (No.)**

The range of per cent heterosis for primary branches per plant was very wide (-100 to 942.54 %). The highest and highly significant heterobeltiosis was displayed by Arka Vijay x Pusa Sawani (942.54%) followed by Arka Anamika x Benolt (88.89%). Phule Utkarsha x Benolt (-88.89%) exhibited significant negative heterobeltiosis. Arka Anamika x Benolt and Arka Vijay x Pusa Sawani also recorded significant heterosis over MP and check.

**4.3.4. Internodes per plant (No.)**

The range of heterobeltiosis for the character internodes per plant was -15.33 to 55.39 per cent. The range for relative and economic heterosis was -12.62 to 71.55 and -24.10 to 60.96 per cent respectively.

The hybrid Arka Anamika x Benolt exhibited the maximum values for all three types of heterosis estimated. Highly significant heterosis over MP (71.55%), BP (55.39%) and the check (60.96%) was registered by this hybrid.

**4.3.5 Days to first picking**

A cultivar which requires less number of days to first picking is favoured by the farmer. Thus, heterosis in the negative direction is considered desirable for this character. The range of heterobeltiosis, relative and economic heterosis was -5.46 to 2.50, -4.56 to 2.84 and -3.11 to 3.11 per cent respectively. The hybrid Arka Vijay x Ajeet-121 showed highest (-5.46%) negative heterosis over better parent. The hybrid Arka

Vijay x Pusa Sawani showed significantly highest (-4.56%) heterosis over MP, while Arka Vijay x Ajeet-121 exhibited highest and highly significant heterosis over the check in the negative direction (-3.11%). Highly significant heterobeltiosis and relative heterosis in the desirable direction was exhibited by Arka Vijay x Ajeet-121, Arka Vijay x Pusa Sawani, Arka Vijay x Phule Utkarsha, Arka Anamika x Benolt and Arka Anamika x Phule Utkarsha. The hybrids Arka Vijay x Ajeet-121(-3.11%), Parbhani Kranti x Phule Utkarsha, Arka Vijay x Pusa Sawani and Arka Anamika x Phule Utkarsha (-2.49%) and Parbhani Kranti x Arka Anamika (-0.62%), exhibited highly significant heterosis over the check.

**4.3.6 Fruits per plant (No.)**

A wide range for per cent heterosis was observed for the number of fruits, i.e. -14.61 to 43.26, -11.60 to 65.22 and -25.66 to 58.33 over BP, MP and check respectively. Highly significant heterobeltiosis was registered by Arka Anamika x Benolt (43.26%). The same hybrid recorded highly significant heterosis over MP (65.22%) and the check (58.33%). Parbhani Kranti x Ajeet–121 exhibited significant heterosis over BP (24.73%) and highly significantly heterosis over MP (32.28%). Arka Anamika x Phule Utkarsha (23.12%), Arka Vijay x Pusa Sawani (24.77%) and Phule Utkarsha x Ajeet–121 (23.43%) exhibited significant relative heterosis, also in the desirable (positive) direction. Arka Anamika x Pusa Sawani (-25.66%) recorded significant heterosis over the check, but in the negative direction.

**4.3.7 Average fruit length (cm)**

Three crosses (Parbhani Kranti x Phule Utkarsha, Parbhani Kranti x Benolt, and Phule Utkarsha x Ajeet-121) exhibited highly significant negative heterobeltiosis for this character. The hybrid Arka Vijay x Ajeet-121 (8.31%) was the only hybrid which exhibited highly significant relative heterosis in the desirable positive direction. Pusa Sawani x

Benolt (6.69%) recorded maximum positive heterosis over check. The range of heterosis observed for this character was -12.47 to 5.34, -5.79 to 8.31 and -7.76 to 6.69 per cent over BP, MP and check respectively.

### 4.3.8 Average fruit girth (cm)

Heterosis in the negative direction is desirable for this character as slender fruits are preferred by the consumers. The range of heterobeltiosis, average and standard heterosis for this character was -8.01 to 5.35, -8.00 to 8.94 and -6.97 to 4.00 per cent respectively. Of the crosses, 71.43 per cent (15 crosses) showed economic heterosis in the desirable (negative) direction. Three of them *viz.,* Parbhani Kranti x Phule Utkarsha (-6.97%) Phule Utkarsha x Benolt (-6.41%) and Ajeet-121 x Benolt (-6.15%) recorded highly significant economic heterosis.

The maximum and significant negative values for all three types of heterosis estimated were registered by the hybrid Parbhani Kranti x Phule Utkarsha.

### 4.3.9 Green fruit yield (g/plant)

For this character, the range of heterosis over BP, MP and check was -24.88 to 55.36, -18.82 to 73.32 and -27.58 to 73.59 per cent respectively. Arka Anamika x Benolt registered highly significant heterosis over BP (55.36%), MP (73.32%) and check (73.59%), in the desirable direction. Significant heterosis over MP was also recorded by Arka Vijay x Pusa Sawani (34.83%). Twelve hybrids (57.14 %) exhibited economic heterosis in the desirable (positive) direction.

## 4.4 Combining ability

### 4.4.1 Analysis of Variance

Table 4.4 presents the analysis of variance for combining ability. The general combining ability (gca) variances were significant for

primary branches per plant, internodes per plant and green fruit yield (g/plant); and highly significant for the rest of the characters.

The specific combining ability (sca) variances were highly significant for plant height at harvest, days to first picking, fruits per plant and average fruit girth, whereas they were significant for days to 50 per cent flowering, plant height at harvest, internodes per plant and green fruit yield (g/plant); but non significant for average fruit length.

As gca is related with the additive and sca with the non-additive components of gene action, significance of both gca and sca mean sum of squares indicate the importance of both additive and non-additive components in the inheritance of these traits.

### 4.4.2 General combining ability effects

The gca effects for the seven parents are tabulated in the table 4.5.

#### 4.4.2.1 Days to 50 per cent flowering (No.)

The gca analysis revealed that five parents showed significant gca effects for this character. As early flowering cultivars are preferred, the combining ability in negative direction is desirable for this character. Out of the seven parents, two exhibited significant gca effects in the desirable (negative) direction. The parent Phule Utkarsha (-0.56) registered the highest significant gca in the negative direction, followed by Parbhani Kranti (-0.49). The parent Arka Anamika (-0.12) exhibited negative but non significant gca effects.

#### 4.4.2.2 Plant height at harvest (cm)

Significant gca effects were registered for only two parents *viz.*, Phule Utkarsha and Benolt. Phule Utkarsha recorded the highest significant negative gca effects (-8.98). Benolt (8.23) was the only parent

**Table 4.4. Analysis of variance for combining ability for 9 characters in 7 x 7 half diallel of okra**

| Sources of variation | D. F. | Mean sum of squares | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Days to 50% flowering (No.) | Plant height at harvest (cm) | Primary branches per plant (No.) | Internodes per plant (No.) | Days to first picking (No.) | Number of fruits per plant | Average fruit length (cm) | Average fruit girth (cm) | Green fruit yield (g/plant) |
| **g. c. a.** | 6 | 1.441** | 359.759** | 0.097* | 9.231* | 1.303** | 10.607** | 0.621** | 0.055** | 1037.444* |
| **s. c. a.** | 21 | 1.365* | 132.455** | 0.053* | 7.108* | 0.848** | 4.962** | 0.128 | 0.024** | 882.929* |
| **error** | 54 | 0.179 | 101.802 | 0.029 | 3.676 | 0.111 | 1.208 | 5.724 | 0.004 | 390.809 |

*, ** - significant at 5 and 1 per cent level, respectively

**Table 4.5. Estimates of general and specific combining ability effects for parents and $F_1$s in a 7 x 7 half diallel of okra**

| Sr No. | Parents/ Hybrids | Days to 50% flowering (No.) | Plant height at harvest (cm) | Primary branches per plant (No.) | Internodes per plant (No.) | Days to first picking (No.) | Number of fruits per plant | Average fruit length (cm) | Average fruit girth (cm) | Green fruit yield (g/plant) |
|---|---|---|---|---|---|---|---|---|---|---|
| **GCA effects** | | | | | | | | | | |
| 1 | Parbhani Kranti ($P_1$) | -0.49** | 4.03 | 0.03 | -0.18 | -0.44** | -0.25 | -0.32** | 0.04* | -5.80 |
| 2 | Arka Anamika ($P_2$) | -0.12 | -0.33 | 0.01 | -0.03 | -0.11 | -0.17 | 0.08 | -0.01 | 0.05 |
| 3 | Arka Vijay ($P_3$) | 0.33* | -5.53 | 0.01 | 0.63 | 0.08 | 0.61 | -0.37** | 0.05* | 3.87 |
| 4 | Phule Utkarsha ($P_4$) | -0.56** | -8.98** | -0.12* | -1.23* | -0.33** | -1.35** | 0.24** | -0.00 | -10.92 |
| 5 | Ajeet-121 ($P_5$) | 0.11 | 5.83 | -0.11* | -0.55 | -0.11 | 0.41 | -0.06 | 0.03 | -5.97 |
| 6 | Pusa Sawani ($P_6$) | 0.30* | -3.25 | -0.03 | -0.54 | 0.20 | -0.53 | 0.11 | 0.07** | -3.11 |
| 7 | Benolt ($P_7$) | 0.44** | 8.23* | 0.20** | 1.90** | 0.71** | 2.09** | 0.32** | -0.17** | 21.88** |
| | S. E. ($\hat{gi}$) ± | 0.13 | 3.11 | 0.05 | 0.60 | 0.10 | 0.34 | 0.07 | 0.02 | 6.10 |
| | C.D. at 5% | 0.26 | 6.24 | 0.10 | 1.19 | 0.21 | 0.68 | 0.15 | 0.04 | 12.23 |
| | C. D. at 1 % | 0.35 | 8.32 | 0.14 | 1.58 | 0.27 | 0.91 | 0.20 | 0.06 | 16.30 |
| | S. E. (gi - gi) ± | 0.20 | 4.76 | 0.08 | 0.90 | 0.16 | 0.52 | 0.11 | 0.03 | 9.32 |
| **SCA effects** | | | | | | | | | | |
| 8 | $P_1$ x $P_2$ | -0.14 | 0.73 | -0.08 | 0.19 | 0.18 | 0.62 | -0.12 | -0.13* | 8.67 |
| 9 | $P_1$ x $P_3$ | 0.24 | -2.94 | 0.15 | -1.11 | 0.66* | -0.82 | -0.12 | 0.21** | -1.83 |
| 10 | $P_1$ x $P_4$ | -0.88** | -6.23 | -0.09 | -1.25 | -0.60* | -1.01 | -0.27 | -0.30** | -4.91 |

## Table 4.5. (Contd.)….

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 11 | $P_1$ x $P_5$ | 1.46** | 8.0 | 0.04 | 2.88 | 1.18** | 2.72** | 0.42* | 0.12 | 26.20 |
| 12 | $P_1$ x $P_6$ | -0.73* | 6.71 | -0.11 | 0.47 | -0.45 | 0.51 | 0.24 | -0.07 | 9.80 |
| 13 | $P_1$ x $P_7$ | 0.13 | -7.50 | -0.10 | -1.51 | 0.03 | -0.27 | -0.16 | -0.01 | -42.99** |
| 14 | $P_2$ x $P_3$ | -0.13 | 0.82 | -0.12 | -1.12 | 0.32 | -1.07 | -0.03 | -0.02 | -22.47 |
| 15 | $P_2$ x $P_4$ | -1.25** | 0.40 | 0.04 | 1.01 | -0.94** | 0.91 | 0.16 | 0.17** | 4.81 |
| 16 | $P_2$ x $P_5$ | 0.09 | 10.53 | -0.07 | 0.20 | -0.16 | 0.33 | 0.01 | -0.02 | -4.55 |
| 17 | $P_2$ x $P_6$ | 1.90** | -14.26 | -0.21 | -3.45* | 1.55** | -3.07** | -0.52** | -0.12 | -42.34** |
| 18 | $P_2$ x $P_7$ | -1.25** | 22.79** | 0.70** | 8.34** | -1.31** | 7.08** | 0.21 | 0.32** | 95.04** |
| 19 | $P_3$ x $P_4$ | -0.69** | 4.27 | -0.06 | 0.88 | -0.45 | 1.48 | 0.37** | -0.05 | 6.01 |
| 20 | $P_3$ x $P_5$ | -1.69** | 12.86 | -0.01 | 0.70 | -1.68** | 0.14 | 0.69** | 0.02 | 13.38 |
| 21 | $P_3$ x $P_6$ | -1.54** | 5.74 | 0.52** | 4.19** | -1.64** | 2.66** | 0.27 | 0.21** | 34.65** |
| 22 | $P_3$ x $P_7$ | 0.98* | 11.93 | -0.11 | 0.01 | 0.51 | -0.36 | -0.69** | 0.05 | -1.05 |
| 23 | $P_4$ x $P_5$ | 1.87** | 8.91 | 0.12 | 1.72 | 1.40** | 1.09 | -0.63** | -0.06 | 11.99 |
| 24 | $P_4$ x $P_6$ | -0.65* | 15.25 | 0.11 | 1.11 | -0.23 | 0.74 | 0.17 | -0.06 | 14.40 |
| 25 | $P_4$ x $P_7$ | -0.80* | -0.961 | -0.25 | -0.60 | 0.25 | -0.81 | -0.13 | -0.06 | -10.91 |
| 26 | $P_5$ x $P_6$ | -0.99** | -4.954 | -0.10 | -1.49 | -0.45 | 0.67 | -0.09 | -0.04 | 0.52 |
| 27 | $P_5$ x $P_7$ | -0.47 | -3.57 | -0.19 | -0.31 | 0.03 | -0.81 | 0.04 | -0.08 | -7.26 |
| 28 | $P_6$ x $P_7$ | -0.32 | 5.51 | 0.00 | 0.45 | 0.07 | 0.04 | 0.38* | 0.03 | 19.27 |
| | S. E. ($s_{ij}$) | 0.32 | 7.71 | 0.13 | 1.46 | 0.25 | 0.84 | 0.18 | 0.05 | 15.10 |
| | C. D. at 5% | 0.65 | 15.45 | 0.26 | 2.94 | 0.51 | 1.68 | 0.37 | 0.10 | 30.27 |
| | C. D. at 1 % | 0.86 | 20.59 | 0.34 | 3.91 | 0.68 | 2.24 | 0.49 | 0.14 | 40.34 |
| | S. E. ($s_{ij}$ - $s_{ik}$) ± | 0.56 | 13.45 | 0.23 | 2.56 | 0.44 | 1.47 | 0.32 | 0.09 | 26.36 |
| | S. E. ($s_{ij}$ - $s_{kl}$) ± | 0.53 | 12.58 | 0.21 | 2.39 | 0.42 | 1.37 | 0.30 | 0.08 | 24.66 |

*, ** - significant at 5 and 1 per cent level, respectively. $P_1$-Parbhani Kranti, $P_2$ -Arka Anamika, $P_3$- Arka Vijay, $P_4$-Phule Utkarsha, $P_5$ -Ajeet-121, $P_6$ -Pusa Sawani, $P_7$ -Benolt.

registering significant gca effects in the desirable (positive) direction, while Parbhani Kranti (4.03) and Ajeet-121 (5.83) exhibited magnitudinally high but non significant gca effects for this character.

#### 4.4.2.3 Primary branches per plant (No.)

Three parents recorded significant gca effects for primary branches per plant. Benolt (0.20) exhibited highly significant gca effects while Phule Utkarsha (-0.12) and Ajeet-121 (-0.11) exhibited significant negative gca effects.

#### 4.4.2.4 Internodes per plant (No.)

Only two parents, Phule Utkarsha and Benolt exhibited significant gca effects. Benolt exhibited highly significant positive gca effects (1.90) in the desirable direction, while Phule Utkarsha (-1.23) exhibited significant negative gca effects. The parent Arka Vijay recorded positive but non significant gca effects for this trait.

#### 4.4.2.5 Days to first picking (No.)

A cultivar requiring less number of days to first picking is preferred by the cultivators. Thus, negative gca effects are desirable for this character. Two parents *viz.*, Parbhani Kranti(-0.44) and Phule Utkarsha(-0.33) exhibited highly significant negative gca effects. Arka Ananika (-0.11) and Ajeet-121 (-0.11) exhibited non significant negative gca effects. The hybrids Arka Vijay (0.08), Pusa Sawani (0.19) and Benolt (0.71) exhibited positive gca effects, among them, Benolt had the highest and highly significant positive gca effects.

#### 4.4.2.6 Number of fruits per plant

Positive gca effects for number of fruits per plant are considered desirable. Only three parents *viz.,* Arka Vijay (0.61), Ajeet -121 (0.41) and Benolt (2.09) exhibited gca effects in the desirable positive direction. Phule Utkarsha (-1.35) and Benolt (2.09) exhibited highly significant gca effects in negative and positive direction respectively. Parbhani Kranti (-0.25), Arka Anamika (-0.17) and Pusa Sawani (-0.53) had non significant negative gca effects for this trait.

#### 4.4.2.7 Average fruit length (cm)

Out of the seven parents, four showed highly significant gca effects for this character of which Parbhani Kranti (-0.32) and Arka Vijay (-0.36) showed highly significant negative gca effects while Phule Utkarsha (0.24) and Benolt (0.32) showed highly significant gca effects in the positive direction.

#### 4.4.2.8 Average fruit girth (cm)

Since less fruit girth is desirable, the gca effects in negative direction are favoured. Three parents exhibited negative gca effects, out of which Benolt (-0.17) exhibited highly significant negative gca effects. Pusa Sawani (0.07) exhibited highly significant positive gca effects followed by Parbhani Kranti (0.04) and Arka Vijay (0.05) which exhibited significant gca effects.

#### 4.4.2.9 Green fruit yield (g/plant)

Among the parents, Benolt was the only parent exhibiting highly significant gca effects (21.88) in the positive direction, which shows that it is a good combiner for green fruit yield (g/plant.). The parents Arka

Anamika (0.05) and Arka Vijay (3.87) had positive but non significant gca effects. The parents Parbhani Kranti (-5.80), Phule Utkarsha (-10.92), Ajeet-121 (-5.98) and Pusa Sawani (-3.11) exhibited non significant negative gca effects for this trait.

### 4.4.3 Specific combining ability effects

The specific combining ability (sca) effects of different hybrids for all the characters are presented in table 4.5.

#### 4.4.3.1 Days to 50 per cent flowering (No.)

In order to isolate early maturity types, hybrids showing negative sca effects for days to 50 per cent flowering are preferred. Out of the 21 hybrids, ten showed highly significant sca effects while four combinations showed significant sca effects. The maximum negative sca effects were registered by the hybrid Arka Vijay x Ajeet-121 (-1.69) followed by Arka Vijay x Pusa Sawani (-1.54), Arka Anamika x Benolt and Arka Anamika x Phule Utkarsha (-1.25).

Parbhani Kranti x Ajeet-121 (1.46), Arka Anamika x Pusa Sawani (1.90), Arka Vijay x Benolt (0.98) and Phule Utkarsha x Ajeet-121 (1.87) displayed significant positive sca effects. All the crosses on Arka Vijay except Arka Vijay x Benolt (0.98) and all the crosses on Aject-121 exhibited sca effects in desirable (negative) direction. Highest positive sca effect was displayed by Arka Anamika x Pusa Sawani (1.90).

#### 4.4.3.2 Plant height at harvest (cm)

For the character of plant height at harvest, only one hybrid i.e. Arka Anamika x Benolt (22.79) exhibited significant positive sca effects. Phule Utkarsha x Pusa Sawani (15.25), Akra Vijay x Ajeet – 121 (12.86)

and Arka Vijay x Benolt (11.93) registered magnitudinally high, but non significant, positive sca effects for this trait. Fourteen crosses showed sca effects in the positive direction. All the crosses on Arka Vijay showed positive sca effects. The combination Arka Anamika x Pusa Sawani (-14.26) registered maximum negative sca effects.

#### 4.4.3.3 Primary branches per plant (No.)

The hybrids Arka Anamika x Benolt (0.70) and Arka Vijay x Pusa Sawani (0.52) exhibited highly significant sca effects for this character. The range of sca effects was -0.25 (Phule Utkarsha x Benolt) to 0.70 (Arka Anamika x Benolt). Out of 21 crosses, eight recorded sca effects in positive direction for this character.

#### 4.4.3.4 Internodes per plant (No.)

Highly significant positive sca effects were recorded by Arka Anamika x Benolt (8.34) and Arka Vijay x Pusa Swami (4.19). Among other crosses, Parbhani Kranti x Ajeet-121 (2.88), Phule Utkarsha x Ajeet-121 (1.72) and Phule Utkarsha x Pusa Sawani (1.11) recorded positive but non significant sca effects. The combination Arka Anamika x Pusa Sawani (-3.45) registered significant negative sca effects.

#### 4.4.3.5 Days to first picking (No.)

The sca effects in the negative direction are considered desirable for the character of days to first picking. Nine crosses recorded significant sca effects for this character, out of which, only five recorded significant sca effects in the desirable (negative) direction. The maximum negative sca effects were registered by the combinations Arka Vijay x Ajeet-121 (-1.68) followed by Arka Vijay x Pusa Sawani (-1.64), Arka Anamika x Benolt (-1.31) Arka Anamika x Phule Utkarsha (-0.94) and Parbhani

Kranti x Phule Utkarsha (-0.60). All those hybrids which exhibited significant sca effects for the character of days to first picking, had also recorded significant sca effects for the character of days to 50 per cent flowering in the same direction. Arka Anamika x Pusa Sawani (1.55), Phule Utkarsha x Ajeet -121 (1.40), Parbhani Kranti x Ajeet-121 (1.18) and Parbhani Kranti x Arka Vijay (0.66) were the hybrids which recorded significant sca effects in the positive direction.

**4.4.3.6 Number of fruits per plant**

The crosses Parbhani Kranti x Ajeet -121 (2.72), Arka Anamika x Benolt (7.08) and Arka Vijay x Pusa Sawani (2.66) recorded highly significant positive sca effects for this character whereas, Arka Anamika x Pusa Sawani (-3.07) recorded highly significant negative sca effects. Positive, but non significant sca effects were also recorded by Arka Vijay x Phule Utkarsha (1.48) and Phule Utkarsha x Ajeet-121(0.38). Thirteen crosses showed sca effects in the desirable (positive) direction. The range of sca effects in desirable direction was 0.04 (Pusa Sawani x Benolt) to 7.08 (Arka Anamika x Benolt).

**4.4.3.7 Average fruit length (cm)**

The range of sca effects for this character was -0.69 (Arka Vijay x Benolt) to 0.69 (Arka Vijay x Ajeet-121). Eleven crosses exhibited sca effects in the desirable (positive) direction, four of them being significant. The hybrids Parbhani Kranti x Ajeet-121 (0.42) and Pusa Sawani x Benolt (0.38) exhibited significant positive and Arka Vijay x Phule Utkarsha (0.37) and Arka Vijay x Ajeet-121 (0.69) showed highly significant positive sca effects. The combinations Arka Anamika x Pusa Sawani (-0.52), Arka Vijay x Benolt (-0.69) and Phule Utkarsha x Ajeet-121 (-0.63) recorded highly significant negative sca effects.

#### 4.4.3.8 Average fruit girth (cm)

Negative sca effects are desirable for this character. Thirteen crosses exhibited negative sca effects, out of which, only two *viz.,* Parbhani Kranti x Arka Anamika (-0.13) and Parbhani Kranti x Phule Utkarsha (-0.30) were significant and highly significant, respectively. Four hybrids *viz.,* Parbhani Kranti x Arka Vijay (0.21), Arka Anamika x Phule Utkarsha (0.17), Arka Anamika x Benolt (0.32) and Arka Vijay x Pusa Sawani (0.21) recorded significant gca effects in positive direction.

#### 4.4.3.9 Green fruit yield (g/plant)

The marketable green fruit yield is an important character for the crop of okra. Out of 21 crosses twelve crosses exhibited sca effects in the desirable (positive) direction. Two crosses *viz.,* Arka Anamika x Benolt (95.38) and Arka Vijay x Pusa Sawani (34.65) exhibited highly significant positive sca effects for this character, whereas Parbhani Kranti x Benolt (-42.99) and Arka Anamika x Pusa Sawani (-42.34) exhibited highly significant negative sca effects. Other hybrids which exhibited magnitudinally high, but non significant positive sca effects were Parbhani Kranti x Ajeet-121 (26.20), Pusa Sawani x Benolt (19.27 ), Phule Utkarsha x Pusa Sawani (14.40), Akra Vijay x Ajeet-121 (13.38) and Phule Utkarsha x Ajeet -121 (11.99).

## 4.5 Heritability and gene action

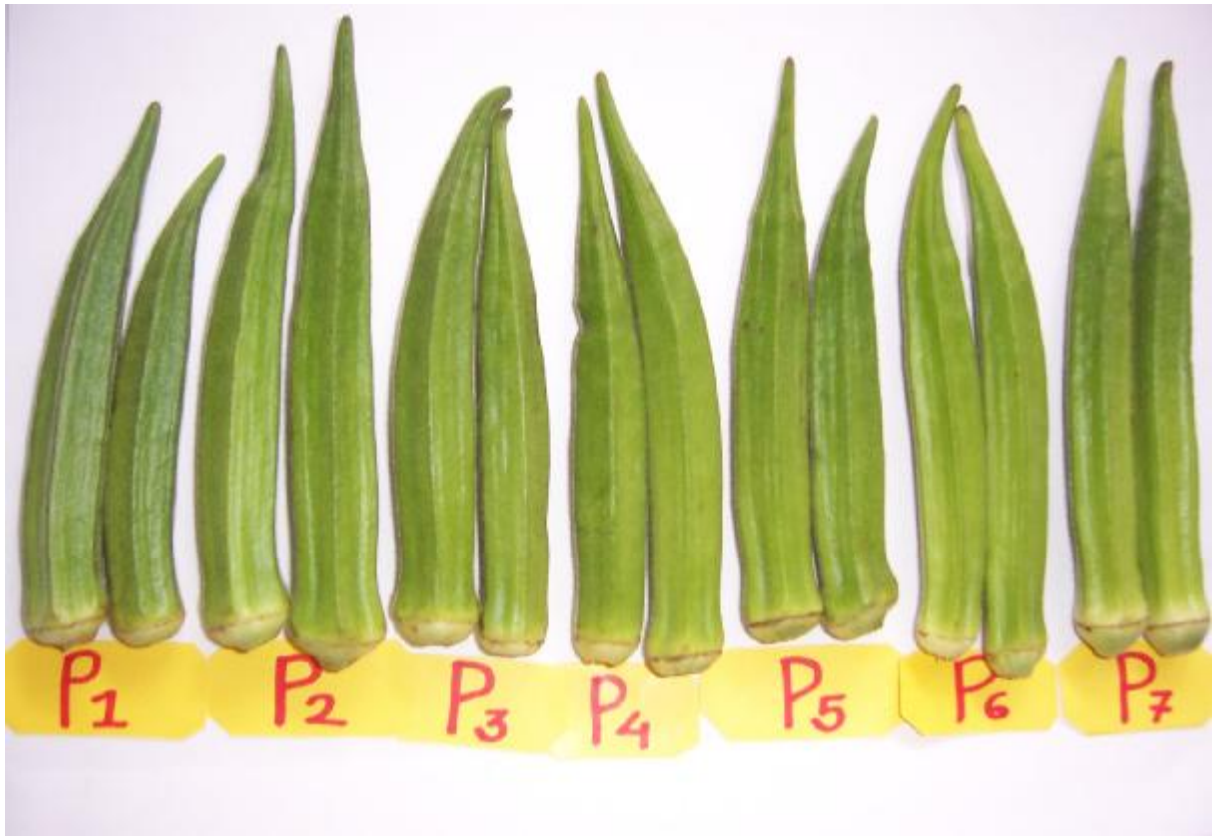
The estimates of The additive ($\sigma^2A$) and dominance variances ($\sigma^2$ D), A:D ratios and heritability ($h^2$ (ns)), are given in Table 4.6. The perusal of Table 4.6 reveals that the $\sigma^2A$ values range from 0.0069 for fruit girth to 34.3367 for green fruit yield. The $\sigma^2D$ values ranged from 0.0191 for fruit girth to 492.12 for green fruit yield respectively.

**Table 4.6. Estimates of additive and dominance variances, A : D ratio and heritability (ns)**

| | Days to 50 per cent flowering (No.) | Plant height at harvest (cm) | Primary branches per plant (No.) | Internodes per plant (No.) | Days to first picking (No.) | Number of fruits per plant | Average fruit length (cm) | Average fruit girth (cm) | Green fruit yield (g/plant) |
|---|---|---|---|---|---|---|---|---|---|
| $s^2$**A** | 0.02 | 50.51 | 0.01 | 0.47 | 0.10 | 1.25 | 0.11 | 0.01 | 34.34 |
| $s^2$ **D** | 1.19 | 30.65 | 0.02 | 3.43 | 0.74 | 3.75 | 0.07 | 0.02 | 492.12 |
| **A : D** | 0.01 | 1.65 | 0.39 | 0.14 | 0.14 | 0.33 | 1.56 | 0.36 | 0.07 |
| **$h^2$ (ns)** | 01.21 | 27.61 | 15.49 | 06.22 | 10.65 | 20.18 | 46.21 | 22.65 | 03.74 |

The highest A:D ratio was obtained for the character plant height (1.6479), while the lowest was recorded for green fruit yield (0.0698). The highest heritability estimate was obtained for fruit length (46.21%) followed by plant height (27.61%).

**PLATE 1. Fruits of Seven Parents Used in 7 x 7 Half Diallel in Okra**




**$P_1$: Parbhani Kranti, $P_2$: Arka Anamika, $P_3$: Arka Vijay, $P_4$: Phule Utkarsha, $P_5$: Ajeet-121**
**$P_6$ : Pusa Sawani and $P_7$: Benolt**

## PLATE 2. Fruits of Superior Hybrids and their Parents


**$P_2$: Arka Anamika, $P_2P_7$: Arka Anamika x Benolt and $P_7$: Benolt**


**$P_3$: Arka Vijay, $P_3P_6$: Arka Vijay x Pusa Sawani and $P_6$: Pusa Sawani**

CHAPTER 5

# DISCUSSION

Ensuring lasting food security to the ever increasing human population is a daunting task. With the increasing population load, shrinking land and water resources and soaring global temperatures (climate change), the challenge is bigger. Increasing agricultural productivity is pivotal to the solution of this problem. In such a scenario, technological innovations assume great importance. Exploitation of heterosis is one such technological breakthrough, which singularly made possible substantial increase in crop yields. Commercial $F_1$ hybrids have been very successful in several crops and have come to occupy huge acreage of all leading crops.

Heterosis breeding is a major breeding approach for increasing the production of vegetable crops as well. It exploits the over dominance variance and is commercially practiced in sweet corn, onion, tomato, brinjal, capsicum, cabbage, carrot, cucumber, pumpkin, squash, watermelon and muskmelon. Usefulness of heterosis breeding approach has been well reported in case of okra (*Abelmoschus esculentus* (L.) Moench). As hybrid technology offers opportunities for improvements in productivity, earliness, uniformity and quality, this approach holds many promises.

The choice of parents for use in a breeding program assumes paramount importance. Suitable parents can be chosen on the basis of the combining ability analysis. The actual value of an inbred line for hybrid breeding lies in its worth (i.e. combining ability) in hybrid combination with other inbreds. Knowing the general combining ability in a series of its crosses and specific combining ability for a parent in a particular cross, helps in prediction of usefulness of a cross. For the study of the

relative merits of parents used (through their gcas) and the comparative performance of $F_1$s, diallel method of testing gca is universally used. Griffing's model I, method II which was followed in the present investigation enables the study of heterosis in relation to combining abilities and also with *per se* performance. The identification of good combiners among the parents and isolation of an outstanding hybrid is attempted and the relative roles of additive and dominant gene actions are also studied and the results obtained discussed below under suitable heads.

## 5.1 Mean performance of parents

The study of mean performance of parents revealed that there was considerable variation among different parents for different characters studied. The parent Parbhani Kranti recorded the best performance for three characters *viz.,* days to 50 per cent flowering (46.33 days), days to first picking (52.33 days) and plant height at harvest (176.07 cm). Thus, it showed earliness and tallness (Table 4.2). While, late flowering bahaviour was exhibited by Arka Vijay as it recorded 49.33 days to 50 per cent flowering and Benolt as it took 55.33 days to first picking. Arka Vijay exhibited relatively shorter fruits (10.60 cm). Phule Utkarsha recorded the shortest plant height (138.60 cm) and also recorded minimum values among the parents for other yield contributing characters such as number of primary branches per plant(0.07), internodes per plant (12.83), fruits per plant and accordingly, exhibited the lowest yield (129.09g/plant) among the parents. The same parent, however, exhibited maximum fruit girth (5.38 cm) along with Parbhani Kranti.

Benolt, the parent of exotic origin recorded the highest yield (179.33g/plant). It also showed the maximum values for other yield contributing characters *viz.,* primary branches per plant (0.60), internodes

per plant (17.33) and fruits per plant (16.80). The fruits were long (12.35 cm) and slender (4.75 cm).

From the study of the mean performance of the parents, Benolt and Parbhani Kranti were observed to be promising. Parbhani Kranti was the best performer for three characters, while Benolt outperformed all other parents in case of six characters.

## 5.2 Heterosis

### 5.2.1 Analysis of variance

Heterosis is defined as the superiority or inferiority of hybrids over their parents. Heterosis may be manifested in the positive or negative direction. The parents Vs. crosses (P Vs. C) interaction mean sum of squares gives the measure of heterosis. The P Vs. C interaction mean sum of squares were significant for days to 50 per cent flowering, plant height at harvest, internodes per plant, days to first picking, number of fruits per plant and green fruit yield (g/plant). It indicates the presence of heterosis for these characters. As suggested by Arunachalam (1976), such heterosis may arise due to a few but highly heterotic crosses .

### 5.2.1 Magnitude and direction of heterosis

The higher magnitude of heterosis in desirable direction is important for isolating heterotic hybrids. The magnitude of heterosis was different for different characters. In the present investigation, the magnitude of heterosis was found to be higher for primary branches, internodes per plant, green fruit yield (g/plant) and number of fruits per plant, while it was low for average fruit length, days to first picking and average fruit girth. This is in agreement with the results obtained by Pawar *et al.* (1999a) and Deshmukh *et al.* (2001).

The magnitudes of mean per cent heterosis over BP, MP and check for all the characters studied are given in table 5.1.

**Table 5.1. Mean per cent heterosis over BP, MP and Check for 9 characters in 7 x 7 half diallel of okra**

| Sr. No. | Character | Mean heterosis (%) over | | |
|---|---|---|---|---|
| | | BP | MP | Check |
| 1. | Days to 50 per cent flowering (No.) | -3.32 | -1.99 | -1.37 |
| 2. | Plant height at harvest (cm) | 3.50 | 9.12 | -0.49 |
| 3. | Primary branches per plant (No.) | 22.89 | 49.43 | 14.92 |
| 4. | Internodes per plant (No.) | 7.16 | 14.30 | 3.15 |
| 5. | Days to first picking (No.) | -1.79 | -0.55 | -0.09 |
| 6. | Fruits per plant (No.) | 6.26 | 15.13 | 2.46 |
| 7. | Average fruit length (cm) | -3.03 | -0.28 | -0.24 |
| 8. | Average fruit girth (cm) | -1.94 | 0.64 | -1.95 |
| 9. | Green fruit yield (g/plant) | 7.26 | 13.83 | 3.87 |

Marketable green fruit yield per plant is the most important character for okra, a vegetable crop. Higher magnitudes of heterosis were estimated for green fruit yield. The mean per cent heterosis over BP, MP and check was 7.26, 13.83 and 3.87 respectively. The hybrid Arka Anamika x Benolt recorded highly significant heterosis over BP (55.36%), MP (73.32%) and check (73.59%). The hybrid Arka Vijay x Pusa Sawani also recorded significant heterosis over MP. Similar results for heterosis in fruit yield and yield contributing characters were also observed by Thaker ***et al.*** (1982), Vijay and Manohar (1986b), Dayasagar (1994), Mohamed ***et al.*** (1994b), Rewale ***et al.*** (2003b) and Bendale ***et al.*** (2003).

Earliness is a preferred trait for any crop, especially for a vegetable crop like okra. The crosses showing negative heterosis for days to 50 per cent flowering in the present experiment were Arka Anamika x Phule Utkarsha, Parbhani Kranti x Phule Utkarsha, Arka Vijay x Ajeet -121 and Arka Anamika x Pusa Sawani. The hybrid Parbhani Kranti x Phule Utkarsha and Arka Anamika x Phule Utkarsha both recorded highly significant values for heterosis over BP, MP and check in the desirable (negative) direction.

Arka Anamika x Phule Utkarsha, Arka Vijay x Ajeet-121 and Arka Vijay x Pusa Sawani exhibited highly significant heterosis over BP, MP and check for days to first picking, in the desirable direction. These three crosses can be desirable for isolating early segregates as they recorded highly significant negative heterosis over BP, MP and check. Heterosis for earliness in okra was also observed by Agarrado and Rasco (1986), Mandal and Dana (1993), Deshmukh ***et al.*** (2001) and Dhall ***et al.*** (2002).

For plant height at harvest, Arka Anamkia x Benolt exhibited highly significant average heterosis and significant economic heterosis (21.54% and 15.33%, respectively). Another hybrid, Arka Vijay x

Ajeet-121 recorded highly significant heterosis over mid parent (19.11%). None of the crosses exhibited significant heterosis over BP. The magnitude of mean heterosis (9.12%) and heteroeltiosis (3.50%) was higher than heterosis over the check (-0.49%). High heterosis for plant height was also reported by El-Maksoud *et al.* (1984), Mandal and Dana (1993), Mohamed *et al.* (1994b), Pawar *et al.* (1999a) Bhalekar (2000) and Deshmukh *et al.* (2001).

The perusal of Table 5.1 revealed that the highest magnitudes for the mean of per cent heterobeltiosis, relative and economic heterosis were observed for primary branches among all the traits studied. The hybrids Arka Anamika x Benolt and Arka Vijay x Pusa Sawani exhibited significant and very high positive heterosis over BP, MP and check for this trait. These two crosses exhibited high branching tendency which also contributed to fruit yield. Similar results were also observed by Pawar *et al.* (1999a) and Deshmukh *et al.* (2001).

Increase in yield of a hybrid is made possible due to increase in the yield contributing characters. In the present investigation, it was observed that those hybrids (e.g. Arka Anamika x Benolt and Arka Vijay x Pusa Sawani) which recorded higher heterosis for yield also recorded higher heterosis for yield contributing characters such as plant height at harvest, primary branches, internodes per plant and fruits per plant. It can also be seen that higher fruit length and fruit girth played a role in fruit yield.

Fruits of okra are borne axially on the nodes, thus more number of internodes means more number of nodes and fruits, it ultimately results in higher fruit yield. The hybrid Arka Anamika x Benolt recorded highly significant positive heterosis over BP, MP and check for internodes per plant and Arka Vijay x Pusa Sawani recorded significant positive heterosis over MP for this character. The magnitudes of mean

heterobeltiosis, relative and economic heterosis for internodes per plant was 7.16, 14.30 and 3.15 per cent, respectively (Table 5.1).

The same hybrid Arka Anamika x Benolt, which registered highest heterobeltiosis, relative and standard heterosis for internodes per plant, also recorded highly significant values for all the three types of heterosis estimated for number of fruits per plant and green fruit yield (g/plant). It is interesting to note that this hybrid involved Benolt as one of its parents which was the best performer for these two characters among the parents.

The consumers find the slender fruits of okra more attractive. Thus, higher fruit length is a desirable trait. Highest per cent of standard heterosis (6.68) for this character was recorded by Pusa Sawani x Benolt. Incidentally, it involved the parent with highest fruit length (Benolt) as one of its parents. Heterosis for fruit length was also reported by Thaker *et al.* (1982), Bhalekar *et al.* (2000), Deshmukh *et al.* (2001) and Veerragavathatham *et al.* (2003).

The hybrid Arka Anamika x Benolt which exhibited significant heterosis over BP, MP and check (55.36, 73.32 and 73.59 per cent respectively) included the highest performer (Benolt) among the parents for green fruit yield (g/plant). The same hybrid also showed significant values for per cent heterosis over BP and check for other characters like plant height at harvest; primary branches, internodes and number of fruits per plant and average length of fruits. Even for these characters, the parent Benolt which recorded the highest values among the parents was involved in the hybrid.

### 5.2.3 Heterosis and *per se* performance

In the present investigation, the highly heterotic crosses also showed high *per se* performance indicating the relationship between the two. The hybrids *viz.,* $P_3$ x $P_5$ for days to 50 per cent flowering; $P_2$ x $P_7$ for plant height, primary branches, internodes and number of fruits per

plant; $P_3$ x $P_5$ for days to first picking, $P_6$ x $P_7$ for fruit length, $P_1$ x $P_4$ for fruit girth and $P_2$ x $P_7$ for green fruit yield exhibited high heterosis as well as *per se* performance suggesting close association between heterosis and *per se* performance. Therefore *per se* performance can be used as an indicator of heterosis.

## 5.3 Combining ability

The ability of a cultivar to transmit its characters in all its progenies is known as its combining ability. The estimation of combining ability and their effects provide a guideline for selecting best combiners to be used in hybridization program.

The analysis of variance for combining ability (Table 4.4) revealed significant differences due to gca and sca for all the characters (except for average fruit girth for sca). This suggests the importance of both additive and non additive gene action, which is in agreement with the results reported by Pratap *et al.*(1981), Arora (1993), Poshiya and Vashi (1995a) and Liou Min Li *et al.* (2002).

### 5.3.1 General combining ability effects

The best general combiners based on the gca effects for all the characters are listed in Table 5.2.

As the marketable green fruit yield is the most sought after character in a vegetable crop like okra, the parent with high desirable significant gca effect for this trait can be selected for use in further breeding programs.

In the present investigation, among the parents, Benolt ($P_7$) recorded highly significant positive gca effects for green fruit yield (g/plant) followed by Arka Vijay (3.87) and Arka Anamika (0.05). High

gca effects for green fruit yield were also reported by Chaudhary *et al.* (1991), Sundhari *et al.* (1992) and Sivakumar *et al.* (1995).

The parent Benolt which recorded highly significant positive gca effects for green fruit yield also recorded high *per se* performance.

For days to 50 per cent of flowering, five parents exhibited significant gca effects, out of which only Parbhani Kranti (-0.49), followed by Phule Utkarsha (-0.56) exhibited highly significant negative gca effects. The same two parents also showed highly significant negative gca effects for days to first picking. Therefore, Parbhani Kranti and Phule Utkarsha were observed to be good general combiners for earliness.

For plant height at harvest, the parent Benolt ($P_7$) exhibited the highest and significant positive gca effects and was thus observed to be the best general combiner for this trait. Phule Utkarsha exhibited highly significant negative gca effects for plant height.

Arka Vijay (-0.116), Phule Utkarsha (-0.116), Ajeet- 121 (-0.105) and Benolt (0.195) exhibited significant gca effects for primary branches per plant. Among them, Benolt (0.195) alone exhibited highly significant positive gca effects, thus it was observed as the best general combiner for branching tendency.

For internodes per plant, Arka Vijay (0.63) and Benolt (1.90) recorded positive gca effects, but Benolt was the only parent displaying highly significant gca effects in positive direction and was adjudged as the best general combiner for this trait also.

For number of fruits per plant, Arka Vijay and Benolt produced positive gca effects, while Benolt (2.09) alone recorded highly significant gca effects and was observed to be the best general combiner for this trait. The parent Phule Utkarsha (-0.41) exhibited highly significant gca effects, but in the negative direction for this trait.

The parents Benolt (0.32) and Phule Utkarsha (0.24) were having highly significant positive gca effects for average fruit length and Benolt appeared to be the best general combiner for this trait. The other two parents *viz.,* Arka Vijay and Parbhani Kranti had highly significant negative gca effects.

For average fruit girth, the only two parents *viz.,* Benolt (-0.17) and Phule Utkarsha registered desirable negative gca effects. Among them, Benolt was the best general combiner showing highly significant negative gca effects.

In a nutshell, Benolt was observed to be the best general combiner among the parents for seven characters including green fruit yield and other yield contributing characters, *viz.,* plant height, primary branches per plant, internodes per plant, number of fruits per plant, average fruit length, average fruit girth and green fruit yield (g/plant). While, Parbhani Kranti and Phule Utkarsha recorded highly significant desirable gca effects for days to 50 per cent flowering and days to first picking.

Thus, the parent Benolt can be used in a breeding program for its high combining ability for yield and yield contributing characters, while Phule Utkarsha and Parbhani Kranti are promising parents which are good combiners for earliness (days to 50 per cent flowering and days to first picking respectively.)

Singh and Singh (1984), Jawili and Rasco (1990), Patil *et al.* (1996a), Pathak (1998), Nichal *et al.* (2001), Dahake (2004) and Kumar *et al.* (2006) also studied combining ability in okra and reported the list of good general combiners for different characters based on gca effects.

### 5.3.2 General combining ability and *per se* performance

For green fruit yield, the parent Benolt which displayed highly significant gca effects also registered highest *per se* performance for this

trait. Benolt also recorded significant gca effects for plant height at harvest, primary branches, internodes per plant, days to first picking, number of fruits per plant, average fruit length and average fruit girth and it also exhibited high *per se* performance for all these characters except plant height at harvest, for which it recorded second highest mean performance among the parents. For average fruit length, it recorded the highest mean performance, while for average fruit girth; it exhibited the lowest fruit girth (4.75) among the parents which is a favoruable trait (Table 4.5).

The parent Parbhani Kranti exhibited high *per se* performance for four characters (days to 50 per cent flowering, plant height at harvest, days to first picking and average fruit girth). It exhibited significant gca effects for all these traits except plant height. The earlier workers *viz.*, Poshiya and Vashi (1995a), Bhalekar (2000) and Kumar *et al.* (2006) also reported similar results.

Thus, it can be observed that there was an apparent relationship between *per se* performance and gca effects. Therefore, selection based on gca effects coupled with *per se* performance will be useful in identifying the suitable parents for a hybridization program.

### 5.3.3 Specific combining ability effects

The sca effects of different crosses are discussed in the succeeding paragraphs, taking into consideration the gca effects of the parents involved in the particular cross. For doing this, the parents were classified as High or Low based on their gca effects for the particular character.

For green fruit yield (g/plant), among the 21 crosses studied, the hybrid Arka Anamika x Benolt showed the highest and highly significant positive sca effects. It recorded the highest (21.79) sca effects and appeared to be the best specific combination for this trait. It was followed

by Arka Vijay x Pusa Sawani ($P_3P_6$) which exhibited significant positive sca effects. The other crosses which recorded higher positive sca effects were Parbhani Kranti x Ajeet-121, Pusa Sawani x Benolt, Phule Utkarsha x Pusa Sawani, Arka Vijay x Ajeet-121 and Phule Utkarsha x Ajeet-121, whereas, the hybrids Parbhani Kranti x Benolt (-42.99) and Arka Anamika x Pusa Sawani (-42.34) exhibited highly significant negative sca effects. The other hybrids $P_2$ x $P_7$ and $P_3$ x $P_6$ involved the parents with High x High gca effects indicating the role of additive effects for this trait.

Out of the 21 crosses studied, 14 crosses (66.67%) exhibited significant sca effects for days to 50 per cent flowering. The crosses ***viz.***, Arka Vijay x Ajeet -121($P_3$ x $P_5$), Arka Vijay x Pusa Sawani ($P_3$ x $P_6$), Arka Anamika x Phule Utkarsha ($P_2$ x $P_4$) and Arka Anamika x Benolt ($P_2$ x $P_7$) exhibited highly significant negative sca effects. Among them, $P_3$ x $P_5$ (-1.69) appeared to be best specific combination followed by $P_3$ x $P_6$. Both of them involved parents with Low x Low gca effects indicating additive gene action.

As regards plant height at harvest, only Arka Anamika x Benolt displayed highly significant sca effects; while for primary branches, $P_2$ x $P_7$ and Arka Vijay x Pusa Sawani ($P_3$ x $P_6$) and for internodes per plant, Arka Anamika x Pusa Sawani ($P_2$ x $P_6$), $P_2$ x $P_7$ and $P_3$ x $P_6$ exhibited significant effects. Among them, P2 x $P_7$ exhibited highly significant positive sca effects and appeared the best specific combination for all the three traits.

**Table 5.2. Best general and specific combiners for 9 characters in 7 x 7 half diallel of okra**

| Sr. No. | Character | GCA | SCA |
|---|---|---|---|
| 1. | **Days to 50 per cent flowering (No.)** | Phule Utkarsha (-0.56) | Arka Vijay x Ajeet-121 (-1.69) |
| 2. | **Plant height at harvest (cm)** | Benolt (8.23) | Arka Anamika x Benolt (22.80) |
| 3. | **Primary branches per plant (No.)** | Benolt (0.20) | Arka Anamika x Benolt (0.70) |
| 4. | **Internodes per plant (No.)** | Benolt (1.90) | Arka Anamika x Benolt (8.34) |
| 5. | **Days to first picking (No.)** | Parbhani Kranti (-0.44) | Arka Vijay x Ajeet-121 (-1.68) |
| 6. | **Number of fruits per plant** | Benolt (2.09) | Arka Anamika x Benolt (7.08) |
| 7. | **Average fruit length (cm)** | Benolt (0.32) | Arka Vijay x Ajet-121 (0.69) |
| 8. | **Average fruit girth (cm)** | Benolt (-0.17) | Parbhani Kranti x Phule Utkarsha (-0.30) |
| 9. | **Green fruit yield (g/plant)** | Benolt (21.88) | Arka Anamika x Benolt (95.04) |

Since earliness is the desirable character, hybrids with negative sca effects are important. For the character of days to first picking, out of the hybrids which showed significant sca effects, $P_3$ x $P_5$ (-1.68) exhibited highest negative sca effects and was the best specific combination for this trait. It was followed by $P_3$ x $P_6$ (-1.64) , $P_2$ x $P_7$ (-1.31), $P_2$ x $P_4$(-0.90) and $P_1$ x $P_4$ (-0.60) which also recorded significant sca effects.

As regards fruits per plant, the hybrid Parbhani Kranti x Ajeet-121 ($P_1$ x $P_5$), $P_2$ x $P_7$ and $P_3$ x $P_6$ exhibited significant sca effects. Among them, $P_2$ x $P_7$ (7.08) was the best specific combination and involved parents with Low x High gca effects indicating complementation.

For the trait average fruit length, the highest sca effects were recorded by $P_3$ x $P_5$ (0.69), followed by $P_1$ x $P_5$ (0.42) and $P_3$ x $P_4$ ( 0.37). These hybrids involved parents with Low x Low, Low x Low and Low x High gca effects, respectively.

In case of fruit girth, the hybrid $P_1$ x $P_4$ (-0.30) registered the highest and highly significant negative sca effects, followed by $P_5$ x $P_7$ (-o.08), $P_1$ x $P_2$ (-0.13) and $P_2$ x $P_6$ (-0.12). All of them involved parents with either Low x High or High x Low gca effects.

The study of the specific combining ability effects revealed Arka Anamika x Benolt as the best specific combiner based on the sca effects for green fruit yield, followed by Arka Vijay x Pusa Sawani. The combination Arka Anamika x Benolt registered highly significant sca effects for all the characters studied except average fruit length. It was observed to be the best specific combination for plant height, primary branches per plant, internodes per plant, number of fruits per plant and green fruit yield. For the rest of the characters *viz.,* days to 50 per cent flowering, days to first picking and fruit length; the hybrid Arka Vijay x Pusa Sawani appeared to be the best specific combination based on sca effects.

### 5.3.4 Specific combining ability and *per se* performance

From the perusal of Table 4.5 and 4.1, it appears that the hybrids showing high sca effects also recorded high *per se* performance.

For green fruit yield, $P_2$ x $P_7$ and $P_3$ x $P_6$ showed high sca effects as well as *per se* performance. Similarly, the crosses $P_3$ x $P_5$, $P_3$ x $P_6$ and $P_2$ x $P_7$ for days to 50 per cent flowering, $P_2$ x $P_7$ for plant height, $P_2$ x $P_7$ and $P_3$ x $P_6$ for primary branches, internodes and fruits per plant; $P_3$ x $P_5$ and $P_3$ x $P_6$ for days to first picking, $P_3$ x $P_5$ and $P_1$ x $P_5$ for fruit length and $P_5$ x $P_7$ and $P_1$ x $P_4$ for fruit girth exhibiting high sca effects also recorded *per se* performance for the respective characters. The results obtained confirm the earlier findings of Yadav *et al.* (2005) and Nimbalkar *et al.* (2004).

This suggests the dependency of sca effects and *per se* performance in the expression of fruit yield and its contributing characters. This also suggests that the selection based on high *per se* performance coupled with high sca effects will result into isolation of useful hybrids in okra.

### 5.3.5 gca and sca effects

In the present investigation, for green fruit yield the crosses with high sca effects involved parents with High x High gca effects suggesting the presence of the allelic interactions for green fruit yield.

For the rest of the traits, the parents with High x High, Low x Low and Low x High / High x Low gca effects were seen to be involved in the hybrids showing high sca effects for different characters. Thus, it indicates the presence of allelic as well as non allelic interactions in the expression of these characters.

## 5.4 Heritability and gene action

Yield is a polygenically controlled trait, involving complicated expression of character. The knowledge of gene action involved is a prerequisite to the selection of best suitable breeding methodology and ultimately, the improvement of the concerned crop in terms of yield and other yield contributing characters.

Three types of gene actions *viz.,* additive, dominance and epistasis determine the expression of a character. The predominance of additive gene action suggests the use of selection methodologies for crop improvement. While, dominance and epistasis gene actions are related with allelic and non allelic gene interactions. In such cases, the exploitation of heterosis or development of composite varieties would be effective. Therefore, the study of gene action provides the useful guidelines to the breeder for adoption of suitable breeding methodology.

The additive ($\sigma^2A$) and dominance variances ($\sigma^2$ D), A:D ratios and heritability ($h^2$ (ns)) estimates given in Table 5.3 revealed that the A : D ratio was less than unity for all the characters except plant height and fruit length, suggesting the predominance of dominance gene action. The earlier workers *viz.,* Sharma and Mahajan (1978), Singh (1986), More and Patil (1997), Mahajan and Ghai (2004), Kumar *et al.* (2006) and Adenji and Kehinde (2007) also reported the predominant role of dominance gene action in the inheritance of major yield and yield contributing characters. Whereas, contrary to this Abid Mahmood *et al.* (2004) reported predominance of additive gene action for fruit yield and related characters.

The predominance of dominance gene action suggests the feasibility of exploitation of heterosis in okra.

The highest heritability ($h^2$(ns)) was estimated for fruit length (46.21%) confirming the results of Lal *et al.*(1977). The heritability (narrow sense) estimates were moderate for plant height (27.61%), number of fruits per plant (20.18%), fruit girth (22.65%) primary branches per plant (15.49%) and days to first picking (10.65%). While, low heritability estimates were obtained for days to 50 per cent flowering (1.21%) and green fruit yield (3.74%) indicating the role of environment in the expression of these characters. The results are in agreement with Thaker *et al.* (1981b).

CHAPTER 6

# SUMMARY AND CONCLUSIONS

The present investigation entitled ‘‘Heterosis and Combining Ability studies in Okra (*Abelmoschus esculentus* (L.) Moench)’’ was undertaken with the objective to study heterosis for yield and its components and to study general and specific combining ability effects to identify superior parents and hybrids.

Seven pure lines of okra *viz.,* Parbhani Kranti ($P_1$), Arka Anamika ($P_2$), Arka Vijay ($P_3$), Phule Utkarsha ($P_4$), Ajeet-121 ($P_5$), Pusa Sawani ($P_6$) and Benolt ($P_7$) were intermated in a 7 x 7 half diallel fashion during Summer, 2006 at the Botany Farm, College of Agriculture, Pune. The resulting 21 hybrids along with 7 parents and a check (Panchali) were sown in a randomized block design with three replications during Kharif, 2007 and the data was recorded on nine quantitative *viz.,* days to 50 per cent flowering (No.), plant height at harvest (cm), primary branches per plant (No.), internodes per plant (No.), days to first picking (No.), number of fruits per plant, average fruit length (cm), average fruit girth (cm) and green fruit yield (g/plant); as well as two qualitative characters *viz.,* reaction to YVM and export parameters. The results were analyzed statistically for heterosis and combining ability following Griffing’s Model I, Method II.

The mean sums of squares due to parents were significant for all the characters. The hybrids also exhibited significant mean sum of squares for all the characters except plant height, indicating the presence of variability among them. The parents vs. crosses interaction mean sum of squares were highly significant for days to 50 per cent flowering and days to first picking; and significant for plant height at harvest, internodes per plant, number of

fruits per plant and green fruit yield per plant, indicating the presence of heterosis for these characters.

In the present investigation, the highest magnitudes of mean heterobeltiosis (22.89%), relative (49.23%) and economic heterosis (14.92%) were observed for primary branches per plant, followed by green fruit yield which recorded 7.26 per cent mean heterosis over BP, 113.83 per cent over MP and 3.87 per cent over standard check. Among the characters studied, the lowest heterobeltiosis (-1.79%) was recorded for days to first picking, relative heterosis (-0.28%) for fruit length and economic heterosis (-0.49%) for plant height.

For the character, green fruit yield per plant the hybrid Arka Anamika x Benolt exhibited the highest and highly significant heterobeltiosis (55.36%), average heterosis (73.32%) and useful heterosis (13.59%). It was followed by the combination Arka Vijay x Pusa Sawani (27.11, 34.83 and 22.77 % respectively). The increase in the heterosis for green fruit yield was found to be associated with the increase in the heterosis for the component characters. The highly heterotic hybrids also recorded high *per se* performance indicating the feasibility of selection based on heterosis coupled with *per se* performance. On the basis of heterosis for green fruit yield, Arka Anamika x Benolt and Arka Vijay x Pusa Sawani appeared to be promising for the exploitation of heterosis.

Significant differences due to gca and sca for all the characters (except for average fruit girth for sca) were observed suggesting the importance of both additive and non additive genetic components.

The parent Benolt ($P_7$) exhibited highly significant gca effects for seven characters out of the nine studied *viz.*, green fruit yield, plant height, primary branches per plant, internodes per plant, number of fruits per plant,

average fruit length and average fruit girth and thus was adjudged as the best general combiner among the parents for these characters. Therefore, Benolt can be used as a parent in hybridization programs aimed for developing high yielding hybrid.

The parents Phule Utkarsha and Parbhani Kranti appeared as the best general combiners for days to 50 per cent flowering and days to first picking respectively. Both of them can be used in a breeding program for evolving early cultivars in okra.

The gca effects of the parents and their *per se* performances were closely associated for most of the characters, indicating that the selection based on gca effects coupled with *per se* performance can prove useful for the identification of good general combiners.

The combination Arka Anamika x Benolt was the best specific combination for green fruit yield, followed by Arka Vijay x Pusa Sawani. The former combination registered highly significant sca effects for all the characters studied except average fruit length. It was also the best specific combination for plant height, primary branches per plant, internodes per plant, number of fruits per plant and green fruit yield. The hybrid Arka Vijay x Ajeet-121 appeared as the best specific combination for three characters *viz.*, days to 50 per cent flowering, days to first picking and fruit length, while for fruit girth, the hybrid Parbhani Kranti x Phule Utkarsha was observed as the best specific combination.

The hybrids showing high sca effects for green fruit yield involved parents with High x High gca effects indicating the presence of allelic interactions. For all other characters except green fruit yield, the superior hybrids based on sca effects involved parents with either High x High, Low

x Low or High x Low / Low x High gca effects indicating allelic as well as non allelic interactions in the expression of these traits.

There was a close relationship between sca effects and *per se* performance in the expression of fruit yield and other yield contributing characters, suggesting that the *per se* performance may be used as an indication of high sca effects.

Based on heterosis, sca effects and *per se* performance, Arka Anamika x Benolt appeared to be the best hybrid for green fruit yield, followed by the combination Arka Vijay x Pusa Sawani, whereas the combination Arka Vijay x Ajeet-121 was the best hybrid for earliness and fruit length.

The estimates of additive and dominance variances revealed the importance of dominance gene action for all the characters except plant height and fruit length, suggesting the feasibility of exploitation of heterosis in okra for these traits. The heritability estimates was high for fruit length and fruit girth while it was low for days to 50 per cent flowering and green fruit yield.

In a nutshell, in the present investigation, the parents Benolt, Parbhani Kranti and Phule Utkarsha were identified as the best general combiners, while the hybrids Arka Anamika x Benolt, Arka Vijay x Pusa Sawani and Arka Vijay x Ajeet-121 were noted as the best specific combinations.

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# VITA

**MISS SMITA BALASAHEB PATIL**

***A candidate for the degree of***

**MASTER OF SCIENCE (AGRICULTURE)**

***in***

**AGRICULTURAL BOTANY**
**(CYTOGENETICS AND PLANT BREEDING)**

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**TITLE OF THESIS : "Heterosis and Combining Ability Studies in Okra (*Abelmoschus esculentus* (L.) Moench)"**

**MAJOR FIELD : Cytogenetics and Plant Breeding**

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**BIOGRAPHICAL INFORMATION:**

**PERSONAL :** Born on June 27th, 1985 at Sankeshwar,
Daughter of Sou.. Sarita and
Shri. Balasaheb Patil

**EDUCATIONAL :**

- Passed S.S.C. from Jawahar Navodaya Vidyalaya, Kagal Dist. Kolhapur with 83.4 per cent marks in 2000.
- Passed H.S.C. from Jawahar Navodaya Vidyalaya, Kagal Dist. Kolhapur with 84 per cent marks in 2002.
- Received B.Sc. (Agri.) degree from Mahatma Phule Krishi Vidyapeeth, Rahuri, College of Agriculture, Pune in 2006

Completed the prescribed course work for Master of Science (Agriculture) degree in Agricultural Botany (Cytogenetics and Plant Breeding) at College of Agriculture, Pune-5 under the Mahatma Phule Krishi Vidyapeeth, Rahuri, in May 2007.

**ADDRESS** **:** c/o Shri Balasaheb S. Patil
At: Rampur Post: Nool
Tal.: Gadhinglaj Dist.: Kolhapur
Pin: 416 551

**E MAIL** **:** smitapatil2007@gmail.com